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Lwungili Justin Bationo, Omer Combary, Youssoufou Hamadou Daouda

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Effect of education on adoption and continued use of improved maize seeds in Burkina Faso

Lwungili Justin Bationo*

Economic and Social Study, Documentation
and Research Center (CEDRES),
Thomas SANKARA University,
12 BP 417 Ouagadougou 12, Burkina Faso
Email: batjustl@gmail.com
*Corresponding author

Omer Combary

Doctoral School,
Thomas Sankara University,
12 BP 417 Ouagadougou 12, Burkina Faso
Email: combaryomer@yahoo.fr

Youssoufou Hamadou Daouda

Laboratory for Analysis and Research on Economic and
Social Development (LARADES),
Tahoua University,
255 Tahoua, 92314934, Republic of Niger
Email: yankori2000@yahoo.fr

Abstract: This paper analyses the effect of education on the adoption and continued use of improved seeds in maize production. A bivariate probit model with sample selection was used on four years' panel data with 529 farmers per year-making a total of 2,116 observations. The results show that levels of primary and secondary education, agricultural supervision and adult literacy encourage the adoption of improved seeds. Secondary education, adult literacy and social capital were found to improve the continued use of improved seeds. The results suggest the need to strengthen extension services and literacy for adults working in agriculture. This could involve increasing the number of literacy centres as well as increasing the number of agricultural technical agents in rural areas.

Keywords: adoption; Burkina Faso; education; extension services; improved seeds; continued use; bivariate probit model.

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Biographical notes: Lwungili Justin Bationo holds a PhD in Applied Economics from Thomas SANKARA University (2022). He defended his single doctoral thesis on ‘Essays on education, the adoption of new technologies and cereal productivity in Burkina Faso’. He is an active member of the Economic and Social Study, Documentation and Research Center. His research focuses on human capital, agriculture, new agricultural technologies, income inequalities and agricultural productivity. He is the author and co-author of several articles in these fields.

Omer Combary is a Full Professor at Thomas SANKARA University and Director of the Doctoral School at Thoams SANKARA University. He is an active member of the Economic and Social Study, Documentation and Research Center (CEDRES), Department of Economics and Management, Thomas SANKARA University (UTS), Burkina Faso. His research interests include analysis of the technology, efficiency and productivity; analysis of inequality, welfare and poverty; impact evaluation of development program interventions and social policies; survival strategies of rural households to climate change; agricultural economics and rural development.

Youssoufou Hamadou Daouda is a Full Professor at the University of Tahoua, Rector of the University of Tahoua and Director of the Laboratory for Analysis and Research on Economic and Social Development (LARADES), Republic of Niger. His research focuses on the evaluation of public policies, the dynamics of poverty and inequality, the economics of well-being, migration and the economics of conflict. He is a member of the Sahel Chair (FERDI) on security and development.

1 Introduction

Improving rural household incomes through agricultural productivity would remain a weak commitment in developing countries if the rate of adoption of new agricultural technologies remains low (Huffman, 2020). Agricultural production and productivity will slow down, and rural poverty will prevail further if the adoption and continued use of agricultural technologies are not given priority (Uaiene, 2011). Although the combined use of agricultural technologies is recommended (World Bank, 2008), improved variety seeds play an important role in the production process, as their contribution alone can increase yields by around 40% (Bikienga, 2002).

However, after adoption, farmers can decide whether or not to continue using the agricultural technology. Little attention has been paid to the factors that drive farmers to continue or stop using the adopted technology. Analyses have shown that the adoption of agricultural technologies will not improve food security or reduce poverty if the barriers to their continued use are not addressed (Oladele, 2005).

On a theoretical level, the literature points out a positive relationship between education and the continued use of agricultural technologies. Indeed, if the new technology requires a higher level of cognitive ability, it is expecting a low adopted rate by farmers with a low level of human capital. The speed with which producers can adapt to an ever-changing set of production possibilities depends in part on the level of their human capital and their knowledge of new technologies (Ridell and Song, 2012). However, empirical findings in sub-Saharan Africa are controversial and do not always

demonstrate this positive theoretical relationship between education and decisions to adopt and continually use agricultural technologies.

Past studies have analysed the factors influencing the adoption and continued use of new technologies by farmers in Burkina Faso (Combary, 2013; Barry, 2016). Most of this work has been limited to the stage of adoption of new agricultural technologies. However, little attention has been given to the factors that drive farmers to continue or not to use the adopted agricultural technology. Moreover, most studies only consider the formal education of the head of the household and do not take into account that of other household members in the process of continued use. To correct these shortcomings, the present work uses panel data and measures education by 'the proportion of adult members with formal or non-formal education'.

