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A Tobit Analysis of Fertilizer Adoption by Smallholder Cassava Farmers in Delta State, Nigeria

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Abstract: The study was conducted to determine the level and extent as well as the factors which influence fertilizer adoption decision of cassava farmers in Delta State, Nigeria. A tobit model was used to analyse the cross sectional data collected from a random sample of 496 farmers selected by means of systematic random sampling technique. The results indicate that currently the average amount of fertilizers applied by the farmers is about 284 kg per hectare representing 61% of recommended dosage and that there is about 58% chance that an average cassava farmer would adopt the use of fertilizers. The expected level of adoption of fertilizers by those farmers on the limit E(Y) is 40.84, which means that new adopters are expected to use about 41% of the recommended dosage of the appropriate fertilizer grades. Also, for farmers above the limit, the expected level of adoption E(Y*) of the recommended dosage is about 71%. A number of factors significantly influenced the fertilizer adoption decision of the farmers, namely, Distance to fertilizer purchasing depot ($p<0.05$), Fertilizer price/50 kg bag ($p<0.01$), Farmer's level of formal education ($p<0.05$), number of contacts with Extension agents ($p<0.10$) and Age of farmer ($p<0.01$). These imply that policies that would make fertilizers affordable by the farmers at close distances as well as those that would encourage young people into cassava production and bring about more education of farmers would encourage increased adoption of fertilizers to boost output.

Key words: Fertilizer application, probability and intensity of adoption, cassava farmers, Delta State of Nigeria, tobit model

INTRODUCTION

Nigeria produces the highest volume of cassava in the world; with estimated annual output standing at about 37 million tonnes by 2003 estimate which is about a third more than the output from Brazil and almost double the production of Indonesia and Thailand[1,2]. Cassava production in other African countries, namely Democratic Republic of the Congo, Ghana, Madagascar, Mozambique, Tanzania and Uganda appears small in comparison to Nigeria's substantial output. At national levels, Benue and Kogi state in the North Central Zone are the highest producers of cassava, while Cross River, Akwa Ibom, Rivers and Delta states dominate cassava production in the South-South[3] .

Although output of cassava over the years in Nigeria has been increasing, evidence from studies as contained in a report by FAO[2], indicates that Nigeria ranked low in terms of yield (output per hectare) relative to such countries as Brazil and Thailand and Indonesia who are major producers of cassava after Nigeria. By 2003 yield estimates, yield per hectare in Nigeria stood at about 10.64 tonnes, while in Brazil, Thailand and Indonesia the estimates were about 13.45, 16.84 and 12.02 tonnes, respectively. India which is not a major producer had yield estimate of about 23.19 tonnes. In addition, while the average growth rate of the hecterage under cassava cultivation was about 7.92%, per annum, the growth rate of output of cassava in Nigeria for the period 1996-2001 was only about 6.83% per annum[2]. These suggest that the outstanding output of cassava tubers in Nigeria can be attributed mainly to expansion in land area cultivated.

Cassava production in Nigeria is dominated by large number of small holdings, which are characterised by the use of low level inputs, low yielding crop varieties, high land and labour intensity as well as high incidence of natural disasters, disease and pests attacks[4]. This traditional system of agriculture which has been and continue to be the major employer of labour in Nigeria thrived well over the years and was able to meet the food and agro-industrial needs of the nation with significant surplus for export depended largely on shifting

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cultivation. This is a farming system which involves the use of a piece of land for crop production for some years and when the soil fertility and crop yield declined, the farmer move to a more fertile land until the fertility of the first plot is restored. For full restoration of fertility, the duration of fallow has to be long.

With increasing population pressure, the durations of the fallow period during which the soil is allowed to regain its fertility have continued to be shortened, leading to geometric decline in crop yields under the traditional farming systems. In order to bridge the increasing supply gap so as to meet the increasing domestic, industrial and export demands for agricultural products, different improved cultivars of crops are continually developed by the nation's research institutions and made available to farmers. These improved cultivars have the potentials for higher yields than the local ones. For the realisation of the farm level yield potentials of these new cultivars, different fertilizer grades suitable for different soils types are required. The application of these fertilizers at the specified regularity and dosage are necessary for optimum results.

