Land tenure security and adoption of agricultural technologies among cassava farmers in Benin

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Abstract

The empirical literature is not unanimous regarding the effect of secure land tenure on the adoption of agricultural technologies. Thus, this study analyzes the effect of land tenure security on the adoption of agricultural technologies in the context of Southern Benin, focusing on cassava producers. Therefore, a multivariate probit model is estimated, using survey data on 90 cassava producers. The findings indicate that holding a land title, meaning having land tenure security, influences positively and significantly the adoption of agricultural technologies by cassava producers. Consequently, policy-makers could ensure access to secure land to farmers to foster the adoption of agricultural technologies.

Keywords: Adoption; agricultural technologies; cassava; land tenure; multivariate probit; Benin

1. Introduction

Low agricultural productivity constitutes an issue in developing countries and this issue is being exacerbated by climate change (Adamopoulos and Restuccia, 2022; Lokonon et al., 2015). For these authors, the explanation of low agricultural productivity in poor countries is of paramount importance in terms of policy implications for poverty reduction, welfare improvement, structural transformation, and economic development. Thus, farmers have to adopt adaptation strategies, among which there are agricultural technologies. Many factors are assumed to influence agricultural technology adoption such as imperfect information, risk, uncertainty, institutional constraints, human capital, input availability, and infrastructure (Adamopoulos and Restuccia, 2022; Feder et al., 1985). Those factors include land tenure security. Indeed, land tenure security is assumed in the theoretical literature to foster the adoption of agricultural technologies. For instance, the literature points out a positive effect of land tenure security on agricultural investment for several reasons. First, secure property rights can provide a guarantee for farmers to undertake long-term investments in soil fertility conservation techniques because of no fear of expropriation (Abdulaye et al., 2011; Goldstein and Udry, 2008; Besley, 1995). Second, secure property rights facilitate using land as collateral to obtain credit to finance agricultural investments (Feder and Feeny, 1991; Feder and Onchan, 1987). This is possible because secure property rights facilitate the development of an efficient land market (Ali et al., 2011). Third, secure property rights promote intra-sectoral mobility of production factors which ultimately has positive effects on investment and agricultural productivity. Despite the unanimous direction of the theoretical literature on the beneficial effect of secured land tenure on agricultural

technologies adoption, the empirical literature found mixed effect, especially in Sub-Saharan Africa (Nonvide, 2023; Lawin and Tamini, 2019; Lokonon and Mbaye, 2018; Arnot et al., 2011; Place, 2009).

The agricultural sector plays a leading role in economic growth of developing countries due to its contribution to wealth and jobs (Adamopoulos and Restuccia, 2022). For instance, in the case of Benin, the agricultural sector provide jobs to around 70% of the active population, and contributes nearly 33% to the formation of the Gross Domestic Product (GDP) (MAEP, 2017). Moreover, this sector accounts for approximately 75% of export revenues and 15% of state revenues. This points out a low labor productivity issue in the agricultural sector of the country. Still, in Benin, agricultural policies to ensure food security are focused on cereals, roots and tubers including cassava. These crops have long been and continue to be part of the concerns of national research institutions as well as agricultural extension services (ONASA, 2011). Cassava production is being intensifying throughout the world thanks to the modernization of its production, its transformation into derivatives (high quality cassava flour, modified starches) used in industry other than traditional derivatives (gari, tapioca, chips, lafu, etc.) among others. Currently, Beninese agricultural policies are grounded on the territory development agencies (MAEP, 2017). Plants with tropical roots and tubers (cassava, sweet potato, yams and aroids) occupy an essential place in agriculture in many regions of the world, particularly in humid tropical zones where most of the world's population is located. It is in fact an important source of locally grown starchy products, which plays an essential role in the food security of poor countries by replacing imported cereals. It should be noted that cassava traditional derivatives are of paramount importance in the diet of the Beninese populations. Despite the importance of land as a productive asset and as a factor favoring technology adoption, its equitable and secure access remains an issue for Beninese farmers. Still, Benin is characterized by traditional cassava production systems and the increase in its production is mainly attributable to land use expansion (MAEP, 2017).

