[Jpn. J. Agric. Econ. Vol.19, pp.21-26, 2017]

Determinants of Adoption and Continuous Use of Improved Maize Seeds in Burkina Faso

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This study aims to identify socio-economic and institutional factors that promote the adoption and continuous use of improved seeds in maize production in Burkina Faso. We use nationally representative panel data and confirm low rates of adoption and continuous use of improved maize seeds. Using a bivariate probit model with sample selection, we find that while the adoption of improved seeds increases with access to credit, membership in farmer organization, and contact with extension services, its continuous use is not affected by such institutional factors after controlling for province level fixed effects that capture agro-ecological variations in the country.

Key words: improved maize seeds, continuous use of technology, Burkina Faso

1. Introduction

The use of agricultural technologies such as chemical fertilizers, pesticides, and improved seeds, has long been considered as an effective pathway to increase agricultural productivity in Sub-Saharan Africa (Feder et al., 1985; Minten and Barrett, 2008; Saka and Lawal, 2009). Although combined use of these technologies is often recommended (World Bank, 2008; Hailemariam et al., 2013), improved seeds in particular play an important role in this process as this input alone may contribute to about 40% increase in yields (Bikienga, 2002). Thereby the use of improved seeds is essential for the transformation of subsistence farming that remains in many African countries into market oriented ones.

In Burkina Faso agricultural productivity remains low in general, especially that of cereal crops. Average yield of cereal from 2002 to 2012 was 1.04 t/ha in Burkina Faso, but it was over 6.50 t/ha in some developed countries like United States, 1.75 and 1.51 t/ha respectively in Côte d'Ivoire and Ghana according to FAOSTAT. Certainly this situation is strongly due to some natural constraints such as climatic hazard and poor quality of soils. However, the weak adoption of new technologies is manifested to be one of the explicative factors. Indeed, irrigation still overstays at an embryonic stage with only less than 14% of potential irrigable lands effectively cultivated. Further, chemical fertilizers are applied to less than 31% of land area for cereal production, and the application rate is estimated to be about 19 kg/ha (Combary, 2013), while it is over 145 kg/ha in developed world (Diiro and Sam, 2015). Moreover, less than 15% of farmers use improved maize seeds (CEFCOD, 2013).

Because of the significant role of new technologies in agricultural production and their low adoption rates in the number of developing countries including Burkina Faso, technology adoption in agriculture has been empirically a topic of considerable interest by scholars. A wide literature on this subject has identified categories of socio-economic, institutional and environmental factors as main determinants of their adoption in developing countries (Feder et al., 1985; Saka and Lawal, 2009) and in Burkina Faso as well (Savadogo et al., 1998; Adeoti et al., 2002; Combary, 2013). However, although the low adoption rates are partly due to disadoption (i.e. farmers who once adopted a new technology have stopped using it) for example Moser and Barrette (2003) and deGraft-Johnson et al. (2014), only a few studies have been focused on the factors affecting continuous or discontinuous use of adopted technologies. Examples of such a few studies are Oladele (2005), Neill and Lee (2001), and Tura et al. (2010).

Oladele (2005), in the case of Nigeria, uses an index number for farmer's degree of discontinuation of adopting improved maize varieties as the dependent variable and identifies variables explaining the index by a single equation Tobit model. On the other hand, both Neill and Lee (2001) and Tura et al. (2010) assume sequential decision making, where a farmer adopts a new technology and then decides to continue using it or to disadopt it because only adopters can be disadopters. In other words, their analysis distinguishes never-adopters and disadopters of a new technology. In order to deal with the two

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decisions, namely to adopt and to continuously use (or not to disadopt) the technology in question, they apply a bivariate probit model with sample selection for the case of cover crop technology for maize production in Honduras (Neill and Lee, 2001) and the case of improved maize seeds in Ethiopia (Tura et al., 2010), and show the importance of the role played by institutional factors such as access to credit, extension services, and membership of farmer organization in farmer's decision to pursue using one technology.

There are three points of common weakness in the previous studies. First is small sample size: 60 in Oladele (2005), 370 in Neill and Lee (2001), and 120 in Tura et al. (2010). None of them can claim that the study uses representative data of a country or a region/state. Second is the lack of time dimension. All of them use cross-section data, and explain adoption and continuous use of a technology by current and time-invariant variables although the decisions as to the adoption and the continuous use should have made in the past. Third is potential endogeneity of the institutional factors used in their regression analyses, that is, unobservable variables may affect both institutional factors and technology adoption/continuous use.