Due to the central role which cassava plays in ensuring food security among producer and consumer nations and being a ready alternative source of foreign exchange, the Federal Government of Nigeria launched a presidential initiative on cassava production and export in the year 2002. The cassava initiative alone seeks to generate about US$5 billion in export revenue by 2007. In order to actualize this initiative it was estimated that about 150 million tonnes of cassava would be needed by the end of the year 2006. This translates to increasing yield per hectare to about 15 tonnes. Raising the productivity per hectare appears to be the ultimate goal and major factor to adequately meet the target of achieving increased cassava output in Nigeria as the opportunity for continuous expansion of cultivated land is limited by population pressure and competition with other land uses.

The goal of increasing the output of cassava cannot be achieved unless the farmer improve their production techniques with the view to overcoming the decline in output resulting from decline in soil fertility and productivity. Notably among these required improved techniques is the adoption of the usage of fertilizer to boost output. To this end, this study seeks to evaluate the adoption of chemical fertilizers by cassava producers in Nigeria, using farmers in Delta State as a case study. Specifically, the study is set to determine:

- the level and extent of adoption of fertilizers by the farmers;
- the factors which determine the level and extent of adoption of fertilizer by the farmers and
- the probability and elasticity of adoption of fertilizer by the farmers.

Increasing agricultural productivity and hence output of the farm sector using improved technologies is a necessary step towards achieving food security in Nigeria. As noted by Langyintuo, Abatonia and Terbobri[5] productivity will remain low as long as farmers continue to use low yielding inputs and technology. The adoption of new agricultural technology has long been recognised as one of the key factors in increasing productivity in the farm sector.

Adoption of innovations refers to the decision to apply an innovation and to continue to use it[6]. Intensity of adoption implies the number of technologies practiced or the extent of adoption of a specified technology by the same farmer. Saha, Love and Schwart[7] observed that producers' adoption intensity is conditional on their knowledge on the new technology and on their decision to adopt.

Although a number of works have been done on technology adoption decisions and the factors which determine them among farmers in Nigeria[6,8-12], only a few of such works were devoted to the specific case of fertilizer usage by cassava farmers, especially in Delta State.

Since the policy objectives of agricultural sector are to attain self-sufficiency in basic food supply and improve the overall welfare of the citizens, technological change is important because it is targeted at ensuring that farmers' welfare is improved by increasing their incomes. As acknowledged by Gunawan[13] the aim of technological change is to maximise production and increase production to meet food demand of the people. The knowledge of the extent of adoption of fertilizer by cassava farmers will serves as a guide for formulating policies to bring about increased output of the farms to enhance the income and welfare of the farmers.

Theoretical model: Adoption of fertilizers by farmers like many other farm technologies is subject to two response choices, namely; non-adoption and adoption. While the process of adoption of innovation goes through a sequence from the awareness to actual adoption stages, the target farming population will be divided into two groups, those not adopting and those adopting the innovation at the end of the process.

In communicating the appropriate fertilizer formulations for cassava production, optimum quantities per unit of land area of the appropriate grades are usually indicated. Particularly, for cassava production, average optimum application rate of about 400 kg per hectare of N P K fertilizers with varying grades depending on soil zones is recommended[14,15]. The response of the farmers to this technology fall into two categories viz, non-adoption (do not apply fertilizer) and adoption (applying varying quantities of the fertilizers). These responses or levels of adoption can be expressed in terms of their percentage of the recommended optimum dosage such that; non-adoption is equivalent to zero percentage adoption and adoption implies varying percentage adoption range of greater than zero percent.

It is assumed that farmers are rational in their decision and respond to their circumstances in a consistent utility-maximizing way. This implies that the level of adoption of fertilizer usage would normally not exceed the optimum dosage. However, it is not unusual to find some farmers who apply the fertilizers in excess of the recommended optimum dosage. To this extent, the response of the farmers fall into the range of lower limit of adoption of zero percent and continuous percent levels of adoption above the limit. This indicates some form of censoring resulting in mass points of observation at the low end called the limit value and continuous values above the limit. This suggests that the model proposed by Tobit[16] is appropriate for analyzing the fertilizer adoption by farmers. Tobin[16] proposed a limited dependent variable model, later called the Tobit model to handle dependent variables which are combinations of those cases, which have mass points at the low end called the limit value and continuous values above the limit. The Tobit model is appropriate in this study since the dependent variable is the quantity of fertilizer used expressed as a percentage of the optimum dosage; thus, the dependent variable must be between 0 limit and continuous levels of adoption above the limit.