Access to land and management of renewable resources are at the heart of questions pertaining to the agricultural development and sustainable management of ecosystems. In rural West Africa, land issues are characterized by increasing marketization and increased competition between actors (between rural and urban people), poor regulations due to social and economic constraints, contradictory public policies and the failures of conflict management systems (Lawin and Tamini, 2019; Abdulai et al., 2011; Gavian and Fafchamps, 1996). This insecurity can contribute to low investments in land and resource degradation. However, the actors do not remain inactive, and new rules, mobilizing local authorities and state representatives, sometimes emerge, with variable effectiveness. For many years, land tenure has been at the heart of political debates (Gavian and Fafchamps, 1996). It involves issues of economic efficiency and productivity, but also of social peace, citizenship, and governance. In the case of Benin, the legislation puts emphasis on holding secure land tenure even in rural areas. So, farmers that inherit land can undertake the administrative procedures to get a customary holding certificate.

Against this background, this study aims to analyze the effect of land tenure security on agricultural technology adoption in Benin. Thus, the main research question is: what is the effect of land tenue security on agricultural technology adoption among cassava producers in Benin? As aforementioned, in the literature, the effect of land tenure on agricultural

technology adoption is widely addressed but the results depend on the context. The findings vary across countries and depend on the technologies considered. As illustration, Lawin and Tamini (2019) indicated that land tenure arrangements have a significant influence on farmers' decisions to invest in agro-environmental practices. In particular, the intensity of the adoption of these practices is systematically higher on owned plots than on borrowed, rented or sharecropped plots. The findings of these authors highlighted the importance of land tenure in the adoption of agro-environmental practices by smallholder farmers. Moreover, Gavian and Fafchamps (1996) found a positive link between property rights and organic fertilizer use in Niger. These authors showed that producers who cultivate borrowed land use less organic fertilizer than those who own their land. In Ghana, Abdulai et al. (2011) found that land security considerably influences farmers' decisions to invest in land improvement and conservation techniques. Deininger et al. (2011) also found a positive effect of land titles on the adoption of soil conservation techniques in Ethiopia. A positive effect of land security on investment and agricultural productivity was also found by Dube and Guveya (2013) in Zimbabwe; Ma et al. (2013) in China; Chankrajang (2015) in Thailand; Grimm and Kalsen (2015) in Indonesia. However, Quisumbing and Kumar (2014) came up with the conclusion that land occupation status has no effect on the adoption of soil conservation practices. Likewise, Place and Otsuka (2002) concluded in the case of Uganda that land tenure has no effect on agricultural productivity. Therefore, this study aims to contribute to this debate focusing on cassava production in the context of southern Benin.

The remainder of the study is organized as follow. Section 2 presents a synthetic literature review on land tenure security and agricultural technology adoption. The methodological approach used is presented in section 3 as well as the data. Results and discussion are reported in section 4 and section 5 concludes along with policy implications.

2. Land tenure security and agricultural technology adoption: a synthetic literature review

In the literature the question pertaining to the effect of land tenure on the adoption of agricultural technologies is widely addressed and the results differ across studies. Thus, the empirical literature is far from being unanimous on the subject. The results depend on the context and technologies. Lawin and Tamini (2019) indicated that land tenure arrangements have a significant influence on farmers' decisions to invest in agro-environmental practices. Precisely, the intensity of the adoption of these practices is systematically higher on owned plots than on borrowed, rented or sharecropped plots. The results highlighted the importance of land tenure in the adoption of agro-environmental practices by smallholder farmers. In the case of Benin, Nonvide (2023) found that the uptake of adaptation strategies to cope with climate change depends on land tenure arrangements. Actually, family land is positively associated to the uptake of adaptation strategies such as planting tree, crop and livestock integration, use of improved variety, and endogenous beliefs. As for own land, it appeared to foster the adoption of tree planting, and endogenous beliefs, while it hinders the uptake of irrigation. So, the findings may depend on the type of crops. It is worth noting that in the Niger Basin of Benin, Lokonon and Mbaye (2018) found that land tenure security fosters the uptake of sustainable land management practices such as intercropping with nitrogen-fixing crops.

Gavian and Fafchamps (1996) found a positive link between the type of property rights and organic fertilizer use in Niger. They show that producers who cultivate borrowed land use less organic fertilizer than those who own their land. In Ghana, Abdulai et al. (2011) found that land security considerably influences farmers' decisions to invest in land improvement and conservation techniques. Likewise, Deininger et al. (2011) found a positive effect of land titles on the adoption of soil conservation techniques in Ethiopia. Similarly, a positive effect of land security on investment and agricultural productivity was also found by Dube and Guveya (2013) in Zimbabwe; Ma et al. (2013) in China; Chankrajang (2015) in Thailand; Grimm and Kalsen (2015) in Indonesia. However, Quisumbing and Kumar (2014) found that land occupation status has no effect on the adoption of soil conservation practices. Moreover, Place and Otsuka (2002) in their study on land tenure systems and their implications on investment and agricultural productivity in Uganda concluded that land tenure has no effect on agricultural productivity.