The aim of this paper is to analyse the effect of education on the continued use of improved maize seeds in Burkina Faso. In this country, 43.7% of people live on less than \$1.90 a day (World Bank, 2019). This essentially agricultural poverty could be explained by a lack of economic incentives. The low rate of adoption and continued use of technologies is proving to be one of the factors explaining low agricultural yields. Less than 14% of potentially irrigable land is irrigated, and less than 15% of maize growers use improved seeds. In addition to the low adoption rate of agricultural technologies, it should be noted that the country has an insufficient human capital endowment, with a national literacy rate of 34.5%, which does not facilitate the adoption and continued use of agricultural technologies. This rate is three times higher in urban areas (64.0%) than in rural areas (23.4%) (World Bank, 2019).

The choice of maize farmers in this paper is justified because maize is one of the highest value-added crops per hectare in Burkina Faso (MASA, 2013). It is grown by 78.6% of farm households and currently ranks second crop in terms of cereal production in the country. Its share of the diet is estimated at 16% (MASA, 2013). Given the importance of this crop, public authorities have taken steps to develop the sector with the aim of improving food security for rural populations. One of these initiatives is adopting high-yielding maize improved hybrid variety named 'Bondofa' to reduce the effect of climatic hazards and increase production.

Given the benefits of education, increasing farmers' access to extension services and literacy is likely to increase their productivity through the adoption of new production techniques. This paper assumes that education positively affects decisions to adopt and continue using improved variety seeds in maize production. The paper is structured into four sections. The first section examines the literature review. The second presents the methodological approach of the study. The third section discusses the econometric results obtained. The final section concludes the article and draws out the economic policy implications.

2 Education and the continuous use of new technologies: a synthesis of the literature review

Since the development of the concept of human capital (Schultz, 1961; Becker, 1964), research has shown that highly skilled workers enjoy a comparative advantage in coping with economic change and implementing new technologies (Wozniak, 1984; Schultz, 1975). Indeed, Wozniak (1984) observes that better-educated farmers are more likely to adopt new technologies than uneducated ones, although education did not affect the use

of technology over several periods after its introduction. Amankwah-Amoah (2015) points out that it's not the mere possession of human capital that offers these advantages, but the ability to deploy and use these people that creates the right conditions for the development and adoption of new technologies. These theoretical analyses have led to the emergence of empirical evidence.

In northern Honduras, Neill and Lee (2001) found that formal education improves the continued use of certified maize seeds. Similarly, Olalekan and Simeon (2015) showed that formal education and contact with extension services positively affect the continued use of improved maize seeds in Nigeria. In Tanzania, Mwakatwila (2016) found that farmers who have received at least seven years of formal education are more likely to adopt improved maize varieties. The author concluded that farmer education is one of the main factors influencing the adoption and intensification of improved seed use in maize production.

Tura et al. (2010) have analysed the factors explaining the adoption and continued use of improved maize seeds in Ethiopia and found that formal farmer education significantly affects the adoption of improved maize varieties, while continued use is influenced by literacy and access to extension services. Other studies conducted in Ethiopia by Asfaw and Admassie (2004) showed that the adoption decision-making process is a decentralised mechanism in which educated adult household members participate. For these authors, the expansion of literacy in rural areas may be more attractive than in modern regions, as education is generally the most effective means of increasing farmers' ability to acquire, synthesise and adopt agricultural technologies such as improved seeds and chemical fertilisers.

However, analyses have not found a significant relationship between education and the continued use of agricultural technologies. In South Asia, Asif and Lahiri (2019) analysed the effects of human capital on technology adoption and diffusion in different sectors of the economy. The authors have observed a positive and significant relationship between human capital and technology adoption in the transport, tourism and health sectors, while no significant relationship was found for the agricultural sector. The authors attributed this non-significant effect of human capital to measurement errors and other aspects not taken into account, such as 'learning by doing', which could have significant effects.

In Ethiopia, Amha (1999) considers the education variable as one of the possible determinants of improved variety seeds adoption. The author observes that formal education has no significant effect on the adoption of improved seeds in the regions considered. Like previous research, this study only considers the educational level of the household head and ignores that of other members, whereas Basu et al. (2000) have shown the importance of the presence of educated adult members within households and the justification for the participation of these educated members in the decision-making process.

In the context of Burkina Faso, Sanou et al. (2017) found that farmer literacy and access to extension services significantly improve the likelihood of continued use of improved maize varieties. However, these authors have observed, that farm households headed by educated leaders are relatively less likely to adopt improved maize varieties.

This article makes a contribution to the literature on the determinants of the continued use of agricultural technologies by highlighting the relative contribution of socio-economic factors, and education in particular, in improving the rates of adoption

and continued use of improved agricultural technologies. The weight of each factor in determining the explanatory factors for the adoption and continued use of agricultural technologies enables us to better orient public policies for improving agricultural productivity in rural Burkina Faso.

3 Modelling the effect of education on the continued use of new technologies

3.1 Theoretical model

Theoretical modelling of the effect of education on adoption and continued use of improved seeds follows the developments of Neill and Lee (2001), Tura et al. (2010) and Srisopaporn et al. (2015).