A particular technology is adopted when the expected utility from using it exceeds that of non-adoption. Though it is not observed directly, the utility (U_{ij}) for a particular farmer (i) to use a particular technique (j) can be defined as a farm-specific function (H_i) of some vector of technology associated characteristics (X_j), plus a error term with zero mean and constant variance (e_{ij}) thus:

$$U_{ji} = e_j F_i(H_i, X_i) + e_{ji} \; j = 1,2,; \; i = 1,....,n, \qquad (1)$$

where 1 represents adoption of the new technology and 0 represents continued use of the old technology. The i^{th} farmer adopts j = 1 if $U_i1 > U_i0$.

Farmer-specific characteristics include such variables as their social standing in society, participation in field-days, agriculture training workshops and on-farm trials and contact with extension agents etc, while technology-specific characteristics include the impact of the technology on yield, availability of the technology on the farmer's farm or in the immediate neighbourhood, convenience in use, cost of adoption of the technology

The utility of adoption U_{ij} can be inferred from farmers' continuous choice over a predefined interval (intensity of adoption). This justifies the use of Tobit model, as has been applied in previous studies of agricultural technology adoption[17-20]. This method enables one to estimate the likelihood of adoption and the extent (i.e., intensity) of adoption of a technology.

The lower-limit Tobit model following from Fernandez-Cornejo and McBrid[21] can be represented as:

$$y_i^* = BX_I + \epsilon_I \qquad (2)$$

where Y_i^* *is* a latent variable (unobserved for values smaller than 0) representing the use of the technology; X is a vector of independent variables, which includes the factors affecting adoption (inclusive of farm/farmer and technology-specific characteristics); β is a vector of unknown parameters and ϵ_i is a stochastic error term assumed to be independently and normally distributed with zero mean and constant variance and i = 1, 2,… n (n is the number of observations). Denoting Y_i (the level of adoption of fertilizer by the farmer) as the observed dependent (censored) variable, as applied by Oladele[6] fall into the range:

$$y_i = \begin{bmatrix} 0 & \text{if} & y_i^* \le 0 \\ y_i^* & \text{if} & y_i^* > 0 \end{bmatrix} \qquad (3)$$

Unlike traditional regression coefficients, the Tobit coefficients cannot be interpreted directly as estimates of the magnitude of the marginal effects of changes in the explanatory variables on the expected value of the dependent variable. Each marginal effect in a Tobit equation, includes both the influence of the explanatory variable on the probability of adoption as well as on the intensity of adoption. As Gould *et al.*[19] and Adesina and Baidu Forson[9] indicated, the total (marginal) effect accounts for the simultaneous affects on the number of adopters and the extent of adoption by both current and new adopters. To decompose the relevant effect of changes in explanatory variables on the dependent variable, the McDonald and Moffit decomposition[22] is employed as follows:

$$E(y) = F(z)E(y^*) = x\beta F(z) + \sigma f(z) \qquad (4)$$

$$E(y^*) = x\beta + \sigma f(z)/F(z) \quad (5)$$

Where;

- E(y) indexes the expected value of the level of technology adoption. It indicates the level of adoption expected to be made by new adopters of the technology;
- E(y*) gives the expected value of the level of adoption by those who are already using the technology;
- z, given as $\frac{(\alpha + \sum_{i=1}^{n} x_i\beta_i)}{\sigma}$ is the z-score for an area under the normal curve, evaluated at the mean values of X_i;
- α is the constant term in the Tobit estimate;
- β_i are the coefficients of the independent variables;
- f(z) is the standard normal density distribution function
- F(z) is the cumulative standard normal distribution function. It predicts the probability of adoption of technology given the mean value of the explanatory variables. That is the percentage chance of a technology being used by new adopters.