3. Material and methods

3.1. Model specification

A given farmer adopts an agricultural technology based on the utility she expects to derive from it; that means the difference between adopting and not adopting the technology. Nevertheless, the utility of the farmer is not directly observable, rather one can observe her action through her choice in terms of agricultural technologies. Also, farmers adopt at the same time more than one technologies. So, the appropriate approach is to analyze the effect of land tenure security on the individual agricultural technologies. However, the discrete choice model (binary probit/logit model) cannot help to account for the relationships between pairs of agricultural technologies. Therefore, the multivariate probit model can be used to account for the heterogeneities in the determinants of the adoption of the different technologies as well as the relationships between pairs of agricultural technologies (Nonvide, 2021; Lokonon and Mbaye, 2018; Kassie et al., 2009). The general form of the multivariate probit model, characterized by a set of m binary dependent variables Y_{ij}, is as follows:

$$Y_{ij} = \begin{cases} 1 \; if \; X_i'\alpha_j + \mu_{ij} > 0 \\ 1 \; if \; X_i'\alpha_j + \mu_{ij} \leq 0 \end{cases}, j = 1,2,\dots,m \qquad (1)$$

where Y_{ij} is the adoption of agricultural technology j by the farmer i, X_i represent the vector of independent variables (land tenure security and control variables), α_j are conformable parameter vectors, and μ_{ij} are the errors terms that follow a multivariate normal (MVN) distribution with zero means, unitary variance and $m \times m$ contemporaneous correlations matrix $R = (\rho_{jj})$, with density $\varphi(\mu_{i1,}\, \mu_{i2,}\, \dots, \mu_{im}; R)$:

$$(\mu_{i1,}\, \mu_{i2,}\, \dots, \mu_{im})' \sim MVN\left[0, \begin{pmatrix} 1 & \rho_{12} & \cdots & \rho_{1m} \\ \rho_{12} & 1 & \cdots & \rho_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{1m} & \rho_{2m} & \dots & 1 \end{pmatrix}\right] \qquad (2)$$

In equation (2), ρ refers to the pairwise correlation coefficient of the error terms between pairs of agricultural technologies. In this framework, a positive and significant pairwise

correlation coefficient indicates a complementary relationship between the agricultural technologies. However, a negative and significant pairwise correlation coefficient denotes a substitution relationship between the agricultural technologies. The estimation of equation (1) is done using the method of simulated maximum likelihood, which relies on the Geweke-Hajivassiliour-Keane smooth recursive conditioning simulator procedure in evaluating the multivariate normal distribution (Cappellari and Jenkins, 2003).

Apart from the independent variable of interest which is land tenure security, several control variables are selected based on the literature and relate to the socioeconomic and demographic characteristics of farmers and institutional factors. These variables include household head age, education of household head, household head sex, experience in agriculture, household size, off-farm opportunities, farm size, and distance to market. Owing to differences in terms of resources between men and women, technology adoption may depend on the sex of the farmer. In this spirit, men may have more chance to adopt agricultural technologies than women (Sodjinou et al., 2015). However, the opposite result is also found in the literature (e.g., Nonvide, 2021). Education level is found to foster the adoption of agricultural technologies (D'Souza et al., 1993). Actually, the likelihood to adopt agricultural technologies increases with the education level of the farmer. Household size can influence positively the choice of agricultural technologies, as large farm households can take up labor-intensive technologies (Kassie et al., 2009). The age of the farmer is found in the literature to have mix effect on the adoption of agricultural technologies; either positive, negative or non-linear (Nonvide, 2023; Nonvide, 2021; Sodjinou et al., 2015). As for the experience in farming, it has the potential to increase the adoption rate of the technologies (Silvestri et al., 2012; Maddison, 2007). For instance, farmers perceive over time the need to modernize farm activities via technology adoption. The distance to market is also assumed to affect technology adoption, in the sense that proximity to markets foster this adoption (Lokonon and Mbaye, 2018; Maddison, 2007). Indeed, being close to market helps to have access to technologies. Off-farm opportunities can provide farmers with financial resources to be invested in the agricultural technologies. Therefore, off-farm opportunities is positively associated to the adoption of agricultural technologies (Silvestri et al., 2012). As for farm size, it is recognized to affect positively the adoption of agricultural technologies (Houeninvo et al., 2020; Lokonon and Mbaye, 2018). Although, factors such as access to extension services, membership to farmers' organizations and ownership of a mobile phone are hypothesized to influence the adoption of agricultural technologies (Nonvide, 2021), they are not included due to the fact that almost all the farmers (more than 97%) included in this study have access to those services, are members of those organizations and owned mobile phones.

