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A Probit Analysis of the Determinants of Fertilizer Adoption by Cocoa Farmers in Ghana

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Cocoa remains an important cash crop in Ghana and plays a major role in the country's socio-economic development. The crop is the mainstay of many smallholder households and this has led to several efforts to enhance its production. The introduction of partial liberalisation has encouraged private sector activity in the Ghanaian cocoa sector, including the privatisation of input supply. A key strategy aimed at improving cocoa production is the adoption of inorganic fertilizer. The current study sought to determine the factors influencing farmers' decision to adopt fertilizer in cocoa production, using cross-sectional data from 80 randomly selected farmers in the Bibiani-Anhwiaso-Bekwai District of Ghana. The study revealed that income from cocoa production increases the probability of fertilizer adoption while farm size and the age of the household head decrease the probability of adoption. Based on the findings, it is recommended that fertilizer for cocoa production should be subsidised by the government to promote adoption. In addition, extension service delivery must be enhanced to ensure that farmers get information on improved production practices.

Keywords: Adoption; cocoa production; Ghana; inorganic fertilizer.

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1. INTRODUCTION

Cocoa production plays a major role in Ghana's economy. The country has a long history of cocoa production and was once the world's leading producer. Currently, Ghana ranks second to Cote d'Ivoire as the global leading producer [1,2]. Several challenges including low prices, aging farmers, pests and diseases, competition with food crop production and bush fires in the early 1990s, led to a gradual decline in the production of the nation's most important agricultural crop. There have been efforts by the Government of Ghana to resuscitate the cocoa sector by improving the price paid to farmers, providing agrochemicals and free spraying of cocoa farms to reduce the incidence of pests and diseases responsible for crop failure and low yield. The Cocoa Research Institute is also implementing strategies to help cocoa farmers increase their yields. These include the introduction of high-yielding varieties and training of farmers on modern production practices. Besides these efforts, there is also the promotion of cocoa fertilizers to enhance farmers' output.

The adoption of fertilizer in cocoa production by farmers in Ghana is a positive development that has the potential to improve output [3]. At the same time, the introduction of fertilizers has the tendency to reduce the organic nature of the country's cocoa that may affect the premium Ghana enjoys on her cocoa on the international market.

There are several studies on agricultural technology adoption in developing countries. [4, 5] carried out detailed survey of agricultural technology adoption in developing countries and found that farm size, risk, human capital, availability of labour, access to credit and land tenure systems were the most important factors influencing farmers' technology adoption decisions.

[6] investigated how risk attitudes affect fertilizer adoption and rate of application in Cote d'Ivoire. The author found that farmers' risk perceptions and risk aversion are strong determinants of fertilizer adoption and intensity use decisions. Other variables such as education, membership of association, farmers' liquidity, farm size, hired labor, soil fertility and access to credit were significant factors explaining farmers' decisions.

[7] summarised adoption studies by the Centro International de Mejoramieto de Maiz Y Trigo (CIMMYT) in six countries namely Kenya, Tunisia, Colombia, El-Salvador, Mexico, and Turkey. The study concluded that the following factors accounted for the differences in adoption rates in the six countries: Differences in information acquired, agro-climatic and physical environments, availability of inputs, differences in market opportunities for the crops, differences in farm size as well as the risk aversion characteristics of farmers.

According to several research reports, the adoption of the cocoa production technologies recommended to farmers by the Cocoa Research Institute of Ghana (CRIG) has been low, resulting in low yields [3,8,9,10,11]. Reasons for the low adoption include lack of financial resources and labour, technical difficulties [10] and high cost of technologies [12].

There are several studies on the adoption of cocoa technologies in Ghana. The objective of the current paper is to determine the factors influencing the adoption of inorganic fertilizer by cocoa farmers in Ghana.

2. METHODOLOGY

The following section is a presentation of the methods used, a description of the study area, the data, as well as the empirical model for the study.