The derivatives of E(y) with respect to X_i yields

$$\frac{\delta E(y)}{\delta x_i} = F(z)\frac{\delta E(y^*)}{\delta x_i} + E(y^*)\frac{\delta F(z)}{\delta x_i} \quad (6)$$

and multiplying both sides of equation (6) by *X*/E(*y*) and following from LeClere[23] results in the estimation of elasticity of expected use intensity and the elasticity of adoption probability thus:

$$\frac{\delta E(y)}{\delta x_i}(x/y) = F(z)\frac{\delta E(y^*)}{\delta x_i}(x/y) + E(y^*)\frac{\delta F(z)}{\delta x_i}(x/y) \quad (7)$$

After some algebraic transformations, the following expression result:

$$\frac{\delta E(y^*)}{\delta x_i} = \beta[(1 - z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}) + z\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2})] \quad (8)$$

where; $\beta[1 - z(\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2})]$, is the elasticity of expected use intensity and

$\beta z(\frac{f(z)}{F(z)} - \frac{f(z)^2}{F(z)^2})$, is the elasticity of probability of adoption.

The summation of the elasticity of expected use intensity and that of the probability of adoption gives the total elasticity.

MATERIALS AND METHODS

The study was conducted in Delta State of Nigeria. The State lies roughly between longitude 5° 00/and 6° 45/east and latitude 5° 00/and 6° 30/north of the equator. It is bounded by Edo, Ondo, Anambra, Rivers and Bayelsa States to the north, north-west, east and south-east respectively.

The rainfall regime of Delta State can be described as humid to sub-humid with distinct dry and wet seasons in most parts with the former, which occurs between December and April is characterised by a dry and dusty north-easterly harmattan-inducing wind. The average rainfall is about 266.5 cm in the coastal areas and 190.5 cm in the northern part with the month of July recording the heaviest rainfall[23]. The daily temperature ranges from 29 to 44°C with an average of about 30°C. Generally, the major food crops grown in order intensity include: cassava, yams, maize, melon, potatoes, cocoyams, rice and assorted leafy and non-leafy vegetable crops. Also of importance is livestock production and capture fishery, besides forest and wildlife products.

Cross sectional data were collected during the field survey of 496 cassava farmers selected through multi-stage selection process using systematic random sampling technique and covered the 2005 cropping season. The target population were farmers who produce cassava.

Data collected relate to input-output of the farmers and their farm characteristics, with particular emphasis on their management of soil fertility. Also of importance were the farmers' socio-economic characteristics as they relate to their farming activities.

The estimated empirical model derived from equations 1 to 3 was developed using farm input-output variables and farmers' specific attributes associated with the use of inorganic fertilizers in cassava production. The dependent variable is the percentage of recommended dosage of fertilizers used by the farmers. The dependent variable was regressed against proxies for various factors hypothesized to influence the producer's adoption decision. The parameter estimates were estimated using Minimum Likelihood (ML) methods. The definitions, measurements and *apriori* expected effects of the independent variables on the adoption of fertilizers are as shown below:

Variables	Definition and Measurement	Apriori expectation
Adoption	The quantity of fertilizer used by a farmer as percentage of the recommended dosage	
Independent Variables		
DIS	Distance (in km) of the farmers house from the fertilizer selling depot.	Negative
PRI	Unit selling price of 50kg bag of the fertilizers (in Naira).	Negative
SIZ	Farmers' farm size (in hectares), being the sum of the current cassava farm plots cultivated by the farmer.	Positive
EDU	Number of years of formal education of the farmer, with the more the number of years, the higher the level of education expected to be acquired.	Positive
EXT	Contact with extension agents, measured as the average number of contacts a farmer had during the current and immediate past farming years.	Positive
AGE	Chronological age of the head of the farm family.	Positive/Negative
CRD	The amount of production credit used by the farmer expressed as a percentage of the total cost of production.	Positive
COM	The degree of commercialisation of the farm investments; measured as the quantity of cassava tuber output sold as a percentage of total farm output.	Positive
ASS	Membership of Cassava Growers Association (Dummy with 1 if yes and 0 otherwise).	Positive
NAI	Estimate of non-farm income expressed as a percentage of farmer's total annum income (in Naira). It is a measure of farmers' involvement in off-farm economic activities.	Positive/Negative
KNG	Knowledge of fertilizer uses and application (Dummy with 1 if yes and 0 otherwise).	Positive
EXP	Number of years of farming experience of the head of farm family.	Positive/Negative
FAL	Fallow periods of cassava farm plots (years)	Negative

