A Double-Hurdle Model of Fertilizer Adoption and Optimum Use among Farmers in Southern Nigeria

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Summary

This study determines decision variables that influence fertilizer adoption and optimal intensity use among crop farmers in Abak agricultural zone of Akwa Ibom state in Southern Nigeria. Primary data were obtained from 150 arable- crop farming household heads in the study area. An independent double hurdle model was used to analyze the objectives of the study on the assumption that adoption and optimal use of fertilizer by respondents were two independent decisions influenced by different factors. Empirical estimates of the first hurdle reveals that family size, farm size, perceived price of fertilizer, years in farming business, value of crop output, extension agent visit, number of goats and sheep kept by farmers, and decision to own poultry are statistically significant decision variables that influenced the probability of adopting fertilizer by farming household heads in the study area. Estimates of the second hurdle revealed that, the decision to use optimum intensity of fertilizer by farming household heads was influenced by age, gender, farm size, purpose of crop production, perceived price of fertilizer, crop output, number of goats and sheep kept by respondents, and distance to fertilizer selling point. To encourage fertilizer adoption and it optimal usage, the price of fertilizer should further be subsidized and extension unit in the state strengthened to educate farmers more on the importance of fertilizer. Also, fertilizer selling units should be located at strategy points in the rural areas in the state so as to reduce the transportation and purchasing costs.

Résumé

Un modèle “Double hurdle” d’adoption d’engrais et son utilisation optimale chez les agriculteurs dans le sud du Nigéria

Cette étude nous démontre des facteurs variables qui influent sur l’adoption de l’engrais et son utilisation optimale parmi les cultivateurs de récolte dans la région agricole d’Abak, située dans l’Etat d’Akwa Ibom au sud du Nigéria. Les données primaires étaient recueillies chez 150 leaders de familles agricultrices qui ont des récoltes arables dans le territoire d’étude. Un modèle indépendant «double hurdle» était utilisé pour analyser les objectifs de cette étude sur l’hypothèse que l’adoption et l’utilisation optimale d’engrais par les sondés étaient les deux décisions indépendantes influencées par différents facteurs. Les estimations empiriques du « first hurdle » nous montrent que la taille de famille, la taille de ferme, le prix discerné de l’engrais, les années d’existence des entreprises agricoles, la valeur de production agricole, des visites de l’agent d’extension agricole, le nombre de chèvres et de moutons chez les fermiers, la décision d’avoir de la volaille sont statiquement des décisions fondamentales variables qui ont influencé la probabilité d’adopter l’engrais par les leaders de familles agricultrices dans le territoire d’étude. Les estimations du «second hurdle» ont révélé que, la décision d’adopter l’intensité optimale d’engrais par les leaders de familles agricultrices était influencée par l’âge, le sexe, la taille de ferme, l’objectif de production de récolte, le prix perçu d’engrais, la valeur de récolte, le nombre de chèvres et de moutons gardé par les sondés, et la proximité au marché d’engrais. Pour encourager l’adoption de l’engrais et son utilisation optimale, le prix d’engrais doit être encore subsidié et le bureau d’extension agricole de l’Etat renforcé pour sensibiliser davantage les cultivateurs sur l’importance des engrais. De plus, les points de vente d’engrais doivent être situés aux localités stratégiques dans les zones rurales de l’Etat pour pouvoir réduire le transport et le coût d’achat.

Introduction

In Africa, agriculture is a sturdy alternative for stimulating economic growth, overcoming rural poverty and enhancing food security as well as achieving sustainable development (6, 11, 12, 13, 15).

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However, agricultural productivity in the Sub Saharan Africa has continued to decline over the last decades and poverty levels have increased (14). Currently, agricultural productivity growth and development in the region are far behind that of other regions in the world, and is well below that which is required to achieve food security and poverty reduction goals of the sub region. Many farmers in the Sub-Sahara African countries are facing declining crop yields, which have adverse effect on the region's economic growth policy. A prominent constraint to higher productivity among farmers in the region is the "soil infertility" related mainly to the low nutrient status of the soils and continuous cultivation without planned replenishment of the depleted soil nutrients (14).