2.1 Study Area and Data

The study was conducted in the Bibiani-Anhwiaso-Bekwai District in the Western Region of Ghana. The district is a major cocoa producing area in the country and is located in the forest belt. The area experiences an average annual rainfall between 1200 mm and 1500 mm. The rainfall distribution is bimodal. The agro-climatic condition of the area is suitable for the growing of important crops like cocoa, rubber, maize, cassava, plantain and cocoyam. Eighty randomly selected cocoa farmers located in four communities in the Bibiani-Anhwiaso-Bekwai District took part in the study. The communities included Bekwai, Baakokrom, Ashiam and Humjibre. Twenty farmers were then selected from each community using random sampling. Farmer interviews took place with the aid of semi-structured questionnaires. Demographic, socioeconomic and production data were solicited from the respondents. To achieve the research objective, the study solicited from farmers whether they use inorganic fertilizer in

cocoa production. The question required a yes or no response. Out of the 80 respondents, 78 provided complete information and these were used in the final analysis.

2.2 Analytical Framework and Empirical Model

The current study used the probit model to analyse adoption decisions of farmers due to the binary nature of the dependent variable. The probit model makes the assumption that while only the values of 0 and 1 for the dependent variable Y_i are observed, there is a latent, unobserved continuous variable Y_i^* that determines the value of Y_i [13]. The probit model ensures that the estimated probabilities lie between 0 and 1.

Suppose the response variable Y_i is binary with only two possible outcomes (1 for adoption and 0 for non-adoption). Consider also a vector of independent variables x_i which is assumed to influence Y_i. Then the probit model takes the form:

$$\Pr(Y_i = 1 \mid x_i) = F(\beta' x_i) = \Phi(\beta' x_i) \qquad (1)$$

Where Pr denotes probability, Y_i is the binary choice variable representing adoption and Φ is the cumulative distribution function (CDF) of the standard normal distribution. β is a vector of unknown parameters.

It is assumed that the latent variable Y* can be specified as follows:

$$Y_i^* = \beta_0 + \sum_{n=1}^{N} \beta_n x_{ni} + u_i \qquad (2)$$

And

$$Y_i = \begin{cases} 1 & if\ Y_i^* > 0 \\ 0 & otherwise \end{cases} \qquad (3)$$

where x_i represents a vector of explanatory variables, u_i is a random disturbance term, N is the total sample size, and β is a vector of unknown parameters to be estimated by the method of maximum likelihood.

Due to the non-linearity of the probit model, the parameters are not necessarily the marginal effects of the various independent variables. The marginal effects of the coefficients are more informative and useful for policy decision-making. To estimate the marginal effect, we differentiate equation (1) with respect to x_i [14]:

$$\frac{\partial Y_i}{\partial x_i} = \phi(\beta' x_i)\beta_i \qquad (4)$$

where ϕ represents the probability density function of the standard normal distribution.

The empirical specification of the probit model for the study is given as follows:

$$y_i = \beta_0 + \sum_{n=1}^{6} \beta_n x_{ni} + v_i \qquad (5)$$

where Y_i = adoption of fertilizer (=1 if farmer adopted fertilizer, 0 otherwise); x_1 =age; x_2 = household size; x_3 = farm size; x_4 = extension contact; x_5 = farm income; x_6 = access to the cocoa praying programme (=1 if farmer participated, 0 otherwise).

The choice of variables in the model was based on intuition and literature [6,11,15-22]. The definition and expected signs of the variables used in the probit model are given in Table 1.

Table 1. Description of variables used in the model

Variable	Description	Expected sign
Adoption of fertilizer	Adoption of fertilizer	
Age	Age of farmer in years	+/-
Access to mass spraying	Dummy: 1 if farmer participated; 0 otherwise	+/-
Farm size	Farm size in acres	+/-
Farm income	Farm income in Ghana Cedis	+
Extension contact	Number of extension visits per annum	+
Household size	Total number of household members	-

There is no consensus among researchers regarding the sign of many of the variables influencing adoption decision as findings reported by many research scientists often differ.

While the reason for the variations may or may not be due to methodological differences, it is important to state that since the socio-cultural and economic settings of farmers vary, empirical results across different geographical regions are likely to show some variations.