The adoption of improved seeds in maize production is something that deserves the attention of policy makers, but what matters most to them is their continued use. The continued use of the technology once adopted can be explained by two discrete sequential decisions with the following decision tree:

- 1 *Adoption* $\begin{cases} \text{Yes} \\ \text{No} \end{cases}$
- 2 *UContinuous use* $\begin{cases} \text{Yes} \\ \text{No} \end{cases}$

The decision to continue using the technology involves a two-step process

- 1 adopting the agricultural technology
- 2 deciding whether or not to continue using it.

The decision to continue using the technology is taken only if the farmer has already adopted the improved seeds. The decision to adopt improved maize seeds is therefore not random, as each farmer decides for himself whether or not to adopt the agricultural technology. In this case, there may be observable and/or unobservable factors that could influence the adoption decision, generating sample selection bias. When this bias is due to unobservable factors (motivation, skills, etc.), models such as Heckman's (1979) are unable to control for the endogeneity bias thus created.

Furthermore, decisions to adopt and continue using the technology are assumed to be made on the basis of the general framework of utility maximisation (Uaiene, 2011). Using a utilitarian framework, this assumes that adoption is motivated by expected utility, which is a function of expected benefit. A farmer decides to apply an improved technology, if he predicts a positive benefit compared to the non-adoption case, estimated by the available information. Then, the following season, this grower will revise the profit forecast according to the past year's performance, and decide to continue using it if he still predicts a positive profit. Although it is not possible to observe utility, the farmers' adoption decision is observed, by which their utility is indirectly inferred.

The utility of adopting agricultural technology (y_{1t}^{*i}) and the utility of continuing to use it (y_{2t}^{*i}) for farmer i at time t depend on the vectors of explanatory variables X_{t1} and

X_{i2} . Assuming the model is linear, we end up with the following system of equations, formed by linear relationships:

$$\begin{cases} Y_{i1}^{*i} = X_{i1}'\beta_1 + \varepsilon_{i1} \\ Y_{i2}^{*i} = X_{i2}'\beta_2 + \varepsilon_{i2} \end{cases} \quad (1)$$

where β_1 and β_2 are parameters to be estimated, ε_1 and ε_2 are unobservable random components. (y_{i1}^{*i}) and (y_{i2}^{*i}) are not directly observable, as the only information available is the decision by producers to adopt the new technology (y_{i1}^i) and to continue using it (y_{i2}^i) .

Unobservable characteristics, captured in the error terms of the adoption equation, are likely to influence the error terms in the ongoing use decision. In this case, relationship (1) generates modelling problems related to sample selection (Greene, 2010). As a result, independent probit models can provide biased and inefficient estimates of both adoption and continued use parameters. To solve this problem and achieve robust results, the bivariate probit model with sample selection is adopted (Neill and Lee, 2001; Tura et al., 2010). This approach allows for selection bias by admitting that, while the outcome of the first decision is fully observable, the outcome of the second decision is observable only for the subset of farmers who have adopted the technology.

3.2 Specification of the bivariate probit model with sample selection

Before outlining the empirical specification of the bivariate probit model with sample selection, it is important to point out that the time dimension is used to construct the dependent variable ‘continuous use of agricultural technology’; which is a process over time.

Let (y_{ik}^{*i}) , $k = 1$, be an unobservable utility perceived by the farmer when adopting improved maize seeds (y_{i1}^{*i}) and using it continuously (y_{i2}^{*i}) as a function of a vector X_i of explanatory variables. Let (y_{ik}) with $k = 1, 2$, binary variables taking the value 1 in the case of adoption of improved seeds and in the case of their continuous use, and the value 0 otherwise. The standard bivariate probit model with additive error is specified as follows:

$$y_{i1}^{*i} = X_{i1}'\beta_1 + \varepsilon_{i1}; \begin{cases} y_{i1}^i = 1, & \text{if } y_{i1}^{*i} > 0 \\ y_{i1}^i = 0, & \text{otherwise} \end{cases} \quad (2)$$

$$y_{i2}^{*i} = X_{i2}'\beta_2 + \varepsilon_{i2}; \begin{cases} y_{i2}^i = 1, & \text{if } y_{i1}^i > 0 \text{ and } y_{i2}^{*i} > 0 \\ y_{i2}^i = 0, & \text{otherwise} \end{cases} \quad (3)$$

where X_{i1} and X_{i2} represent vectors of the adoption and continuous use variables respectively, β_1 and β_2 are parameters to be estimated; ε_{i1} and ε_{i2} are unobservable random error terms and are jointly and normally distributed, independently of X_{i1} and X_{i2} .

The conditional distribution of y_{i2}^{*i} knowing y_{i1}^{*i} can be written as:

$$Y_{i2}^{*i} = X_{i2}'\beta_2 + \alpha Y_{i1}^i + \rho \frac{\sigma_2}{\sigma_1} (Y_{i1}^{*i} - Y_{i1}^i \beta_1) + \mu_i,$$

the error term u following a normal distribution with zero expectation and variance $\sigma_2^2(1 - \rho^2)$. Thus $\rho \neq 0$ implies that $E(\varepsilon_2/x_{i2}, y_{i1}) \neq 0$.

