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Decisions for adopting and intensifying the use of chemical fertilizers in cereal production in Burkina Faso

Omer S. Combary

Department of Economics and Management, University Ouaga II, Burkina Faso.

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This article used a Tobit model to analyze what determines the decisions to adopt and intensify the use of chemical fertilizers in cereal production in Burkina Faso. The results show that the main factors that explain the adoption and increased use of chemical fertilizers are: agricultural potential of the area of production, ownership of a radio set, formal education of actives household members, closeness to an earth-built road, amount of credit and membership in a group of producers. The marginal effects showed that the probability of adoption of chemical fertilizers by new entrants is greater than the probability of existing producers intensifying the usage of chemical fertilizers. These results imply that the incentives for the adoption and intensification policies should primarily target producers who have not yet used chemical fertilizers.

Key words: Tobit model, adoption, intensification, fertilizers, cereals.

INTRODUCTION

The liberalization of the economy in 1991 has ended input subsidy policies in Burkina Faso's agricultural sector. Although subsidies were no more available, domestic consumption of chemical fertilizers continued to grow due to the expansion of cotton production. The proportion of farmlands that use chemical fertilizers increased from 7% in 1993 to 30% in 2006. The rate of chemical fertilizers application also increased from 12 to 40 kg/ha over the same period. This increase was transmitted to cereal production for which the rate of chemical fertilizers application increased from 5 to 19 kg/ha due to the diversion of inputs from cotton production[1].

However, consumption of chemical fertilizers for cereal production had strongly decreased since 2006 due to the crisis in the cotton sector. This is an obstacle to the improvement of agricultural productivity, revenue increment and poverty reduction efforts of rural households. These rural households representing about 80% of the population have agricultural production as the main source of livelihood. The poverty profile shows that more than 50% of rural people live below the poverty line[2].

Cereal production (sorghum, millet, maize, rice) occupies more than 88% of farmland and is the main staple food crops for the majority of the population. It is an extensive farming practice that increasingly faces significant constraints such as population pressure, scarcity of arable land, and the degradation of natural resources[3]. Preservation of natural resources and improvement of agricultural productivity necessarily require the adoption and increased use of new technologies. With the 2008 food crisis, the government of Burkina Faso has renewed its interest in subsidizing agricultural inputs for the intensification of cereal

[1] Ministry of Agriculture, Water and Fisheries Resources, 2011

[2] Ministry of Economy and Finance, 2010

[3] Ministry of Agriculture, Water and Fisheries Resources, 2008

production. Thus, the government has implemented a policy based on agricultural intensification and the use of chemical fertilizers and high yielding seed varieties, to fight against recurrent food insecurity. However, there is almost no research on what determines the adoption and the intensity of the use of chemical fertilizers.

An abundant literature has identified the socio-economic, demographic, agro ecological and institutional factors as the key determinants of the decision to adopt new technologies in developing countries (Zegeye et al., 2001; Knepper, 2002; Feder et al., 1985; Moreno and Sunding, 2005). The adoption of a new technology is driven by the profit expected by producers and the availability of information on its implementation and effectiveness. In this regard, it had been found that the formal education increases the probability of technology adoption (Wozniak, 1984; Feder et al., 1985; Doss et al., 2003; Asfaw and Admassie, 2004).

Access to agricultural extension services encourages producers to adopt new technologies in developing their activities (Bacha et al., 2001; Kherallah et al., 2002). In an environment where technology transfer is difficult, the standard of formal education of the actives is critical (Wozniak, 1984; Ersado et al., 2004). The number of actives also plays a key role in the decision to adopt and increase the use of technology (Lee, 2005). Larger households have a greater adoption probability of new technologies (Croppenstedt and Demeke, 1996; Zegeye et al., 2001; Doss et al., 2003).

Availability of off-farm income helps to remove credit constraints and improve the probability of adoption of a new technology (Feder et al., 1985). On the other hand, producers who have low-income or credit constraint are less likely to adopt new technologies that are risky (Adesina, 1996). The research results have also shown that agro-ecological conditions influence the probability of adoption of agricultural technology (Chirwa, 2005; Doss, 2006). Thus, producers located in low rainfall areas are less likely to adopt chemical fertilizers (Freeman and Omiti, 2003; Chianu and Tsujii, 2004).