3.2. Data and summary statistics

This research was carried out in the municipality of Toffo in the southern part of Benin. Toffo is characterized by a subequatorial climate, with two rainy seasons (the main from mid-March to mid-July and the second from September to November) and two dry seasons (the main from December to mid-March and the second from mid-July to August). The municipality benefits from a rainfall around 1100 mm and 800 mm during the main rainy season and the second rainy season, respectively, and a large part of the population draw their livelihoods from agricultural activities. The municipality of Toffo was chosen owing to the importance of cassava production. The survey covered three randomly selected districts

namely, Damè, Colli and Coussi. Finally, 90 farmers were randomly selected for the purpose of this study. A questionnaire was used to collect the data from the 90 farmers and the interviews were done with the household heads. Data analysis is done with Stata version 15.1.

Table 1 presents the main technologies adopted by cassava farmers in the study area. The statistics indicate that improved cassava varieties are adopted by 75.556% of the farmers. So, many farmers gave up already the traditional varieties to shift to the improved ones in order to improve cassava yield. Nevertheless, it remains about 25% of farmers that are still relying on traditional varieties. As for fertilizers, it is adopted by 78.889% of the farmers, so their adoption rate is greater than that of improved varieties. There are other technologies adopted by the farmers (80%) such as herbicides, ensuring one meter between two cassava plants, etc. Overall, 87.778% of the farmers adopted at least an agricultural technology. The summary statistics of the independent variables are presented in Table 2. It appears that 67.800% of farmers held a land title. However, around a third of the farmers still do not have access to secure land. Most of the farm households in the study area (78.889%) are headed by males. The average household head age is about 38 years. Thus, cassava farmers are relatively young in the study area. The average household size is 8 persons, with disparities across households (minimum of 3 and maximum of 17). This suggests that farm households in the study area are characterized by large size. In terms of experience in cassava production, the average farmer had 7.133 years of experience. But this figure hidden the disparities between farmers when looking at the minimum of 2 and the maximum of 30. Regarding the formal education level of the household head, the statistics show that 17.780% do not have any formal education level. The majority of the household head have either primary or secondary education level. Taking benefit from off-farm activities is common to the farmers. In fact, 92.222% of the farmers had off-farm opportunities, and this may help them to have financial resources to be invested in agricultural technologies. Moreover, the average farm size is 8.706 ha, with a minimum of 2 ha and a maximum of 20 ha. In terms of proximity to markets of farmers, the average distance to market is 12.222 km.

Table 1. Agricultural technologies adopted by cassava producers

Agricultural technologies	Adoption (%)
Improved varieties	75.556
Fertilizers	78.889
Other technologies	80.000
All	87.778

Table 2. Summary statistics of the explanatory variables

Variables	Description	Mean	Standard Deviation	Minimum	Maximum
Land tenure security	1 if the farmer hold a land title and 0 otherwise	0.678	0.470	0	1
Household head age	In years	38.556	6.569	23	54
Household size	In number of persons	8.256	3.495	3	17
Experience in agriculture	In years	7.133	5.806	2	30
Education of household head					
None	1 if yes and 0 otherwise	0.178	0.384	0	1
Primary	1 if yes and 0 otherwise	0.556	0.500	0	1
Secondary	1 if yes and 0 otherwise	0.222	0.418	0	1
University	1 if yes and 0 otherwise	0.044	0.207	0	1
Off-farm opportunities	1 if yes and 0 otherwise	0.922	0.269	0	1
Household head sex	1 if male and 0 if female	0.789	0.410	0	1
Farm size	In ha	8.706	3.494	2	20
Distance to market	In km	12.222	1.613	7	15

4. Empirical results and discussion

The estimation results of the multivariate probit are reported in Table 3. The results of the correlation coefficients of the error terms are positive and significant at the 1% level of significance. These indicate that the agricultural technologies adopted by the farmers are complement, supporting the hypothesis of interdependence between them and justifying the use of the multivariate probit model. These findings are somehow in line with previous studies such as Nonvide (2021) and Lokonon and Mbaye (2018). The complementary relationship between the agricultural technologies suggests that the technologies are not conflicting. So, these technologies can be adopted together to optimize their effect on cassava productivity. As expected, land tenure security fosters the adoption of agricultural technologies. Indeed, the findings reveal that the coefficient associated with land tenure security is positive and significant in the three equation. This suggests that when farmer hold a land title granting her tenure security, she fills more comfortable to invest in agricultural technologies related to cassava production, ceteris paribus (Lawin and Tamini, 2019; Abdulaye et al., 2011; Ali et al., 2011). Therefore, these findings show the importance of securing access to land to farmers in developing countries in order to foster the adoption of agricultural technologies and to speed up the structural transformation of the agricultural sector.