In Nigeria, agricultural production like in most developing countries is dominated by small scale farm producers who constitute about 80% of the farming population (4, 12). One major problem faced by farmers in Nigeria especially in the erosion prone region of the South-South is "land fragmentation" imposed by increasing population density and urbanization. This has resulted in increasing land use intensification leading to the collapse of the traditional fallow system of cropping, increase soil depletion and low crop yield among farmers (5). Food and Agricultural Organization (FAO) reports on fertilizer use intensity among Nigerian farmers revealed an increasing fertilizer use rate from 1970 to 1993. The intensity however drops from 11.8 kg/ha in 1995 to 8.90 kg/ha, 9.0 kg/ha and 13.0 kg/ha in 1996, 2003 and 2009 respectively. The report further reveals that the fertilizer use rate among farmers in the country was far below the 200 kg/ha recommended by FAO for the sub Sahara African countries (1).

Many researchers in Africa (3, 11, 14) have found that the probability of adoption of fertilizer by arable crop farmers was affected by the ecological zone, farmer's age, education, credit, purpose of crop production, distance to fertilizer market, output of crop, farm size, price of fertilizer and change agent (extension) visit to farmers. Also, past studies in developing countries have documented some factors that influenced fertilizer use intensity among arable crop farmers. For instance, (8, 11, 13) identified plot size, previous experience with fertilizer, supply of fertilizer, farm size, amount of rainfall, household size, price of fertilizer, credit availability, education of household head, household head expenditure, commercial crops, number of domestic animals, price of crops, club membership, extension service, number of adults per acre, idea or prediction of rainfall pattern by farmers, soil textures, prices of manure, age, farmer's perception of price change, and employment type of household head as statistically significant decision variables that influenced the intensity of fertilizer application.

Akwa Ibom State like other parts of Nigeria has suffered gross soil nutrient mining due to the continuous cropping and environmental pollution through activities of oil exploitation (2). In the state, intensive cropping is gradually replacing the traditional shifting cultivation that is associated with the long period of land fallowing. Hence, declining soil fertility has been highlighted as one of the major reasons for the slow growth rate in food production in the state (10). In spite of the early adoption of fertilizer technology by arable crop farmers in Akwa Ibom state, arable crop outputs have not shown encouraging growth (2, 6). Also, past efforts of the state government in ensuring the availability of fertilizer and at a subsidized rate to farmers has not yielded the intended objective, given the present low productivity among crop farmers in the state (2, 6). Therefore, following the current situations of low growth rate of arable crop outputs, there is need to uncover factors which could hinder smooth adoption and optimal used of fertilizer technology among arable crop farmers in Akwa Ibom state. The study specifically determines factors that influenced adoption of fertilizer technology and the optimum use intensity among farming household heads in Akwa Ibom state in southern part of Nigeria.

Research Methodology

1. Study Area, Sampling Procedure and Source

The study was conducted in Abak agricultural zone of Akwa Ibom State in the Southern part of Nigeria. The zone consists of five local government areas; these are Abak, Oruk Anam, Etim Ekpo, Ukanafun and Ika local government areas. The state has a population of about 3,920,208 consisting of 2,044, 510 males and 1,875,698 females (9). Multi-stage random sampling procedure was used to select 150 respondents who were solely arable crop farming household heads.