This paper focuses on the low adoption rate of improved technologies in Burkina Faso, especially improved maize seeds, and applies a bivariate probit model with sample selection like Neill and Lee (2001) and Tura et al. (2010) to identify socio-economic and institutional factors that determine the adoption of improved maize seeds and those influencing farmers' decision to continuously use them. However, in order to improve the existing studies and to make academic contribution, we use representative data of Burkina Faso and predetermined variables to predict decisions to be made in the future. In addition, since our data cover all the 45 provinces of Burkina Faso, province fixed effects are used to control for observable/unobservable province-level variations that affect both institutional factors and technology adoption/continuous use.

2. Methodology

1) Analytical framework

Adoption and continued use of one technology are outcomes of two interrelated decisions. Indeed, continuous use is subsequent to the decision to adopt the technology and can be observed only among the adopters. However, factors explaining the two decisions can be different for a given farmer, although some factors can explain the both. Because of the subordination in both decisions, it is necessary to take into account of potential correlation between the unobservable factors captured by the error terms, and a bivariate probit model with sample selection is suggested (Neill and Lee, 2001; Tura et al., 2010).

2) Bivariate probit model with sample selection

We assume that adoption decision is motivated by the expected utility, which is a function of the expected profit. Thus, a household will decide to apply one technology like improved seeds on its farm if he predicts a positive profit relative to the case without adoption estimated by available information including output and input prices. Then in the following year, this household will revise the prediction of profit based on the performance in the last year and decide to continue its use if he still predicts a positive profit.

The bivariate probit model with sample selection is similar to the Heckman's sample selection model. However unlike in the Heckman's model, the outcome equation is also a probit model in the bivariate model with sample selection.

Let us assume (y_k^*) k=1, 2 to be unobservable farmer's utility perceived from adoption of improved maize seeds (y_1^*) and from continuous use of them (y_2^*) depending on a vector X of explanatory variables. Suppose that (y_k) k=1, 2 are binary variables taking unity in the case of adoption of improved maize seeds and in the case of continuous use of them respectively and 0 otherwise. Then the standard bivariate probit model with additive error is specified as:

$$y_1^* = X_1'\beta_1 + \varepsilon_1; \begin{cases} y_1 = 1, if\ y_1^* > 0 \\ y_1 = 0, otherwise \end{cases} \quad (1)$$

$$y_2^* = X_2'\beta_2 + \varepsilon_2; \begin{cases} y_2 = 1, if\ y_1^* > 0\ and\ y_2^* > 0 \\ y_2 = 0, otherwise \end{cases} \quad (2)$$

where X_1 and X_2 are a vector of explanatory variables of the adoption decision and the continuous use respectively, β_1 and β_2 are parameters to be estimated, and ε_1 and ε_2 are error terms.

The log-likelihood function of the model is given by the following equation:

$$\begin{aligned} lnL = \textstyle\sum_i^N \{ & y_{i1}y_{i2}ln\Phi_2(X_1'\beta_1, X_2'\beta_2, \rho) \\ & + y_{i1}(1-y_{i2})\ ln\Phi_2(X_1'\beta_1, -X_2'\beta_2, -\rho) \\ & + (1-y_{i1})ln\Phi_1(-X_1'\beta_1)\} \end{aligned} \quad (3)$$

where i=1, 2, …, N.

In this specification, Φ_1 is the univariate normal distribution, and Φ_2 is the bivariate normal distribution. y_{i1} and y_{i2} are binary variables taking unity if farmer i adopts improved maize seeds and if farmer i continuously use them respectively and 0 otherwise. And ρ is the coefficient of correlation.

3. Data and Statistics Analysis

1) Data and variables created

Our study utilizes data of the Agricultural Permanent Survey collected by the Ministry of Agriculture of Burkina Faso from 2009/2010 to 2012/2013. This survey, regularly conducted each year since 2009/2010, forms a four-year panel of national representative sample of 4130 households drawn from all the 45 provinces, of which we select 2043 maize producers spread over 406 villages in 45 provinces for the analysis.

The model has two dependent variables: adoption and continuous use of improved maize seeds. These variables have been observed from the same farmers every year from 2009/10 to 2012/13. We take advantage of the panel structure to define "never-adopter", "disadopter", and "continuous user" as explained in the following paragraphs.

In this paper we classify maize seeds into either "improved" or "conventional" depending on farmer's judgement because they can tell which seeds are improved in most cases. Since the survey does not record the name of varieties or their sources, we cannot use such information for the classification of maize seeds.[1] Therefore, farmer's judgement is the most reliable information available for us.