RESULTS AND DISCUSSION

The summary statistics of the basic socio-economic characteristics of the farmers are presented in Table 1. On the average, the farmers were about 40 years of age, with a range of 24-61 years. The average family size was about 7, with some families having as many as 21 members, while a few had just 2 members. Majority of the farmers had formal education ranging from incomplete primary education to tertiary education. On the average, they had about 10 years of formal education. The average farm size of the respondents was about 2.6 hectares, with some having just about 0.37 hectare. The farmers can be said to be mainly smallholders. They cultivate on the average about 3 plots at the same time. Many of them plant multiple crops, with an average of about 4 crops per plot. Average capital and labour input per hectare were about N20109 and N36550, respectively. The farmers used on the average, about 284 kg of fertilizers per hectare representing about 71% of the recommended dosage of about 400 kh per hectare. Many of the farmers however, do not use fertilizers at all. The mean value of farm output was about N71353 per hectare. The average net farm income of about N14694 per hectare was made. Also, the volumes of credit used by the farmers were about 23% of total cost of production, with many of the farmers using no credit at all for their farming activities. The inability of many of the farmers to use credit has been identified by Okorji *et al.*[25] as a factor responsible for limiting them to using less capital intensive and traditional methods of farming.

Table 2 shows the Tobit coefficients, the standard errors, t-ratios and their levels of significance as well as mean values of explanatory variables. All the coefficients had the hypothesised signs, with distance to fertilizer depot, fertilizer selling price per unit, age, farming experience of the head of the farm family and number of years of fallow of farm land having negative signs. These imply that a unit decrease in the distance to the nearest fertilizer selling depot, unit selling price and fallow of farm land would bring about increased adoption and intensity of use of fertilizer by cassava farmers in Delta State. Proximity to fertilizer selling depot determines the transportation costs involved in the use of the input. The cost of transporting fertilizers, being bulky products determines the extent to which farmers most of who are low income earners can use them.

The effect of the distance to fertilizer selling depot contradicts the findings of Daramola[8] and Daramola and Aturamu[26] who obtained positive effects on the probability and intensity of adoption of agricultural technologies. They concluded however that the farmers seemed indifferent to distance to input sources provided they obtained the type and quantity they needed at affordable prices. In other words, they were of the view that the total cost of purchases rather than the distance to input source that matters. The effects of age and number of years of farming experience bring to bear the conservative attitude of many farmers towards the adoption of new farming innovations. With experience and age, many farmers stick to the old ways of farming rather than trying new techniques, probably due to their risk averse tendencies.

On the other hand, farm size, level of formal education of the head of the farm family, number of instructional contacts the farmer had with extension agents, ratio of credit to total cost of production, degree of farm enterprise commercialisation, membership of farmers' associations, knowledge of fertilizer use and application as well as ratio of non-farm to total annual income of farmers had positive signs, implying direct effect on the probability of adoption and intensity of use of fertilizer by

Table 1: Summary statistics of the basic socioeconomic characteristics of the farmers (N = 496)

Variable	Mean	Standard deviation	Minimum	Maximum
Age (Years)	40.29	6.9	24	61
Family size (No.)	7.12	3.87	2	21
Formal Ed. (Years)	9.86	4.48	0	18
Farm size (ha)	1.38	1.94	0.37	7.21
No. of farm plots maintained	2.6	0.39	1	6
No of crops produced	4	0.28	1	8
Capital input (N *)/ha	20109.25	5337.09	3576.68	31880.50
Labour input (N)/ha	36549.59	7410.15	6025.20	46276.90
Fertilizer input (kg/ha)	284	79.41	0	550
Ratio of credit to total production cost	0.23	0.18	0	0.77
Value of farm output (N)/ha	71352.68	4954.08	12348.05	95183.25

* Note: One USA Dollar is equivalent to about 138 Nigerian Naira for 2005 average exchange rate. Source: Authors' survey data, 2005