Age is an important variable which influences most household and farm decisions and is widely used as a variable in adoption studies. It has been shown that young people are more likely to take risks associated with innovation, hence more likely to be adopters [23,24]. However, [25] obtained a positive association between age and fertilizer adoption by cocoa farmers in Ghana. Hence the sign of the variable in this study is considered to be indeterminate.

Access to the mass cocoa spraying exercise is expected to influence the decision to adopt fertilizer either positively or negatively. Farmers who had their farms sprayed are expected to obtain higher yields due to the control of pests and diseases. Such farmers may be motivated to adopt fertilizer to further enhance their production. On the other hand, other farmers may consider the spraying exercise enough to guarantee them a good yield, especially when cash is a limiting constraint. Hence the influence of the variable is indeterminate.

It has been shown that the cultivated area has a positive influence on farmers' adoption of chemical inputs [26-28]. According to [29], the positive influence of farm size on adoption may be attributed to economies of scale effects or the ability to bear the risks associated with adoption of new technology. However, as shown by [6], farm size decreases the adoption of fertilizer by farmers. The influence or sign of farm size is therefore indeterminate.

Farm income is hypothesised to have a positive influence on adoption. This is because an increase in farm income is expected to increase farmers' ability to pay for the cost of agrochemical inputs.

Extension contact is also expected to have a positive influence on adoption since it enhances farmers' knowledge of technology. Farmers who possess knowledge about an innovation are more likely to adopt the innovation than those without adequate knowledge.

Household size is expected to have a negative influence on adoption. This is due to the important role family labour plays in rural households' farming activities. An increase in household size is likely to increase the household labour supply. Excess labour can then be substituted for agrochemical input, including fertilizer.

3. RESULTS AND DISCUSSION

The following section is a presentation of the results of the study and discussion of the main findings. The description of the characteristics of the respondents is followed by a presentation of the results of the probit analysis and the discussion of the major findings.

3.1 Characteristics of the Respondents

A brief description of the characteristics of the respondents is presented in Table 2. About two-thirds of the respondents adopted cocoa fertilizer and were able to access finance for production. Close to 70 percent of the respondents participated in the cocoa mass spraying exercise while 40 percent had access to extension service. Notwithstanding the fact that these services are free of charge to farmers, the study shows that not all farmers are able to participate. The average farm size was 7.8 acres, which shows that the respondents are smallholder farmers. The average age of respondents was 48 years while the average household size and average income was 10 members and 1937 Ghana Cedis respectively.

A comparative analysis of the main characteristics of the respondents shows that

Table 2. Descriptive statistics of respondents

Variable	Mean	Std. Dev.	Minimum	Maximum
Farm size	7.76	5.76	2	32
Farm income	1937	2029	204	10200
Extension contact	0.36	0.81	0	3
Age	47.6	11.0	25	65
Household size	9.99	2.94	3	23

adopters had significantly higher farm income but were significantly younger than non-adopters. These variables are therefore likely to influence adoption of fertilizer by respondents. Adopters also had larger farm size than non-adopters. However, the mean difference was not significant. Adopters however had less contact with extension agents and smaller household size with insignificant mean difference.

Table 3. Descriptive statistics of the respondents according to adoption status

Variable	Adopters (N = 48)	Non-adopters (N = 30)	t-test
Farm size	8.25	6.98	1.63
Farm income	2546	962	-3.61***
Extension contact	0.29	0.47	0.93
Age	45.6	50.7	2.01**
Household size	9.56	10.7	1.63

**** and ** mean significant at 1% and 5% respectively*

3.2 Determinants of Fertilizer Adoption

Table 4 is a presentation of the maximum likelihood estimates of the parameters of the probit analysis of fertilizer adoption by cocoa producers in Ghana. The diagnostic statistics reveal a good fit of the model, as indicated by the highly significant Chi-square test statistic and the percentage of the variables correctly classified. The result shows that the explanatory variables included in the model are relevant and jointly explain the adoption decision of farmers. The results show that the significant factors that affect fertilizer adoption decision of farmers are farmers' age, farm size and farm income. Household size, extension contact, access to finance and access to the mass spraying exercise were however insignificant in explaining adoption of fertilizer by cocoa farmers.