As for the definition of adoption, this paper considers a farmer as an adopter of improved maize seeds if he/she planted improved maize seeds (as defined earlier) even partially at least once during the 4 years surveyed; and as a never-adopter of improved maize seeds if he/she never planted improved maize seeds during the 4 years surveyed. Then, adopters can be further classified as either continuous users, disadopters, or others (cases not possible to be classified): continuous users are farmers who planted improved maize seeds every year during the 4 years surveyed or farmers who did not plant improved maize seeds in the first year surveyed (i.e. 2009/10) but planted improved maize seeds during the last three years (i.e. from 20010/11 to 2012/13); and disadopters are farmers who experienced "disadoption" at least once during the 4 years surveyed. "Disadoption" is defined as the case where a farmer adopted improved maize seeds in a year and he/she did not adopt (or disadopted) them in the following year. Thus, in order for a farmer to be a disadopter, he/she must have adopted improved maize seeds in either 2009/10, 2010/11, or 2011/12 and disadopted them in the respective following year. We use this definition of disadoption since our concern is the stability or instability of technology adoption regardless of current status of technology use. There are two cases that are neither continuous users nor disadopters (i.e. others). One is the case where a farmer did not adopt in the first two years and adopt in the last two years. The other is the case where a farmer did not adopt in the first three years and adopted in the last year. Since we cannot classify them based on our definition, we drop such cases from the analysis.[2]

By definition, the classification of never-adopter, disadopter, and continuous user is a fixed household characteristic over the survey period, or in other words cross-sectional variation. Thus, our empirical strategy is to estimate equation (3) cross-sectionally using only predetermined variables at the beginning of the survey period, namely in 2009/10. Since the latent variables in equations (1) and (2) depend on the expected profit, explanatory variables should be ones that can affect it. Hence, as the explanatory variables, we consider sex, age, marital status, and literacy of household head, household size, livestock ownership, dry season cropping, quality of roof and wall of the house, access to credit[3], membership in farmer organization, and access to extension services. The last three (credit, membership, and extension) are regarded as institutional variables in this paper, which can potentially be endogenous in the model.

In addition, we use dummy variables for all the 45 provinces in order to control for observable and unobservable province-level fixed factors such as mean yield, production risk, expected input/output prices, and market/infrastructure development.[4] Although our data, just like Neill and Lee (2001) and Tura et al. (2010), do not allow us to calculate profit realized in the previous year, which as discussed above will influence farmer's decision to continue using improved maize seeds, we use province dummies as proxies of expected yield, production risk, and input/output prices unlike Neill and Lee (2001) and Tura et al. (2010). With respect to the yield and production risk, the 45 provinces are comprised of 10 provinces in the Sudanian zone, 25 provinces in the Sudano-Sahelian zone, and 10 provinces in the Sahelian zone. The three agro-ecological zones are distinguished by annual rainfall: the Sudanian zone located in the south-western part of the country with about 1000 mm of annual rainfall in five months; the Sahelian zone in the north-eastern part with less than 400 mm of annual rainfall in three months;

1) In Burkina Faso both open-pollinated and hybrid varieties are available as improved maize seeds. While open-pollinated improved seeds can be recycled, conventional varieties may sometimes be sold in the market. Therefore, the sources of seeds are not important information for the classification.

2) Since we have 4 years, the number of permutations of "1=adopt" and "0=non-adopt" is 16. Out of the 16 permutations, the excluded permutations are (0, 0, 1, 1) and (0, 0, 0, 1). The number of such households are 78 and 129 respectively.

3) Access to credit means an acquisition of credit during the latest twelve months.

4) For the regression analysis, one of the province dummies is excluded to avoid multicollinearity. Bam province in the Sahelian zone is excluded and is served as the reference category.

and the Sudano-Sahelian zone occupying between the two.[5)]

2) Descriptive statistics

Right half of Table 1 is for the descriptive statistics of the explanatory variables. It stands out that 763 (37.5%) of the 2033 sample maize producers have at least once used improved maize seeds (i.e. adopters), and that continuous users constitute only 248 (12.2%) of the sample maize producers. These results reflect the low utilization of improved seeds in maize production in Burkina Faso, as shown in CEFCOD (2013).