Table 2: Tobit coefficients, standard errors, t-ratios, levels of significance and means of variables

Variable	Coefficients	S.E.	t-ratio	Level of significance	Mean of variable	Mean multiplied by coefficient
Constant	275.9513	17.0996	9.9970	0.0000***	1.00	275.95
Distance to fertilizer purchasing depot (DIS)	-0.4000	0.1671	-2.3940	0.0167**	37.35	-14.94
Fertilizer price/50 kg bag (PRI)	-0.0687	0.0053	-5.3640	0.0000***	2562.68	-175.95
Farm size (SIZ)	2.0656	0.9660	1.5170	0.1292	2.74	5.67
Farmer's level of formal education (EDU)	0.4833	0.2378	2.0320	0.0421**	8.23	3.98
No of contacts with Extension agents (EXT)	0.7221	0.4055	1.7810	0.0750*	2.98	2.15
Age of farmer (AGE)	-2.0023	0.3795	-5.9870	0.0000***	40.66	-81.42
Credit to total cost (CRD)	2.6288	5.2164	0.5040	0.6143	0.31	0.82
Degree of commercialisation (COM)	1.2462	5.1692	0.2410	0.8095	0.35	0.44
Farmer's Association (ASS)	0.2684	1.6192	0.1660	0.8683	0.44	0.12
Ratio of Non-farm to total annual income (NAI)	4.5398	5.6064	0.8100	0.4181	0.22	0.98
Knowledge of fertilizer use and application (KNG)	0.9296	1.5167	0.6130	0.5399	0.74	0.69
Farming experience (EXP)	-0.1032	0.2050	-0.5030	0.6149	9.24	-0.95
Fallow period of farm lands (FAL)	-0.5050	0.4314	-1.1710	0.2418	2.86	-1.44

$X\beta$ = 16.08907446, σ = 80.96270, Z = $X\beta/\sigma$ = 16.08907446/80.96270 = 0.19872, E(Y = 40.8362829, E(Y*) = 70.5579822, Note: *** = 1%, ** = 5% and * = 10% level of significance, Source: Authors' survey data, 2005

the farmers. Specifically, they imply that a unit increase in the farm size, level of formal education of the head of the farm family, number of instructional contacts the farmer had with extension agents, ration of credit to total cost of production, degree of farm enterprise commercialisation and ratio of non-farm to total annual income of farmers would bring about increased adoption and intensity of use of fertilizer among the farmers. Also, membership of farmers association bring about increased awareness on the part of the farmers regarding existing and new farming technologies. With increased awareness of the availability of improved farm inputs, coupled with information on their applicability, the level of adoption and intensity of use of fertilizer would increase. These views have also been expressed by Chukwuji and Inoni[12].

Cultivation of large farm sizes make it more economical for farmers to apply fertilizers. Also, the larger the size of farm cultivated and therefore output produced, as noted by Johnson[27], the more commercialised the farm would be. Increased level of education of farmers and contacts with extension agents lead to increased knowledge of input uses and their application because ignorant of the uses and abuses of inputs in crop production could discourage farmers from using them. These findings are in line with the reports of Daramola and Aturamu[26] who noted that contacts with extension agents as well as acquisition of formal education exposes the farmers to the availability and technical-know-how of innovations and increases their desirability for acquiring them. The high and positive effect of off-farm incomes on the adoption indices of the farmers is an indication that they need improved financial bases in order to adopt better farming technologies. Availability of off-farm incomes is an indication of farmers involvement in non farm economic activities, with complementing income effects on farming activities. The incomes generated serve to ferry the farmers over the periods of waiting for their crops to mature. The incomes also help the farmers to acquire the necessary farm inputs. Daramola[28] and Savadogo *et al.*[29] obtained similar results. Daramola and Aturamu[25] however, reported opposite effects and pointed out that a high proportion of off-farm relative to farm income suggests that incomes from farm investments are not enough to encourage farmers to take on some 'risks' and adopt. It is obvious therefore that making the rewards from farm investments attractive through appropriate policies would discourage farmers from going into off-farm economic activities so as to increase the efficiency of farming activities. The financial bases of the farmers can also be increased through policies aimed at making them have easier access to production credits at affordable prices so as to increase their ability to purchase and use fertilizers. In a similar vein, Daramola and Aturamu[26] pointed out that the level of credit availability to farmer is a measure of his financial worth and that most of them cannot adopt any innovations when their purchasing power is ineffective.