Although most of these studies address the issue concerning the elements determining the adoption of new technologies, they do not give satisfactory information on the intensity of their use. For this objective, they have used Probit or Logit models to model the adoption decision. The objective of this paper is to identify the effects of factors that influence decisions of adoption and intensification of the use of chemical fertilizers in cereal production in Burkina Faso. To this end, the Tobit model is the most suitable one (McDonald and Moffit, 1980).

Theoretical framework for the adoption and intensification of a technology

The producer establishes his decision to adopt a new technology on the expected profitability. He adopts the new technology only if the expected profitability is higher than that of the non-adoption (Marenya and Barrett, 2007; Nkamleu and Adesina, 2000). The Probit, Logit, and Tobit models are the ones that are most commonly used to identify factors that influence the decision for adopting a new technology (Imai, 2003).

Probit and Logit models allow the modeling of the adoption of a new technology when the dependent variable is binary. The Tobit model enables the modelling of both the adoption and intensification of the use of a technology when the dependent variable is continuous and censored at 0 (Adesina and Zinnah, 1993; Kazianga and Masters, 2002; Anley et al., 2007). The Tobit model is therefore, the most appropriate for understanding the factors that influence the decision of adoption and intensification of the use of chemical fertilizers.

The expected profit (y_i^*) is an unobserved latent variable that depends on the alternative choices and socio-economic, demographic, and institutional characteristics of the producer (X_i). The stochastic form of Tobit model (McDonald and Moffit, 1980; Yilma et al., 2008) can be represented as follows:

$$y_i^* = X_i'\beta + \varepsilon_i\,, \quad i = 1, \ldots, n \qquad (1)$$

$y_i = 0$ if $y_i^* \leq 0$, non-adoption of chemical fertilizers

$y_i = y_i^*$ if $y_i^* > 0$, adoption of chemical fertilizers

Where y_i is the observed variable, β a vector of unknown parameters and ε_i is independently and normally distributed error term with mean 0 and constant variance, σ^2.

McDonald and Moffit (1980) specify the expected value of y as follows:

$$E[y] = X'\beta F(z) + \sigma f(z) \qquad (2)$$

They specify the expected value of y for observation over Censorship ($y^* > 0$) as follows:

E-mail: combaryomer@yahoo.fr. Tel: (226)70290924.

Abbreviations: JEL classification: O33, O55, Q12. .

Table 1. Definition of explanatory variables in the model of adoption and intensification of chemical fertilizers.

Description	Expected affects
Agricultural potential of the area (1=area of high agricultural potential, 0=otherwise)	+
Radio set ownership (1=yes, 0=no)	+
Age of head of household (years)	+/-
Non-farm income (FCFA)	+
Average years of education of workers (years)	+
Distance to a land-built road (km)	-
Number of household workers	+/-
Total amount of credit received (FCFA)	+
Member of a group of producers (1=at least one member in a group, 0=otherwise)	+
Quantity of organic manure (Number of carts)	-

Source: Construction of the author from the review of theoretical and empirical literature.

$$E[y^*]= X'\beta + \sigma f(z)/F(z) \quad (3)$$

Where z represents $X'\beta/\sigma$, $f(z)$ the normal density function, and $F(z)$ the distribution of the normal cumulative function. According to the method of McDonald and Moffit (1980), the effect of explanatory variables of Tobit model can be split into decision of adoption and intensification of the use of chemical fertilizers. The marginal effect of each explanatory variable X_i on the expected value of the dependent variable is defined by:

$$\frac{\partial E(y)}{\partial X_i} = F(z)(\delta E(y^*)/\delta X_i) + E(y^*)(\delta F(z)/\delta X_i)$$

The change of the adoption probability of chemical fertilizers due to the variation of an explanatory variable is measured by:

$$\frac{\delta F(z)}{\delta X_i} = \frac{f(z)}{\sigma}\beta_i$$

The change in the intensity of the use of chemical fertilizers due to the variation of an explanatory variable is measured by:

$$\frac{\delta E(y^*)}{\delta X_i} = \beta_i \left[1 - z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}\right]$$

The parameters of the presented Tobit model can be estimated using the method of the maximum likelihood based on households' data.