In order to restore identification of the two equations, the error terms are frequently constrained to have unit variance ($\sigma_1 = \sigma_2 = 1$) (Maddala, 1983; Lollivier, 2001). Maddala (1983) shows that the parameters of this type of model are identifiable on condition that the outcome equation (3) includes at least one variable that is not included in the selection equation (2). To correct for endogeneity bias, the two equations are estimated simultaneously while respecting the previous condition (Greene, 2010), resulting in consistent and efficient estimates.

The parameter $\rho = \text{Corr}(\varepsilon_{i1}, \varepsilon_{i2})$ represents the correlation coefficient of the random components. By writing this way, we obtain the pair $(\varepsilon_{i1}, \varepsilon_{i2})$ which follows a bivariate normal distribution: $(\varepsilon_{i1}, \varepsilon_{i2}) \sim N(0, 0, 1, \rho)$.

The bivariate probit model considers the effect of X_i^i on three outcomes:

- 1 the probability that a farmer adopts and continues to use the agricultural technology
- 2 the probability that a farmer adopts and then abandons the system
- 3 the probability that a farmer never adopts.

Subsequently, the following unconditional probabilities are derived:

$$\begin{aligned} 1 \quad y_{i1}^i = 1 \text{ and } y_{i2}^i = 1 : \text{Prob}(y_{i1}^i = 1, y_{i2}^i = 1) &= \Phi_2[\beta_1 X_{i1}^i, \beta_2 X_{i2}^i, \rho] \\ 2 \quad y_{i1}^i = 1 \text{ and } y_{i2}^i = 0 : \text{Prob}(y_{i1}^i = 1, y_{i2}^i = 0) &= \Phi_2[\beta_1 X_{i1}^i - \beta_2 X_{i2}^i, -\rho] \\ 3 \quad y_{i1}^i = 0 : \text{Prob}(y_{i1}^i = 0) &= \Phi_1[-\beta_1 X_{i1}^i] \end{aligned} \quad (4)$$

Continuous adoption for the i th farmer is the product of each of these individual probability density functions, which is more easily expressed as a logarithm. Summing over all the individuals in the sample gives the following log likelihood function

$$\begin{aligned} \ln L = \sum_{i=1}^N \{ & Y_{i1}^i Y_{i2}^i \ln \Phi_2(\beta_1 X_{i1}^i, \beta_2 X_{i2}^i, \rho) + Y_{i1}^i (1 - Y_{i2}^i) \ln \Phi_2(\beta_1 X_{i1}^i, -\beta_2 X_{i2}^i, \rho) \\ & + (1 - Y_{i1}^i) \ln \Phi_1(-\beta_1 X_{i1}^i) \} \end{aligned} \quad (5)$$

where $i = 1, 2, \dots, N$.

Estimation of model (5) by the maximum likelihood method is relevant given the additional assumption that the errors are jointly and normally distributed, homoscedastic and potentially correlated (Maddala, 1983; Srisopaporn et al., 2015).

3.3 Presentation of the data and variables used to estimate the model

3.3.1 Data presentation

The data used in this paper are rural household data from the Permanent Agricultural Survey (EPA) of the Ministry of Agriculture of Burkina Faso. Data from the 2014–2017 agricultural season were used for the analysis of the effect of education on the use of improved seeds. The EPA is a sample panel survey based on a stratified two-stage probability sampling. In the first stage, villages (primary units) are stratified according to their production potential (low or high potential). In the second stage, farm households

(secondary units) stratified into small and large farming households according to criteria such as size and productive assets owned. The main objective of this permanent survey is to estimate provincial and national production for each crop. For the purposes of this work, we have considered only maize-producing households in rural areas. A four-year cylindrical panel of 529 rural households per year is used for the analysis, i.e., 2,116 observations.

3.3.2 Measuring the main variables

The model's dependent variables are the adoption and continued use of improved seeds in maize production. According to Moore and Benbasat's (1996) theory of the diffusion of innovation, the adoption and continued use of agricultural technologies depend on the characteristics of the farm and the farmer. Table 1 shows the variables used in the estimation.

3.3.2.1 Socio-economic characteristics of the farmer and farm

The empirical human capital literature on the adoption and continued use of technology state that education is assumed to play a much more important role in determining allocative capacity than worker ability (Schultz, 1961). Farmers with higher levels of education are assumed to have a better understanding of technology, and therefore more willing to judge its usefulness and adoption on an ongoing basis. Extension services is an important element in the process of adoption and continued use of new agricultural technologies. Contact with agricultural agents facilitates access to information and promotes the adoption of agricultural technologies.

The wealth of a farm can be approximated by its size, through the useful agricultural area. Tura et al. (2010) have shown that the amount of land allocated to maize cultivation has a positive effect on the adoption and continued use of improved seeds in Ethiopia, respectively. Neoclassical theory predicts a positive relationship between property rights and agricultural investment.