Table 3. Estimation results of the multivariate probit model of the effect of land tenure security on the adoption of agricultural technologies

Variables	Improved Varieties	Fertilizers	Other technologies
Land tenure security	0.880***	0.843**	1.036***
	(0.316)	(0.335)	(0.319)
Household head age	0.029	-0.032	-0.020
	(0.040)	(0.035)	(0.026)
Household size	0.022	0.089	-0.021
	(0.054)	(0.064)	(0.053)
Experience in agriculture	-0.018	-0.019	0.152***
	(0.041)	(0.034)	(0.038)
Education of household head (Reference=None)			
Primary	0.727*	-0.031	0.763*
	(0.418)	(0.422)	(0.430)
Secondary	0.799	0.113	0.552
	(0.517)	(0.499)	(0.494)
University	5.158***	1.593	2.253***
	(0.654)	(1.006)	(0.671)
Off-farm opportunities	0.883	1.897***	2.030***
	(0.697)	(0.731)	(0.690)
Household head sex	-0.357	0.537	-0.268
	(0.379)	(0.400)	(0.356)
Farm size	0.038	-0.078	
	(0.063)	(0.049)	
Distance to market		-0.014	
		(0.084)	
Constant	-2.465	-0.403	
	(1.698)	(1.586)	
rho21	0.903***		
	(0.097)		
rho31	0.907***		
	(0.042)		
rho32	0.706***		
	(0.163)		
Wald chi2 (30) = 867.330			
Prob > chi2 = 0.000			

Likelihood ratio test of rho21 = rho31 = rho32 = 0
chi2 (3) = 33.188
Prob > chi2 = 0.000

Notes: *** *p<0.01,* ** *p<0.05,* * *p<0.10*. Standard errors are in parentheses.

Experience in agriculture is positively associated with the adoption of other technologies. Thus, farmers get over years of producing cassava the importance of need to use herbicides, to ensure at least one meter between two cassava plants, etc. to improve cassava yield. This finding corroborates those of Lokonon and Mbaye (2018) on the positive effect of experience in agriculture on the uptake of sustainable land management practices. The findings indicate that off-farm opportunities facilitate the adoption of fertilizers and other technologies. Thus, off-farm activities provide farmers with financial resources to be invested in the use of fertilizers and herbicides. In fact, using those inputs requires financial means, as cassava farmers have to buy them; it is not possible to get inputs as credit like what exists regarding cotton production. Nonetheless, this finding is not in line with that of Lawin and Tamini (2019) that suggested that off-farm income has no effect on the adoption of agri-environmental practices. Formal education of the household is somehow related to the adoption of agricultural technologies. Actually, the households whose heads have a primary education level have significantly more chance to adopt improved varieties and other technologies than those that do not have any formal education level. Moreover, the households whose heads have an university education level have significantly more chance to adopt improved varieties and other technologies than those that do not have any formal education level. These findings are in some extent in line with those of literature (e.g., Nonvide, 2021; Lawin and Tamini, 2019).

5. Conclusion and policy implications

One of the main concerns in developing countries is low agricultural productivity and this issue is being exacerbated by climate change. This issue can be handled by agricultural technology adoption. Despite the unanimous direction of the theoretical literature on the beneficial effect on secure tenure and agricultural technologies adoption, the empirical literature found mixed effect, especially in Sub-Saharan Africa. Thus, this study analyzed the effect of land tenure security on the adoption of agricultural technologies in Benin. To that end, a multivariate probit model is estimated using survey data on 90 cassava producers in Southern Benin. The findings indicate that land tenure security fosters the adoption of agricultural technologies. Therefore, promoting land titling and ensuring access to secure land is desirable to improve the adoption of agricultural technologies for the structural transformation of the agricultural sector. Nevertheless, a main limitation of this study is the focus on a municipality of Southern Benin. Moreover, the study does not assess in which extent land tenure security can contribute to improving agricultural productivity. Consequently, future studies could address these limitations.

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