VARIABLES FOR ANALYSIS AND METHOD OF DATA COLLECTION

In order to implement the Tobit model of adoption and intensification of the use of chemical fertilizers, appropriate variables have been considered and data have been collected on them through a survey of cereal producers.

Definitions of variables of the model

The producer's decision to adopt a technological innovation depends on complex factors. The most conventionally analyzed ones are the socio-economic and demographic characteristics of the producer, as well as the institutional and agro-ecological factors. The choice of the relevant variables for the present study is based on the theoretical and empirical literature related to technological adoption.

The dependent variable of the Tobit model is defined as the proportion of farmland devoted to cereal production using chemical fertilizers. The main cereals (sorghum, millet, maize, rice) produced in Burkina Faso have been taken into consideration in the analysis. The study focused on the usage of NPK and urea, which are the main chemical fertilizers used in cereals production in the country. The dependent variable is a continuous variable, but its value is between 0 and 1. Table 1 presents the independent variables and the expected signs of the associated parameters.

Source of the data used

The data for this study were collected by the Laboratoire d'Analyse Quantitative Appliquée au Développement–Sahel (LAQAD-S), in the context of collaborative research between the International Food Policy Research Institute (IFPRI), several African universities[4] and the University of Goettingen (Germany). The aim of the project («Convergence») was to conduct researches on maximizing the impact of social service expenditures on agricultural labor productivity and incomes in African countries.

The national scope of the study led to the subdivision of the whole rural area of Burkina Faso into 6 strata based on the quality of social characteristics (health, education, nutrition, access to drinking water) of the populations and the concentration of non-governmental organizations in the community. Thus, 8 of the 45 provinces of Burkina Faso were selected on the basis of their agricultural potential and the weighting given to each stratum.

In each province, 2 departments were selected randomly and in

4 University Ouaga II (Burkina Faso), Sakoine university of agriculture (Tanzania) et National university of Rwanda (Rwanda)

each department 4 or 5 villages were randomly selected depending on its size. In this way, the survey covered 36 villages and in each village, 15 farming households were selected randomly, totaling 540 households. The sampling focused on the spatial distribution of the surveyed villages, in order to take into account the differences in behavior and regional diversities.

The data was collected from farming households from January to February 2011. The survey was conducted using questionnaires on a declarative basis of farming households, generally on a recall period covering the last 12 months. The data contained information on the socio-economic, demographic, and institutional characteristics of the households. Detailed data were collected on the situation of health, education, social safety nets and agricultural production among rural households.

Factors determining the adoption and intensification of chemical fertilizers

This section presents the socio-economic, demographic and institutional factors affecting the decisions of adoption and intensification of the use of chemical fertilizers in cereal production.

Characterization of households according to the use of chemical fertilizers in cereal production

A description of the characteristics of households is presented in Table 2. It shows a general low level of the use of chemical fertilizers. On average, only 31.0% of cereal farmlands received chemical fertilizers; this rate reaches 72.5% if we consider only the producers who used chemical fertilizers in cereal production. Mean-comparison tests indicate a significant difference at the threshold of 5% of socio-economic, demographic, institutional, and agro-ecological characteristics between the producers who adopted and those who did not adopt chemical fertilizers (Table 2). Producers who use chemical fertilizers mostly are those living in areas with high agricultural potential, having at least one radio set, and having working members that have attended formal school. They also live near a land-built road, have the larger number of active members, receive more credit, and have at least, one member in an organization.

RESULTS

Estimation results of the Tobit model for adoption and intensification of the use of chemical fertilizers

The results of the econometric estimation of Tobit model of adoption and intensification of the use of chemical fertilizers are reported in Table 3. The likelihood ratio test indicates that the estimated model is globally significant at 1%. Individual significance tests indicate that the agricultural potential of the area of production, possession of at least one radio set, average number of years of formal education of the workers, proximity to a land-built road, and the amount of credit and membership in an association significantly influence the decision to adopt and intensify the use of chemical fertilizers at a threshold that is lower or equal to 5% and have the expected signs.