2. Method of Data Analysis

Equation 1 shows the fertilizer use intensity (Y) as defined by (8).

$$Y = {kg\ of\ fertilizer}/{hectare\ of\ land} \ldots\ldots\ldots (1).$$

This study employs the double-hurdle model with the assumption that, fertilizer adoption and optimum use intensity are two distinct or independent decisions. Double-hurdle model was formulated by Cragg (7); the model assumes that farming household heads make two sequential decisions with regard to adoption and intensity of use of fertilizer technology. The first hurdle is the fertilizer adoption equation estimated by using a probit model as described in equation 2.

$$Index\ Equation \quad d_i^{*} = X_{Ii}'\beta_1 + U_i, \quad U_i \sim N(0,1) \ldots (2)$$

$$Threshold\ index\ Equation \quad d_i = \{1\ if\ d_i^{*} > 0, and\ is\ 0\ if\ d_i^{*} \leq 0\}$$

Where d_i^{*} is the latent discrete adoption choice

variable that denotes binary censoring, X'_{Ii} X'_{Ii} is vector of explanatory variables hypothesized to influence adoption choice and $\beta_i \beta_i$ is vector of parameters. U_i U_i is the standard error term and d_i d_i is the observed quantity of fertilizer representing the respondent's participation decision (i.e. 1 means the respondent is reporting fertilizer intensity greater than 0, and 0 means otherwise). The second hurdle involves an outcome equation, which uses a truncated model to determine the extent of optimum intensity use of the fertilizer technology. This stage uses observations only from farming household heads who reported positive and greater than optimum fertilizer intensity use. The truncated model, which closely resembles Tobit's model, was expressed as shown in equation 3.

$$Y_i^* = X'_{2i}\beta_2 + V_i, \quad V_i \sim N(0.\delta^2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\{Double-Hurdle\ Model \quad Y\}_i = \{Y_i i^{\uparrow} * \ if\ d_i i = 1\ and\ Y_i i^{\uparrow} * > Y_i 0\ \ and\ is\ 0\ if\ d_i i \leq 1\ and\ Y_i i^{\uparrow} * \leq Y_i 0$$

Y_i Y_i is the observed fertilizer use intensity for the sample respondents. Y_0 is the threshold or the minimum fertilizer use intensity consider as the optimum in the study area. In this study, we kept the threshold intensity at 100 kg/ha. This figure was arrived at by using the reports from the Akwa Ibom state ministry of agriculture and supported by the data we got from the field.

Therefore the empirical model used to estimate the Probit and the truncated model of fertilizer use intensity is given below;

$$Adopt\ or\ Y_i = \beta_0 + \beta_1 AGE + \beta_2 GEN + \beta_3 EDU + \beta_4 HHS + \beta_5 CRE + \beta_6 LANS + \beta_7 CRP + \beta_8 PRI + \beta_9 EXP + \beta_{10} OUT + \beta_{11} EXTEN + \beta_{12} DANI + \beta_{13} PANI + \beta_{14} LAC$$

Where Adopt is the fertilizer adoption among farming household heads and which takes the value of 1 for adopters and 0 otherwise. $Y_i Y_i$ is the quantity of fertilizer per hectare use by respondents in the study area;

Other variables in the model are as defined below;

AGE= age of a farmer (years); GEN= gender of a farmer (1= Male, 0= female); EDU= years of formal education of farmers (years); HHS= household size of farmer (number); CRE= access to farm credit by farmers (1= accessed and 0 otherwise); LANS= land size cultivated by farmers (hectare); CRP= purpose of crop grown by farmer (1= commercial crop, 0 = otherwise); PRI= perceived price of fertilizer by farmers (1= high price and 0= low price); EXP= number of year(s) spent as a crop farmer; OUT= value of farm output of farmers in naira (₦); EXTEN= extension agent contact (number of times); DANI= number of domestic animals (i.e. Goats and Sheep); PANI= Poultry ownership (1= own poultry enterprise, 0 otherwise); LAOW= Land ownership (1= inheritance, 0 otherwise); DIS= distance to fertilizer selling point (1= far, 0= otherwise); U= stochastic error term

Results and Discussion

The independent double hurdle model assumes that the two error terms from the two hurdles are normally distributed and uncorrelated. This implies that the two-stage decision of adoption and optimum fertilizer use intensity are done independently by respondents. To test whether the two decisions were independent, we investigated the relationship between the error term in the first hurdle and second hurdle in our models. The result of the exercise revealed that the error terms were uncorrelated. This implies that factors that influence farming household heads decision to adopt fertilizer were unassociated with the decision variables in the second hurdle involving optimal use of fertilizer technology. This result confirmed the relevant of the double hurdle model used in this study.