3.3.2.2 Institutional factors

Social capital enables farmers to acquire the resources they need for agricultural production. In this case, farmer membership of a farmer organisation is expected to positively affect the adoption and continued use of new technologies.

Agriculture is a capital-intensive and investment-heavy sector. Implementing new technologies can lead to new investments, some of which may be partially unrecoverable. Access to credit increases the financial capital of farmers and affects their ability to obtain new agricultural technologies. In the context of Burkina Faso, where most rural households face liquidity constraints, access to credit becomes a determining factor in acquiring inputs.

Table 1 Presentation of the variables used in the econometric model

<i>Variable</i>	<i>Type</i>	<i>Description</i>
<i>Dependent variables</i>		
Adoption	Dichotomous	1 if the farmer adopts improved maize seeds and 0 otherwise
Continuous use	Dichotomous	1 if the farmer continues to use improved maize seeds
<i>Independent variables of interest</i>		
Extension services	Dichotomous	1 if the farmer has benefited from extension services and 0 otherwise
Literacy	Continuous	The proportion of literacy adults in the farm household
Primary	Continuous	The proportion of adults with primary education in the household
Secondary	Continuous	The proportion of adults with secondary education in the household
<i>Control variables</i>		
Age	Continuous	Age of head of household in years
Area	Continuous	The area allocated to maize cultivation (ha)
Social capital (1 = Yes)	Dichotomous	Social capital in the form of membership in a farmers
Chemical fertiliser	Continuous	Quantity of organic fertiliser per hectare (kg/ha)
Access to farm credit	Dichotomous	1 if the farmer benefited from agricultural credit during the analysis period and 0 otherwise
Organic fertiliser	Dichotomous	1 if the farmer uses organic fertiliser and 0 otherwise
Land security	Dichotomous	1 if the farmer owns the plot and 0 otherwise

Source: Author's construction based on EPA data, 2014–2017

4 Results and discussion

4.1 Presentation of descriptive statistics for maize farmers in Burkina Faso

The statistics (Table 2) show that 58.84% of maize growers adopted improved seeds over the period 2014–2017. The adoption of improved maize varieties was not continuous over the analysis period. In fact, the data indicate that 37.19% (or 463 farmers) of those who had adopted improved maize seed stopped using it.

The main socio-demographic characteristics presented in this sub-section are the age of the household head, the education of adults in the household, extension services and membership of a farmers' organisation. Descriptive statistics show that household heads are adults, with an estimated average age of 46. According to classical theory, one of the main characteristics of the household head is his or her recognition by other household members as the main decision-maker within the household. The literature has shown that the household head's decisions are generally influenced by the other adult members of the household, and in particular by those who are educated.

Analysis of the statistics shows that 14% of adults in farming households who have adopted new technologies are literate. It also shows that the rates of agricultural

supervision and membership of a producers' organisation are 59% and 64% respectively for adopters of agricultural technologies.

The average characteristics of the variables presented in Table 2 show that maize growers have difficulty securing their plots, which can be used as collateral to access credit from formal and/or informal financial institutions. These statistics are supplemented by a comparison of means test to ensure the significance of discrimination linked to the adoption process. This test assumes the null hypothesis of no difference in access versus the alternative hypothesis of the presence of a difference.

Table 2 Descriptive statistics of socio-economic characteristics

<i>Variables</i>	<i>Adoption</i>	<i>No-adoption</i>	<i>Sample</i>	<i>Difference in group means</i>	<i>t-statistic</i>
	<i>Mean</i>	<i>Mean</i>	<i>Mean</i>		
<i>Quantitative variables</i>					
Age	46	46	46	0.00	0.44
Area	3.03	0.99	2.19	−2.04***	−22.07
Chemical fertiliser	161.5	141.5	153.2	−20***	−19.70
Literacy	0.14	0.07	0.11	−0.03***	−7.70
Primary	0.41	0.41	0.41	0.00	0.25
Secondary	0.11	0.10	0.10	−0.01	−0.45
<i>Qualitative variables</i>					
	<i>Proportion</i>	<i>Proportion</i>	<i>Proportion</i>	<i>Difference</i>	<i>Z-statistic</i>
Training or extension services	0.59	0.41	0.52	−0.18***	−8.31
Social capital	0.64	0.45	0.56	−0.19***	−8.74
Organic fertiliser	0.38	0.42	0.39	0.04*	1.84
Access to farm credit	0.43	0.33	0.38	−0.10***	−4.47
Land security	0.39	0.33	0.37	−0.06***	−2.72
Number of observations	1,245	871	2,116	374	

Source: Author's construction based on EPA data, 2014–2017

4.2 Results of the effect of education on the adoption and continued use of improved seeds

4.2.1 Model validation tests

The likelihood ratio test indicates that the model is globally significant at the 1% threshold. The result of this test implies that there is at least one coefficient statistically different from zero in the model. Overall, the results of the model largely confirm the findings of previous work on the adoption and continued use of improved seeds.