Also given in Table 2 are the probability of adoption F(z), expected level of adoption of fertilizers by those farmers on the limit E(Y), the expected use intensity by those above the limit E(Y*) as well as other parameters of the Tobit model. The last column of the table gives the product of the Tobit coefficients and the mean values of the explanatory variables which, when divided by the standard error of the model (σ) resulted in the z value of 0.19872. The predicted probability of adoption of fertilizer by the farmers given as the cumulative distribution function F(z) is 0.5788. This indicates that there is about 58% chance that an average cassava farmer would adopt the use of fertilizer. The expected level of adoption of fertilizers by those farmers on the limit E(Y) is 40.84, which implies that new adopters are expected to use about 41% of the recommended dosage of the appropriate fertilizer formulations for cassava production. Also, for farmers above the limit, the expected level of adoption E(Y*) of the recommended dosage of the appropriate fertilizer formulations is about 71%.

Table 3 presents the first-order partial derivatives of the Tobit function, the marginal effects and elasticity estimates, in addition to the explanatory variables and their coefficients as earlier given in Table 2. Column 3 gives the first-order partial derivatives, depicting the effects of changes in the explanatory variables on the level of adoption of fertilizer for all the farmers on and above the limit. The first-order partial derivatives reflecting the marginal effects (which are used to calculate adoption elasticities) of changes in the explanatory variables on the level of fertilizer adoption on observations on and above the limits are given in Columns 4 and 5, respectively. Columns 6 and 7 present the elasticity of intensity and probability of adoption of the fertilizer technology by the farmers, respectively.

The signs of the coefficients of elasticities of adoption intensities and probabilities of adoption with respect to the explanatory variables follow those of the individual Tobit coefficients estimated. However, elasticities are interpreted in absolute terms, with the signs only indicative of direction of their effects. The results indicate that fertilizer selling price per 50 kg bag exhibited the highest elasticity of all the explanatory variables with coefficients of about 1.02 and 1.47 in absolute terms for adoption intensity and probability of adoption respectively. These imply that a 10% reduction in the unit selling price of fertilizers would lead to about 10% increase in the intensity and probability of adoption of fertiliser usage by the farmers respectively. In other words, current users of fertilizers will increase their level of usage by about equal proportion for a given percentage reduction in the unit selling price of fertilizers. Similarly, the probability that more farmers would adopt the use of fertilizer would increase by about one and a half times for a given percentage reduction in the unit selling price of the input.

Other variables that showed high elasticities were age of farmers with 0.47 and 0.68, distance to fertilizer selling depot with about 0.09 and 0.12, farm size with about 0.03 and 0.05 as well as farmers level of formal education with about 0.02 and 0.03 coefficients in absolute terms for

Table 3: Partial derivatives and estimates of elasticities and intensities of adoption

Variable	Coefficient	Partial derivatives $\frac{\partial E(y)}{\partial x_i}$	Partial derivatives $\frac{\partial E(y^*)}{\partial x_i}$	Partial derivatives $\frac{\partial F(z)}{\partial x_i}$	Elasticities: Elasticity of Adoption $\frac{\partial F(z)}{\partial x_i} \times \frac{x}{F(z)}$	Elasticities: Elasticity of Intensity $\frac{\partial E(y^*)}{\partial x_i} \times \frac{x}{E(y^*)}$
Constant	275.9513	114.1867	112.8536	1.3332	1.5994	2.3055
Distance to fertilizer purchasing depot (DIS)	-0.4000	-0.1655	-0.1636	-0.0019	-0.0866	-0.1247
Fertilizer price/50kg bag (PRI)	-0.0687	-0.0284	-0.0281	-0.0003	-1.0198	-1.4687
Farm size (SIZ)	2.0656	0.8547	0.8447	0.0100	0.0329	0.0473
Farmer's level of formal education (EDU)	0.4833	0.2000	0.1977	0.0023	0.0231	0.0332
No of contacts with Extension agents (EXT)	0.7221	0.2988	0.2953	0.0035	0.0125	0.0180
Age of farmer (AGE)	-2.0023	-0.8285	-0.8189	-0.0097	-0.4719	-0.6796
Credit to total cost (CRD)	2.6288	1.0878	1.0751	0.0127	0.0047	0.0068
Degree of commercialisation (COM)	1.2462	0.5157	0.5096	0.0060	0.0026	0.0037
Farmer's Association (ASS)	0.2684	0.111	0.1098	0.0013	0.0007	0.0010
Ratio of Non-farm to total annual income (NAI)	4.5398	0.8785	1.8566	0.0219	0.0057	0.0082
Knowledge of fertilizer use and application (KNG)	0.9296	0.3847	0.3802	0.0045	0.0040	0.0057
Farming experience (EXP)	-0.1032	-0.0427	-0.0422	-0.0005	-0.0055	-0.0080
Fallow period of farm lands (FAL)	-0.5050	-0.2089	-0.2065	-0.0024	-0.0084	-0.0120