However, household's head's age, off-farm income, number of working household members and the amount of organic manure have no significant effects on the adoption and intensification of the use of chemical fertilizers. Apart from the effect of the number of working household members, the results are consistent with the descriptive analyzes that have been done through mean-comparison

tests of the socioeconomic, demographic, agro-ecological and institutional characteristics among the producers who adopted chemical fertilizers and non-adopters. The results of the econometric analyses indicate that the estimated Tobit model is well specified and the socio-economic, demographic, institutional, and agro-ecological factors that have been identified explained significantly the adoption and intensification of the use of chemical fertilizers.

Decomposition of the marginal effects of factors on the use of chemical fertilizers

The program of Cong (2000) was used for implementing the breakdown of the marginal effects of the explanatory variables both on the adoption probability and the intensification of the use of chemical fertilizers.

Table 4 presents the results from the breakdown of the marginal effects of Tobit model. The results indicate that carrying out agricultural activities in an area of high agricultural potential increases significantly at the threshold of 1%, the probability of adopting chemical fertilizers by 0.22. Specifically, this probability increases by about 0.24 for households that were not using chemical fertilizers yet. On the contrary, households that were already using the technology intensify its usage by an increase of 0.16.

Having a radio set increases significantly at the threshold of 1% the probability of adopting chemical fertilizers by about 0.15. This increase is mainly driven by the probability of the adoption of non-user households that increased by about 0.19, against an improvement of 0.12 related to the intensification of use of chemical fertilizers by households that already use it. The level of education has a very significant positive effect at the threshold of 1% concerning the probability of adoption of chemical fertilizers. Each additional year of education of a worker improves the probability of adoption of chemical fertilizers by 0.03. Non-user households contribute mostly with an increase in the probability of adoption by 0.04, against 0.02 related to the intensification of household using chemical fertilizers. These results are contrary to what was reported by Zhou et al. (2010) in Northern China, but support findings by Thuo et al. (2011) in Senegal.

Easy access to an earth-built road increases significantly at the threshold of 1% the probability of adoption of chemical fertilizers. If the distance from a producer to an earth-built road increases by one kilometer, the probability of adoption of fertilizer

Table 2. Characterization of households according to the use of chemical fertilizers in cereal production.

Description	Average	Chemical fertilizers non–users	Chemical fertilizers users	Difference
Proportion of cereal farmlands using chemical fertilizers (%)	31.0	0.0	72.5	-72.5***
Agricultural potential of the area (%)	25.0	13.6	40.3	-26.7***
Possession of a radio set (%)	64.6	56.3	75.8	-19.4***
Age of household head (years)	45.0	45.5	44.4	1.1
Non-farm income (FCFA)	14063	131526	152814	-21288
Average years of education of workers	0.80	0.69	0.95	-0.3**
Distance to a land-built road (km)	7.9	9.1	6.2	3.0***
Number of household workers	3.9	3.7	4.1	-0.5***
Total credit received (FCFA)	38202	15729	68263	-52534***
Belonging to a producers association (%)	46.5	36.6	59.7	-23.2***
Quantity of organic manure (carts)	8.6	8.2	9.0	-0.8

Source: Author's computation based on data of the project "Convergence" / Burkina Faso, 2011. *** Significant at 1%, ** Significant at 5%.

Table 3. Estimation results of the Tobit model for adoption and intensification of the use of chemical fertilizers.