In addition, the descriptive table shows 37.1% of adopters received credits. Credit access is higher with continuous users (60.5%) than with disadopters (9.9%). Regarding farmer organization, 53.0% of adopters belong to a farmer organization for crop production including cotton production. While only 20.9% of disadopters are members of a farmer organization for crop production, 73.4% of continuous users are members of such an organization. Extension services from cotton companies shows a similar tendency. 18.5% of adopters received extension services from cotton companies. Receivers of extension services are much higher among continuous users (29.4%) than disadopters (4.6%). Thus, those institutional factors seem to contribute to continuous use of improved maize seeds.

4. Estimation Results and Discussions

Left part of Table 1 presents the results of the estimation. Considering the potential endogeneity of institutional variables, we estimate 4 models: model 1 has no institutional variables, model 2 includes credit, model 3 includes membership in farmer organization, and model 4 includes extension services. By comparing the 4 models, the inclusion of the institutional variables affect little the estimation results of other variables. Thus, we assume that province dummies control for unobservable/observable factors well and we interpret the estimation results of the institutional variables as they are.

The ρ parameter is not significantly different from zero in all the models, implying that the residuals of the two probit equations are not significantly correlated. However, since simultaneous estimation by maximum likelihood can be more efficient than separate estimation of each probit equation, we accept the estimation results.

1) Role of socio-economic variables of the model

One of the socio-economic factors drawing our attention is household size: it appears to be decisive in the both decisions of adoption and continuous use of improved maize seeds. In rural area of Burkina Faso where labor market is not well developed, household size strongly determines labor availability. Thus the adoption of improved maize seeds, which may require more financial investment in seeds and chemicals than otherwise, is done under an assurance of labor availability; this may denote its importance in increasing the likelihood of continuous use of improved maize seeds. Neill and Lee (2001) reached a similar result by highlighting that availability of family labor is positively linked to adoption decision of "mucuna", a cover crop for maize production, in northern Honduras.

Literacy and household assets like tin roof and thatch wall are found to have influence in technology adoption, as is common in the literature. But literacy has no effect on continuous use. As for household assets, relatively rich households (with tin roof) are indifferent to continuous use, but very poor households (with thatch wall) are likely to disadopt improved maize seeds.

2) Roles of institutional factors of the model

As for institutional factors models 2, 3, and 4 show that all the institutional variables except for government extension services have significantly positive influences on farmers' adoption decisions. In Burkina Faso, where most of rural households are faced with liquidity constraints, credit is very essential for the acquisition of improved maize seeds. This result is consistent with many previous findings regarding the role of credit in technology adoption including Tura et al. (2010). Membership in farmer organization is known to facilitate farmers' access to technology such as fertilizers and improved seeds. In Burkina Faso, it is quite common that farmer groups serve as guarantees before acquisition of input credit. Extension services have also a positive impact on the adoption of improved maize seeds, although those from the government is not statistically significant. Thus, information about new technologies is important for farmers to adopt them.

In spite of the significant effect of the institutional variables on the adoption, none of them influences significantly the continuity of using improved maize seeds. The findings are not consistent with the above mentioned existing literature. As discussed in the previous section, the descriptive statistics in Table 1 indicate strong association of the institutional variables with continuous use of improved seed. But the estimation results imply that the association is due to ago-ecological conditions probably such as expected yield and risk in each province.[6)]

5) Average maize yield was 1.45t/ha, 1.26t/ha, and 0.88t/ha and its standard deviation was 0.21t/ha, 0.28t/ha, and 0.36t/ha in the Sudanian, the Sudano-sahelian, and the Sahelian zones respectively from 2009/10 to 2012/13 (Direction Générale des Etudes et des Statistiques Sectorielles, 2014). Almost all maize is grown under rainfed condition in Burkina Faso, but some maize is planted in garden with manual watering from well and/or pond.