1. Factors that influence probability of fertilizer adoption and the optimal intensity use among farming household heads in Abak Agricultural Zone in Akwa Ibom State, Nigeria

Table 1 presents the maximum likelihood estimates of the independent double-hurdle model. The log-likelihood ratio (LR) and the information criteria attest to the reliability of the model. This implies that factors that influence the two-stage decision relating to adoption and optimum use of fertilizer in the study area can well be expressed in the independent double hurdle model. Coefficients in the first hurdle indicate how a given decision variable affects the likelihood (probability) to adopt fertilizer. Those in the second hurdle indicate how decision variables influence the level of optimum fertilizer usage.

The result of the first hurdle (Probit Model) indicates that family size, farm size, perceived high price of fertilizer, number of years spent as farmer, value of farm output, number of extension agent visits, number of goats and sheep kept by the farmers and poultry ownership are statistically significant decision variables that influenced the probability of adopting fertilizer technology among farming household heads in the study area. The marginal effects of the Probit model show changes in the probability of adoption of fertilizer for additional unit increase in the independent or decision variables.

The probability of fertilizer adoption reduces by 1.22% for every member increase in the farming household head's family. This implies that, as the family size of farming household head increases, the probability of adopting fertilizer reduces.

The result satisfies *a priori* expectation, because increase in the household size would increase the family expenditure and probably reduce farm expenditures. This also shows that most farming household heads

Table 1
Maximum likelihood estimates of Double Hurdle models for adoption and optimum fertilizer use intensity among farming household heads in Abak Agricultural Zone in Akwa Ibom State, Nigeria

	Independent Double Hurdle Model		
Variables	1st Hurdle (Probit)	Marginal effect in Probit model	2nd Hurdle (truncated model)
Constant	-0.779(-0.69)	–	-816.734(-3.62)***
Age	-0.007(-0.27)	-0.0004	29.347(3.35)***
Age^2	–	–	-0.290(-3.33)***
Gender	0.384(0.76)	0.0295	157.448(2.83)***
Education	0.018(0.37)	0.001	-4.179(-0.28)
Education^2	–	–	0.473(0.61)
Family size	-0.192(-2.17)**	-0.0122	-3.025(-0.46)
Credit access	-0.078(-0.14)	-0.0052	-0.452(-0.01)
Farm size	2.081(2.46)**	0.1323	-115.964(-1.92)*
Purpose of crop	0.253(0.61)	0.0173	140.983(3.31)***
Price of fertilizer	-2.361(-5.37)***	-0.2442	-267.268(-6.52)***
Years in farming	-0.062(-2.78)***	-0.0039	0.799(0.41)
Output value	7.8e-06(2.42)**	4.95e-07	0.001(1.79)*
Extension agent	1.171(2.47)**	0.1174	21.513(0.55)
Domestic animal	-0.215(-3.32)***	-0.0137	-10.451(-3.80)***
Poultry birds	-0.673(-1.67)*	-0.0460	-78.772(-2.03)**
Land ownership	-0.016(-0.039)	-0.0010	16.746(0.42)
Distance to selling point	0.357(0.83)	0.0234	-101.320(-2.60)***
Chi square	52.25(0.00)		45.53(0.00)
Log-likelihood	-38.71		-503.87
Akaike criterion	109.43		1045.74
Hannan-quinn	128.99		1068.97
Schwarz criterion	157.59		1102.94

Note: *, ** and *** represent 10%, 5% and 1% significant levels respectively. Variables are as defined in equation 4.

in the study area are poor.

A unit increase in the household head farm size reduces the likelihood of adopting fertilizer by 13.23%. The result perhaps suggests the subsistence nature of arable crop production in the study area.