The estimated correlation coefficient (ρ) is statistically significant ($\chi^2(1) = 4.59$ and $\text{Prob} > \chi^2 = 0.0321$). This result suggests that the bivariate probit model with sample selection is a better specification for observed data. A significantly non-zero correlation coefficient between technology adoption and continued use decisions suggests that there are unobservable factors affecting both choices and reveals an association between the two decisions. This also implies that ignoring the effect of selection in adoption status

would render estimates of a univariate probit equation for continuous use of improved seed biased and inconsistent.

As both models are nonlinear, the estimated coefficients have no direct economic interpretation, due to the problem of normalising the residual variance. Thus, the only direct information that can be used is the sign of the estimated parameters, indicating whether the associated variable positively or negatively influences the probability of the event under consideration. To compare the magnitude of the relationships, we estimated the marginal effects of the explanatory variables on the probability of observing a given outcome, i.e. the change in probability resulting from a unit increase in the explanatory variable, holding all other variables constant.

4.2.2 *Presentation of econometric results on the adoption and use of improved maize seeds*

4.2.2.1 *Factors explaining the adoption of improved seeds*

Table 3 shows the determinants of adoption of improved maize seed. As for the variables of interest, it emerges that training or extension services, adult literacy and formal education have a positive and significant effect on the adoption of improved seeds. Marginal effects show that literacy increases the probability of adopting improved seeds by 26.2%. These results are in line with theoretical expectations.

Some control variables also affect the adoption of improved maize seed. These include the total area sown to improved maize varieties, which has a positive and significant effect on the probability of adopting improved seeds. As for the quantity of chemical fertiliser used and the use of organic manure, they have a positive and significant influence on the adoption of improved maize seed. It also appears that the more farmers have access to agricultural credit, the lower the probability of adopting improved seeds.

Table 3 Factors explaining the adoption of improved maize seeds

<i>Variable</i>	<i>Coefficient</i>	<i>Marginal effect</i>
Age of head of household	-0.022 (-1.42)	-0.0056 (-1.42)
Age squared	0.0002 (1.17)	4.72e-05 (1.17)
Maize area	0.764*** (12.85)	0.194*** (14.78)
Chemical fertiliser	0.001*** (4.21)	0.0003*** (4.28)
training or extension services	0.160** (2.08)	0.0406** (2.09)
Literacy	1.030*** (5.35)	0.261*** (5.47)

Note: The superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels. Values in parentheses are Student statistics.

Source: Author's construction based on EPA data, 2014–2017

Table 3 Factors explaining the adoption of improved maize seeds (continued)

<i>Variable</i>	<i>Coefficient</i>	<i>Marginal effect</i>
Primary	0.219** (2.09)	0.056** (2.09)
Secondary	0.416** (2.16)	0.106** (2.17)
Social capital	0.099 (1.18)	0.025 (1.18)
Organic fertiliser	0.200*** (2.85)	0.051*** (2.87)
Access to farm credit	-0.282*** (-3.36)	-0.072*** (-3.39)
Land security	0.065 (0.94)	0.016 (0.94)
Constant	-1.030*** (-2.75)	
/athrho	-0.416** (-2.37)	
Corrélation (ρ)	0.394*** (2.66)	
Wald chi2 (10) = 44.32; Prob > chi2 = 0.0000		
LR test of indep. eqns. ($\rho = 0$): chi2(1) = 4.59 and Prob > chi2 = 0.0321		
Number obs.	2,116	
Censored obs.	871	
Uncensored obs.	1,245	

Note: The superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels. Values in parentheses are Student statistics.

Source: Author's construction based on EPA data, 2014–2017

4.2.2.2 *Presentation of the determinants of the continuous use of improved maize seeds*

Table 4 shows the factors influencing the continuous use of improved maize seed. With regard to the variables of interest, it emerges that adult literacy and secondary education level positively and significantly affect the probability of continued use of improved seed in maize production. These results are in line with theoretical expectations.

As for the control variables, some influence the continued use of improved seeds. The total area sown with improved maize seeds had a positive and significant effect on the continued use of improved seed. As for the quantity of chemical fertilisers used, this has a positive and significant influence on the continued use of improved maize seed. Social capital (membership of a farmers' organisation) was also found to improve the likelihood of continued use of improved seed in maize production. Furthermore, the results indicate that the older the farmer, the lower the probability of continued use of improved seeds.

Table 4 Estimated effect of education on continued use of improved seeds

<i>Variables</i>	<i>Coefficient</i>	<i>Marginal effect</i>
Age of head of household	−0.027 (−1.38)	−0.010* (−1.67)
Age squared	0.0002 (1.02)	7.67e-05 (1.26)
Maize area	0.191*** (3.34)	0.116*** (5.69)
Chemical fertiliser	0.0006** (2.30)	0.0003*** (3.47)
training or extension services	−0.0489 (−0.50)	−0.004 (−0.13)
Literacy	1.213*** (4.79)	0.4602*** (6.32)
Primary	0.036 (0.27)	0.027 (0.65)
Secondary	0.2787* (1.71)	0.120* (1.71)
Social capital	0.2202** (2.05)	0.077** (2.33)
Organic fertiliser	0.0769 (0.88)	0.039 (1.37)
Access to farm credit	−0.148 (−1.46)	−0.067 (−2.13)
Constant	0.681 (1.43)	

Note: The superscript ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels. Values in parentheses are Student statistics.