Table 1. Estimation results with descriptive statistics

Explanatory Variables	Model 1 Adoption	Model 1 Cont. use	Model 2 Adoption	Model 2 Cont. use	Model 3 Adoption	Model 3 Cont. use	Model 4 Adoption	Model 4 Cont. use	Descriptive statistics (mean) Adopters	Descriptive statistics (mean) Disadopters	Descriptive statistics (mean) Cont. users
Sex of household head	0.38	1.07^{*}	0.48^{*}	1.09^{*}	0.36	0.85	0.30	0.83	0.978	0.950	0.996
(1=male, 0=female)	(0.25)	(0.56)	(0.25)	(0.57)	(0.23)	(0.61)	(0.24)	(0.69)			
Age of household head	-0.01^{***}	-0.00	-0.01^{*}	-0.00	-0.01^{*}	-0.00	-0.01^{***}	-0.00	47.9	50.8	46.6
(years)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)			
Household size	0.03^{***}	0.02^{***}	0.02^{***}	0.02^{**}	0.02^{***}	0.02^{*}	0.03^{***}	0.00	11.7	10.2	13.5
(head count)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)			
Marital status of household head	-0.03	0.03	-0.06	-0.05	-0.06	0.01	0.00	0.08	0.942	0.926	0.956
(1=married, 0 otherwise)	(0.22)	(0.26)	(0.21)	(0.28)	(0.21)	(0.26)	(0.22)	(0.27)			
Literacy of household head	0.23^{**}	0.00	0.24^{**}	0.04	0.20^{**}	-0.05	0.22^{**}	-0.08	0.320	0.240	0.331
(1=yes, 0 otherwise)	(0.10)	(0.13)	(0.10)	(0.15)	(0.10)	(0.13)	(0.10)	(0.14)			
Household having livestock	0.13	0.26	0.10	0.28	0.10	0.29	0.16	0.25	0.972	0.969	0.976
(1=yes, 0 otherwise)	(0.21)	(0.34)	(0.24)	(0.29)	(0.22)	(0.34)	(0.21)	(0.34)			
Quality of house roof	0.29^{***}	0.13	0.26^{***}	0.15	0.25^{***}	0.04	0.31^{***}	0.06	0.549	0.441	0.589
(1=tin, 0 otherwise)	(0.09)	(0.17)	(0.09)	(0.17)	(0.09)	(0.18)	(0.09)	(0.18)			
Quality of house wall	-1.15^{***}	-5.10^{***}	-1.27^{***}	-5.80^{***}	-1.09^{***}	-5.14^{***}	-1.23^{***}	-5.17^{***}	0.003	0.020	0
(1=thatch, 0 otherwise)	(0.37)	(0.35)	(0.39)	(0.47)	(0.35)	(1.86)	(0.33)	(1.98)			
Maize growing in rainy season	-0.02	-0.15	-0.09	-0.24	-0.10	-0.26	-0.09	-0.27	0.973	0.967	0.972
(1=yes, 0=no, in dry season)	(0.26)	(0.27)	(0.27)	(0.26)	(0.26)	(0.28)	(0.25)	(0.33)			
Access to credit	-	-	1.21^{***}	0.73	-	-	-	-	0.371	0.099	0.605
(1=yes, 0=no)			(0.17)	(0.50)							
Membership in crop production	-	-	-	-	0.87^{***}	0.32	-	-	0.530	0.209	0.734
organization (1=yes, 0=no)					(0.11)	(0.46)					
Membership in other production	-	-	-	-	0.32^{**}	0.19	-	-	0.056	0.061	0.044
organization (1=yes, 0=no)					(0.16)	(0.33)					
Extension services from NGO	-	-	-	-	-	-	0.45^{**}	0.23	0.063	0.048	0.060
(1=yes, 0=no)							(0.19)	(0.37)			
Extension services from government	-	-	-	-	-	-	0.04	0.41	0.039	0.037	0.048
(1=yes, 0=no)							(0.14)	(0.28)			
Extension services from cotton companies	-	-	-	-	-	-	1.13^{***}	0.22	0.185	0.046	0.294
(1=yes, 0=no)							(0.20)	(0.41)			
Province Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes			
Constant	-2.13^{***}	-7.08^{***}	-2.42^{***}	-8.21^{***}	-2.06^{***}	-6.38^{*}	-2.09^{***}	-5.86			
	(0.40)	(1.33)	(0.43)	(0.89)	(0.41)	(3.41)	(0.39)	(4.02)			
Wald test for $\rho=0$	0.05 (0.59)		0.36 (1.22)		-0.34 (0.80)		-0.38 (0.85)				
Number of Samples	2033		2033		2033		2033		763	515	248

Note: Absolute standard errors are in parentheses. They are heteroskedasticity robust and clustered by province. ***, ** and * indicate significance level at 1%, 5% and 10% respectively.

5. Conclusion

This study aims to identify socio-economic and institutional factors facilitating the adoption and the continuous use of improved seeds in maize production in Burkina Faso. A bivariate probit model with sample selection is used to identify these factors. The results indicate that the adoption of improved maize seeds increases significantly with socio-economic factors such as literacy of household head, availability of family labor, household assests as well as with institutional factors namely access to credit, membership in farmer organization, and access to extension services. Thus, such institional factors are considered to provide farmers with "easy" conditions to access to this technology.