Description	Coefficients	Standard errors	T-statistics
Constant	-0.5051	0.1535	-3.29
Agricultural potential of the area	0.4377***	0.0861	5.08
Possession of a radio set	0.3567***	0.0825	4.32
household head Age	-0.0019	0.0029	-0.68
Non-farm income	0.0000003	0.0000002	1.38
Average years of workers education	0.0736***	0.0263	2.80
Distance to an land-built road	-0.0125***	0.0038	-3.27
Number of household workers	0.0057	0.0186	0.31
Total credit received	0.0000006**	0.0000003	1.96
Belonging to a group of producers	0.2558***	0.0760	3.36
Amount of organic manure	0.0007	0.0025	0.28
Log likelihood		-430.9	
Pseudo R^2		0.1120	
LR test		108.7***	
Number of observations		540.0	
Proportion of users of chemical fertilizers		42.8%	

Source: Author's computation based on data of the project "Convergence" / Burkina Faso, 2011.*** Significant at 1%, ** Significant at 5%

decreases by about 0.006. This effect is greater on the probability of the adoption of non-user producers which decreases by 0.007 when distance to an earth-built road increase by one kilometer, compared to chemical fertilizers users which decreases by 0.004 when distance to an earth-built road increase by one kilometer. These results are consistent with those reported by Zhou et al. (2010) in Northern China, but contrary to findings by Martey et al. (2014) for smallholder farmers in Northern Ghana.

Access to credit has a significant positive effect at the threshold of 5% on the probability of the adoption of chemical fertilizers. An additional FCFA 10 000 credit increases the probability of adoption of chemical fertilizers by 0.003. This effect is mainly attributed to the probability of adoption by non-user households that increase by about 0.003, against an improvement of 0.002 associated with the increased use by households that were already using chemical fertilizers. These results are contrary to what Martey et al. (2014) found on smallholder farmers in Northern Ghana.

Membership to an association of producers improves significantly the probability of adoption of chemical fertilizers by approximately 0.12 at the threshold of 1%.

Table 4. Decomposition of the marginal effects of factors on the use of chemical fertilizers.

Description	Marginal effects	Effects on the probability of adoption	Effect on increasing the use
Agricultural potential of the area	0.2243***	0.2359***	0.1629***
Possession of a radio set	0.1517***	0.1899***	0.1160***
Age of head of household	-0.0009	-0.0011	-0.0007
Non-farm income	0.0000001	0.0000001	0.0000001
Average years of education of the workers	0.0333***	0.0400***	0.0249***
Distance to a land-built road	-0.0057***	-0.0068***	-0.0042***
Number of household workers	0.0026	0.0031	0.0019
Total credit received	0.0000003**	0.0000003**	0.0000002**
Belonging to a group of producers	0.1172***	0.1385***	0.0874***
Quantity of organic manure	0.0003	0.0004	0.0002

Source : Author's computation based on data of the project "Convergence" / Burkina Faso, 2011 *** Significant at 1% ** Significant at 5%.

Non-user households contribute mostly by increasing their adoption probabilities by 0.14 in comparison with the user households for whom the probability of intensification of chemical fertilizers increases by only 0.09. These results are consistent with those reported by Martey et al. (2014) for smallholder farmers in Northern Ghana (Table 4).

CONCLUSION AND POLICY IMPLICATIONS

A Tobit model was used to examine the decision of adoption and intensification of the use of chemical fertilizers in cereals production in Burkina Faso. The parameters of the model were estimated using the method of the maximum likelihood. The results show that the model is well specified and most of the estimated coefficients are significant and have the expected signs.

The results indicate that the decision to adopt and intensify the use of chemical fertilizers increase significantly with the following variables: agricultural potential of the area of production, possession of a radio set, level of formal education of the workers, closeness to an earth-built road, amount of credit received, and membership of a producer group. Splitting up of the marginal effects shows that the effect of the probability of adoption by the non-user producers is prominent than the effect due to the intensification of fertilizers by existing users.

These results allow us to draw several implications for agricultural policy to improve the productivity of cereals production. Policy makers should first focus on dissemination of information, training, and availability of chemical fertilizers. To this end producer groups and radio stations can be used for training and extensions on the use of chemical fertilizers. The second aspect to consider in terms of agricultural policy is about the promotion of support services to grain production. Research - development should be more oriented towards the production and dissemination of chemical fertilizers tailored to each area of agro- ecological production. These various changes should be accompanied by access of cereal producers to agricultural credits and the development of rural roads to facilitate access to inputs and the flow of cereals. These policies recommended for implementation should primarily target cereal farmers who do not as yet resort to chemical fertilizers usage.

Conflict of Interests

The authors have not declared any conflict of interests.

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