Source: Author's construction based on EPA data, 2014–2017

4.2.3 Discussion

4.2.3.1 Effect of variables of interest on the adoption of improved seeds

The positive and significant effect of agricultural extension services could be explained by the fact that training sessions on the adoption of improved seeds enable growers to become better informed about the new technologies available and their nature, which in turn influences the adoption decision. The training not only exposes the beneficial effects of improved seeds but also equips farmers with new practices associated with their adoption. From this perspective, farmers who receive agricultural extension services are more inclined to adopt improved seeds. This result is consistent with those obtained by Mahoussi et al. (2017), who showed that agricultural training received on the use of improved maize seeds increases the intensity of improved seed adoption in Benin. Extension services also reduce the cost of accessing information to encourage the adoption of agricultural technologies. To illustrate the importance of access to information, Jack (2013) indicates that profitable technologies may not be adopted if information about their profitability and how to use them correctly is not available. This

result is in line with those obtained in Tanzania by Mmbando and Baiyegunhi (2016) and in Kenya by Timu et al. (2014).

Adult literacy, primary and secondary education have a positive and significant impact on the probability of adoption of improved maize seed. Education is considered the most important form of human capital (Becker, 1964). It boosts agricultural productivity by influencing decision making, technology adoption and information acquisition. Educated farmers are quicker to adopt new production techniques because they have the knowledge to distinguish between promising and unpromising technologies.

By way of illustration, at a time when educated farmers are adopting the new technology, uneducated farmers will wait until it has proven itself in terms of yield before proceeding with its adoption (Knight et al., 2003). Although some studies do not find a significant relationship between education and the adoption of agricultural technologies, it can be considered that better-educated farmers have more information at their disposal, enabling them to better evaluate the technology and thus limit their level of uncertainty.

Overall, the obtained results align with the theory of human capital, which states that farmers with higher levels of education have access to more information, enabling them to better evaluate new technologies and are more motivated to invest in techniques that enhance agricultural productivity. These results also highlight the need for the Burkinabe Government to improve the level of education among agricultural households. Literacy and extension services are alternatives to low enrolment rates and can increase the probability of adopting improved maize seeds.

4.2.3.2 Effect of control variables on the adoption of improved maize seeds

In general, the cultivated land area plays a crucial role in the adoption process of new technologies. The estimated effect of the proportion of land allocated to maize cultivation is positive and significant on the probability of adopting improved seeds. This implies that farmers with larger land areas tend to adopt improved seeds, unlike households with smaller land areas, which are more vulnerable to the risks associated with the new technology. Barry (2016) found that in the context of Burkina Faso, having a larger cultivable land area increases the probability of adopting maize varieties by 0.30 percentage points, holding all other factors constant.

The use of chemical fertilisers and organic manure has a positive and significant marginal effect on the probability of adopting improved maize seeds. These results show that adopting another component of the technological package increases the likelihood that agricultural households will adopt the essential component of the package (improved seeds). In fact, the adoption of improved seeds requires the use of other components to achieve better results. Faye-Mané's (2017) research in Senegal also indicates that fertilisers are a determining factor in the adoption process of improved maize seeds.

In the literature, access to credit generally has a positive effect on the adoption of agricultural technologies. However, the contribution of agricultural credit to increasing the probability of adopting improved variety seeds is negative and significant. There are various explanations for this result. The implementation of new technologies can lead to new investments, some of which may be partially unrecoverable. Liquidity constraints among farmers could have a determining effect on the acceptance of new technology. A study conducted in Kenya showed that some farmers tend to defer decisions to purchase fertilisers for their crops to the future (Duflo et al., 2011), which ultimately reduces the

adoption rate due to liquidity constraints. This means that a slight surplus, for a short period during harvests, can significantly increase the rate of fertiliser use, which is not the case for a surplus, even larger, at a later time after harvests. Here, it is found that liquidity constraints faced by farmers during non-harvest periods negatively affect the adoption rate of agricultural technologies. These results suggest that facilitating the diffusion and use of new agricultural technologies could be achieved by easing liquidity constraints among farmers.

4.2.3.3 Effect of variables of interest on continued use of improved seeds

Reading, writing and basic mathematical skills, which are fundamental components of literacy, play a crucial role in empowering adults to master techniques and skills, thus motivating them through action. Literacy empowers farmers to acquire new knowledge and skills, leading to a better understanding of new agricultural techniques and, consequently, encouraging their ongoing use. These findings align with the conclusions of Tura et al. (2010) in Ethiopia, who found that the literacy of the agricultural household head encourages the continued use of improved maize seeds once they have been adopted.