However, none of these institutional factors contributes to continuous use of improved maize seeds. Except for some household socio-economic factors like family size and assets, the continuous use is largely determined by province level observable/unobservable factors such as expected yield and its variability. This findings are the contribution of this paper that uses nationally representative data unlike existing literature on this topic. The results may imply that the observed frequent disadoption is caused by farmers' trial use of improved seeds without good knowledge about the suitable conditions for growing new varieties.

This study does not consider the price of improved maize seeds in comparison with that of conventional ones because such information is not available in the dataset. Making the model dynamic incorporating realized profit in previous year is a necessary extension of this study.

References

Bikienga, I. M. (2002) *Une Evaluation des Secteurs des Engrais et des Semences au Burkina Faso*, African Trade Investment Program.

CEFCOD: Centre d'Etude, de Formation et de Conseil en Développement (2013) *Situation de Reference des Principales Filieres Agricoles au Burkina Faso*, Ministère de l'Agriculture et de la Securite Alimentaire.

Combary, O. S. (2013) Décisions d'adoption et d'intensification de l'utilisation des engrais chimiques dans la production céréalière au Burkina Faso, *Revue CEDRES-Etudes* 56: 22-35.

deGraft-Johnson, M., A. Suzuki, T. Sakurai, and K. Otsuka (2014) On the Transferability of the Asian Rice Green Revolution to Rainfed Areas in sub-Saharan Africa: an Assessment of Technology Intervention in Northern Ghana, *Agricultural Economics* 45(5): 555-570.

Diiro G. M. and G. M. Sam (2015) Agricultural Technology Adoption and Nonfarm Earnings in Uganda: A Semiparametric Analysis, *The Journal of Development Area* 49(2): 45-162.

Direction Generale des Etudes et des Statistiques Sectorielles (2014) *Annuaire des Statistiques Agricoles 2012*, Misnistère de l'Agriculture et de la Securité alimentaire.

Doss, C. R. (2006) Analyzing Technology Adoption Using Microstudies: Limitations, Challenges, and Opportunities for Improvement, *Agricultural Economics* 34: 2 07-219.

Feder, G., R. Just, and D. Zilberman (1985) Adoption of Agricultural Innovations in Developing Countries: A Survey, *Economic Development and Cultural Change* 33(2): 255-298.

Hailemariam, T., K. Menale, and S. Bekele (2013) Adoption of Multiple Sustainable Agricultural Practices in rural Ethiopia, *Journal of Agricultural Economics* 64(3): 597-623.

Minten, B. and B. C. Barrett (2008) Agricultural Technology, Productivity, and Poverty in Madagascar, *World Development* 36(5): 797-822.

Moser, C. and B. C. Barrett (2003) The Disappointing Adoption Dynamics of a Yield-increasing, Low External-input Technology: the Case of SRI in Madagascar, *Agricultural Systems* 76(3): 1085-1100.

Neill, S. P. and D. R. Lee (2001) Explaining the Adoption and Disadoption of Sustainable Agriculture: The Case of Cover Crops in Northern Honduras, *Economic Development and Cultural Change* 49(4): 793-820.

Oladele, O. (2005) A Tobit Analysis of Propensity to Discontinue Adoption of Agricultural Technology Among Farmers in Southwestern Nigeria, *Journal of Central European Agriculture* 6(3): 249-254.

Saka, J. O. and B. O. Lawal (2009) Determinants of Adoption and Productivity of Improved Rice Varieties in Southwestern Nigeria, *African Journal of Biotechnology* 8(19): 4923-4932.

Savadogo, K., T. Reardon, and K. Pietola (1998) Adoption of Improved Land Use Technologies to Increase Food Security in Burkina Faso: Relating Animal Traction, Productivity, and Non-Farm Income, *Agricultural Systems* 58(3): 441-464.

Tura, M., D. Aredo, R. La Rovere, G. Tesfahun, W. Mwangi, and G. Mwabu (2010) Adoption and continued use of improved maize seeds: Case study of Central Ethiopia, *African Journal of Agricultural Research* 5(17): 2350-2358.

World Bank (2008) *World Development Report: Agriculture for the Development*, World Bank.

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6) Although the results are not shown, if the province dummies are grouped for each agro-ecological zone, the zone dummies are significant in both equations, and the most favorable zone (i.e. the Sudanian zone) is the most influential in the adoption and the continuous use of improved maize seeds as expected.