The result also revealed that, when farming household heads perceived higher price for fertilize, the tendency of adopting fertilizer technology would reduce by 24.42%. The result satisfies the *a priori* expectation because farming household heads are assumed to be rational consumers and will adjust to input price change subject to budget constrained.

The magnitude of the marginal effect of the perceived high price of fertilizer suggests that fertilizer price is the most important decision variable that prevents farming household head to overcome the second hurdle.

The probability of adopting fertilizer by farming household heads in the study area decreased by 0.39% for every additional year they spent as farmers. This could be attributed to the experience gather over the years in coping with the menace of soil infertility. The use of substitutes and conservativeness due to the cultural practice could also be linked to the result.

Increase in agricultural extension visit increases the probability of adopting fertilizer technology by 11.74%. The result indicates that the extension agent visit has the tendency of creating more awareness and better information to the farming household heads on the importance of fertilizer technology.

The result also revealed that increase in the value of farm output increases the probability of adopting fertilizer technology by 0.000000495%. Though the increase is marginal; this could be attributed to the beliefs often associated to the cultural norms, values and beliefs among farmers in the study area. Furthermore, increase in the number of goats and sheep kept as well as poultry ownership reduces the probability of fertilizer adoption by 1.37% and 4.60% respectively. The results satisfy *a priori* expectation, because these domestic animals constitute a good source of organic manure which serves as a good substitute to fertilizer. However, based on the magnitude of the slope coefficients, farm size and extension agent visits impacted more on the probability of fertilizer adoption compared to other significant variables. These findings however agree with the reports of many researchers (8, 11, 13, 14).

The result of the truncated model reveal that age, gender, farm size, purpose of crop cultivation,

perceived price of fertilizer, value of crop output, number of goats and sheep kept, decision to keep poultry birds and distance to fertilizer selling point are statistically significant decision variables that influence the decision to use optimum fertilizer by the farming household heads in the study area. Increased in the Age of farming household head, commercial purpose of arable crop production and male gender of the farming household heads in the study area are positive determinants of optimum fertilizer use intensity in Abak agricultural zone of Akwa Ibom state in southern Nigeria.

On the other hand, continuous increase in the respondent's age, farm size, perceived high price of fertilizer, value of crop output, number of goats and sheep kept by respondent and decision to own poultry as well as the far distance to fertilizer selling point were negative determinants of optimum fertilizer use among farming household heads. The result corroborates the finding of many researchers (3, 11, 14)

Conclusion

The study identifies factors influencing fertilizer adoption and optimum intensity use among small holder arable crop farmers in Abak agricultural zone of Akwa Ibom state, southern Nigeria. Econometric analysis of decision variables reveal that family size, farm size, perceived price of fertilizer, years in farming business, value of crop output, extension agent visit, number of goats and sheep kept by farmers, and decision to own poultry are statistically significant decision variables influencing the probability of adopting fertilizer by farming household heads in the study area. However, the magnitude of farm size and extension agent visit were greater compared to other significant variables. On the other hand, the decision to use optimum intensity of fertilizer by farming household heads was influence by age, gender, farm size, purpose of crop production, perceived price of fertilizer, crop output, number of goats and sheep kept by respondents, and distance to fertilizer selling point. To increase the probability of fertilizer adoption in Akwa Ibom state, southern Nigeria the study advocates for the sensitization of arable crop farm household heads in the state on the current method of family planning as this would help to cut non -farm cost and help increase fertilizer procurement. Also, the extension department of the Akwa Ibom State Ministry of Agriculture should be strengthened to educate arable farmers more on the importance of fertilizer use. On the other hand, to promote sustainable optimum intensity of fertilizer use, the study calls for the following intervention policies: First, the Akwa Ibom state government should further subsidize the price of fertilizer to make fertilizer more affordable to poor small holder farmers in the state. Second, the fertilizer selling units should be located in strategy points at the rural areas in Akwa Ibom State so as to reduce the transportation and purchasing costs. Finally, research on the development of local manure sources to complements the use of the mineral fertilizer should be intensify as this would encourage adoption and optimal use of fertilizer in the study area.

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