It also emerges that secondary education significantly affects the continued use of improved maize seeds. This result could be explained by the fact that farmers with higher levels of education have a better understanding of the technology and are thus more inclined to assess its utility and continuous its use. Additionally, if the new technology requires higher cognitive capacity, it is expected to be more readily accepted by farmers with higher education levels. Research has shown that the level of education is a determining factor, not only in adoption decisions, but also in the intensity of use of the new technology (Croppenstedt et al., 2003).

4.2.3.4 Effect of control variables on continued use of improved seeds

Farm size is often used as an indicator of a farmer's wealth. It therefore seems logical that the effect of farm size on the probability of continued use of improved technologies should be the same as that of wealth. This result is in line with those found by Tura et al. (2010) in Ethiopia. However, increasing farm size requires additional labour and capital resources. As a result, some farmers may find it difficult to make continued use of improved technologies on their farms if they require additional capital and labour time.

The use of complementary technologies also increases the likelihood of continued use of improved maize seeds. Inputs, in this case, fertilisers, are a component of the technological package used in agriculture. This result confirms the complementarity between improved seeds and fertilisers (Abebaw and Haile, 2013), especially in the context of Burkina Faso, which is severely affected by declining soil fertility.

Membership in a farmers' organisation has a significant positive impact on the likelihood of continued use of improved seed in maize production. The organisation of producers into groups plays a decisive role in reducing transaction costs. Producer groups can also be seen as frameworks for training, exchange and replication of cultivation practices. Through this channel, producers can easily access the inputs and information required for the various agricultural technologies available to these farmers' organisations. Taking into account the cooperation between farmers helps to explain their behaviour in the process of continuous use of agricultural technologies. Obtaining

information through farmer organisations reduces uncertainty and enables farmers to perceive the characteristics of the technology and the associated risks more objectively.

The literature indicates that as farmers age, they become more conservative and less open to new technologies (Tshikala et al., 2015). Older farmers, therefore, have a shorter planning horizon, which does not encourage them to change their farming practices. This results in a decrease in interest in maize production due to the physical demands of cultivation and the increased viability of alternative solutions without maize. In Zambia, Ng'ombe and Kalinda (2014) show that there is a point in the life of the head of household when age no longer improves the process of continuous use of agricultural technologies, but negatively.

5 Conclusions

The adoption of yield-enhancing agricultural technologies is certainly an effective means of reducing poverty and ensuring food security in Burkina Faso. However, the adoption of agricultural technologies is not sufficient to meet these national needs. There is a need to ensure that farmers use adopted technologies in a sustainable way. Beyond the analysis of farmers' post-adoption behaviour, the literature identifies factors such as low levels of education and access to agricultural credit as the main constraints on the adoption and continued use of agricultural technologies. The aim of this paper was to analyse the effect of education on the adoption and continuous use of improved maize seeds in Burkina Faso. The full-information maximum likelihood method was applied to the bivariate probit model with sample selection on 2,116 maize farmers.

The results allow us to draw the main conclusions that primary and secondary education levels, extension services and adult literacy promote the adoption of improved maize seed. However, continuous use is not affected by all education components such as farmer coaching and primary education. Adult literacy and secondary education are positively and significantly associated with the likelihood of continuous use of improved seeds.

The results also demonstrate that the area of land sown to maize, the use of chemical fertilizers and organic fertilisers were important factors in the adoption of improved maize seeds. With regard to their continued use, we note that the area of land and membership of a farmers' organisation are the main factors favouring the continuous use of improved maize seeds in Burkina Faso. Analysis of the results shows that access to agricultural credit does not encourage the adoption and continued use of improved maize seeds in Burkina Faso.

Furthermore, actions aimed at increasing the adoption rate of improved seeds should focus on improving primary and secondary education levels, farmer coaching and adult literacy. In terms of their continuous use, the emphasis should be on literacy and secondary education for adults involved in agriculture. However, adults already working in agriculture can no longer be channelled into the formal education system. Such education can only come from adult literacy. This means increasing the number of literacy centres in rural areas.

Appropriate policy interventions that take these factors into account are needed so that improved maize seeds can be adopted and used on an ongoing basis to increase agricultural yields and improve food security. To achieve this, these results suggest that

policies targeting rural people should be specific through the integration of education and literacy programs adapted to agricultural techniques and practices into the education system in rural areas. Extension services should facilitate the grouping of farmers into small economic interest organisations. It is therefore necessary not only to raise farmers' awareness of the need to participate in farmers' organisations, but also to encourage these organisations to facilitate their integration with a view to the continued use of improved seeds in maize production.

This article focuses on a single crop. However, it would be interesting to carry out the analysis taking into account all the crops present. Also, due to data constraints, it was not possible to clearly identify the type of improved maize seed. An analysis by category of improved seed would make it possible to identify farmers' preferences for each variety.

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