Source: Authors' survey data, 2005

intensity and probability of adoption of fertiliser usage by the farmers respectively. These indicate that a percentage reduction in the mean age of the farmers can result in increase in adoption intensity and the probability of more farmers adopting the use of fertilizers by about 0.5 and 0.7%, respectively. Also, a reduction in the distance to fertilizer selling depot and increase in farm size as well as farmers' level of formal education by one percent would lead to increase intensity and probability of adoption of fertiliser usage by the farmers by about 0.09, 0.12, 0.03 and 0.05% as well as 0.02 and 0.03%, respectively. These results indicate that younger farmers are more likely to adopt the use of fertilizers than older ones. Similarly, it appears that most farmers who are willing to adopt the use of fertilizers are unable to do so due to the long distances they have to travel with the attendant high transport costs to purchase the input. In the same vein, creating more conducive atmosphere for educated people to go into farming would increase the adoption of fertilizers thereby leading to increased cassava yield per land area.

For all variables, the elasticity coefficients for probability of adoption were higher than those of intensity of use. This implies that the effect of adjustments in the explanatory variables would be felt more by non-adopters who would be motivated to become adopters by changes in the prevailing constraining factors. Rogers[30] and Fernandez-Cornejo *et al.* [31] had observed that adoption of agricultural technologies are more responsive to policy adjustments at the innovation stage but declines as intensity of the diffusion increases.

CONCLUSION

The study had looked at cassava production vis-avis the adoption of fertilizers by farmers in Delta State, Nigeria. Specifically, it investigated the probability and intensity of adoption of fertilizers by the farmers. A tobit model was used to analyse the cross sectional data collected from a random sample of 496 farmers selected by means of systematic random sampling technique during the 2005 cropping season. The results indicates that the average farm size of the respondents was about 2.6 hectares, with some having just about 0.37 hectares. They cultivate on the average about 3 plots at the same time. Many of them plant multiple crops, with an average of about 4 crops per plot. The average capital and labour input per hectare were about N20109 and N36550, respectively. The average value of farm output was about N71353 per hectare, while net farm income of about N14694 on the average per hectare was recorded. The results further indicate that currently the average amount of fertilizers applied by the farmers is about 61% of recommended dosage and that there is about 58% chance that an average cassava farmer would adopt the use of fertilizers. The expected level of adoption of fertilizers by those farmers on the limit E(Y) is 40.84, which means that new adopters are expected to use about 41% of the recommended dosage of the appropriate fertilizer grade. Also, for farmers above the limit, the expected level of adoption E(Y*) of the recommended dosage is about 71%. A number of factors significantly influenced the fertilizer adoption decision of the farmers, namely, Distance to fertilizer purchasing depot ($p<0.05$), Fertilizer price/50 kg bag ($p<0.01$), Farmer's level of formal education ($p<0.05$), No of contacts with Extension agents ($p<0.10$) and Age of farmer ($p<0.01$). These imply that policies that would make fertilizers affordable by the farmers at close distances and those that would encourage young people into cassava production as well as increased education of farmers would encourage increased adoption of fertilizers to boost output.

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