The age of respondents was negatively related to adoption and significant at the 5 percent level. The result indicates that an increase in age of the farmer decreases the probability of fertilizer adoption in cocoa production. A unit increase in age decreases the probability of fertilizer adoption by 0.01. Age is a proxy for farming experience, which means that experienced farmers are less likely to adopt fertilizer in cocoa production compared to relatively inexperienced farmers. The result is at variance with [25] who reported a positively significant influence of age on fertilizer adoption by Ghanaian cocoa farmers. Furthermore, [6] found a positive but insignificant relationship between age and fertilizer adoption by cocoa farmers in Cote d'Ivoire. The implication of the research finding is that older farmers are less likely to adopt fertilizer application which may be attributed to their familiarity with farming and a reliance on their personal knowledge or experience in farming. As farmers grow older, they accumulate knowledge of farming and may rely on this at the expense of new knowledge from research. Furthermore, older farmers may have more financial obligations as they are more likely to take care of larger households, a situation which can adversely affect their adoption decisions.

Farm size had a negative relationship with adoption of fertilizer and was significant at the 10 percent level. The result implies that an increase in farm size decreases the probability of adopting fertilizer in the production of cocoa. A unit increase in farm size leads to a 0.024 decrease in the probability of adopting fertilizer. The result implies that farmers with smaller farms are more likely to adopt fertilizer in cocoa production in Ghana. The result is consistent with the finding of [6] who reported a negatively significant relationship between farm size and fertilizer adoption in Cote d'Ivoire. It can be deduced that as farms become larger, the high cost of applying fertilizer on the entire farm tends to inhibit farmers from adopting fertilizer application. Furthermore, farmers with large farm holdings who lack the ability to purchase chemical fertilizers may still expect to obtain some output by virtue of their large acreage if they manage to maintain basic agronomic practices.

Farm income exhibited a positive and highly significant relationship with adoption of cocoa fertilizer, implying that as farm income increases, so does the probability of adoption of fertilizer by farmers. A unit increase in farm income increases the probability of adoption of fertilizer by 0.38. It is reported by the World Bank that cocoa production in Ghana is a major source of income to over 800,000 farmers and many others engaged in trade, transportation and processing of cocoa [30]. Since cocoa production is the mainstay of smallholder producers, it is the expectation that an increase in farm income will enhance the adoption of fertilizer and other productivity-enhancing technologies.

Table 4. Probit model of adoption

Variable	Coefficient	Std. error	P>|z|	Marginal effect
Age	-0.044	0.017	0.010**	-0.012
Household size	-0.091	0.071	0.200	-0.024
Farm size	-0.081	0.045	0.072*	-0.021
Extension contact	-0.294	0.249	0.239	-0.077
Farm income	1.448	0.448	0.001***	0.380
Access to mass spraying	0.560	0.396	0.157	0.147
Constant	2.508	1.327	0.059*	-

****, ** and * stand for statistical significance at the 1%, 5% and 10% level, respectively. Log likelihood = -36.3; Wald chi2 (6) = 31.4; Prob > chi2 = 0.00; Pseudo R2 = 0.30*

4. CONCLUSION

The study employed a probit model to analyse the determinants of fertilizer adoption by Ghanaian cocoa farmers. The study revealed that farmers' age, farm size and farm income were the critical determinants of adoption. The implications of the findings are that younger farmers are more likely to embrace technological change in cocoa production and efforts to encourage them to increase production can improve Ghana's cocoa output level. Furthermore, farmers with larger farms were less likely of adopt fertilizer, which could be attributed to the high cost involved in applying fertilizer on a large farm, compared to a small farm. This shows that farmers with very low incomes are likely to be non-adopters. This point is buttressed by the high significance of the income variable in the model. Farmers are thus more likely to adopt fertilizer when their income increases. Efforts to enhance the productivity and income of cocoa farmers will therefore enhance the adoption of fertilizer which in turn has the potential to spur productivity growth.

Based on the findings, the study recommends that fertilizer for cocoa production should be subsidised by the government to promote adoption. In addition, extension service delivery must be improved to ensure that farmers get information on improved production practices. The negative and insignificant value of the extension variable depicts the weak extension programme in the study area.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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