

Original Research Article

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

ABSTRACT

Cocoa remains an important cash crop in Ghana and plays a major role in the country's socio-economic development. As the mainstay of many smallholder households and the most important agricultural crop in Ghana, there are several efforts to enhance the production of the crop. The introduction of partial liberalisation of the cocoa sector in Ghana has encouraged private sector activity in the industry, including the privatisation of input supply. A key strategy aimed at improving cocoa production is the adoption of inorganic fertilizer. This study seeks to determine the factors influencing the decision of cocoa farmers 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. The study recommends the improvement of extension service delivery to farmers, the training of farmers on the recommended practices of fertilizer application and the subsidisation of fertilizer to increase the yield of cocoa in Ghana.

Keywords: Adoption, Cocoa production, Ghana, Inorganic Fertilizer, Input Subsidy

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 product. There have been attempts to resuscitate the cocoa sector through the provision of better pricing, provision of 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 seen as a positive development which 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 which may affect the premium Ghana enjoys on her cocoa on the international market.

Several studies have been carried out 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 found to significantly explain farmers' decisions.

[7] Perrin and Winkelman (1976) summarized adoption studies by the Centro Internacional de Mejoramiento de Maiz Y Trigo (CIMMYT) in six countries namely Kenya, Tunisia, Colombia, El-Salvador, Mexico, and Turkey. The study came to the conclusion that differences in adoption rates in the six countries were explained by the following factors: 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 yield and production levels that are below potential [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].

The current paper investigates the factors influencing the adoption of inorganic fertilizer by cocoa farmers in Ghana. Several studies have been carried out on the adoption of cocoa technologies in Ghana. However research on the adoption of fertilizer by Ghanaian cocoa farmers is still hard to find. The current study therefore seeks to fill the knowledge gap.

The paper is structured as follows: section 1 is the introduction which is followed in section 2 by the methodology which includes the data, study area, analytical and empirical models. Section 3 deals with the results of the study and the discussion of the main findings. The paper ends with the conclusion and recommendations in section 4.

2. METHODOLOGY

The following section is a presentation of the methods used, a description of the study area, 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, which has a bimodal distribution. The agro-climatic condition of the area is suitable for the growing of important crops like cocoa, rubber, maize, cassava, plantain and cocoyam. Eighty (80) cocoa farmers located in four communities in the Bibiani-Anhwiaso-Bekwai District were randomly selected for the study. The farmers were interviewed using a semi-structured questionnaire. 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 we only observe the values of 0 and 1 for the dependent variable Y_i , 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:

$$\Pr(Y_i = 1 | x_i) = F(\beta' x_i) = \Phi(\beta' x_i) \quad (1)$$

Where $\Pr$ denotes probability, Y_i is the binary choice variable indicating 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 latent variable Y^* can be specified as follows:

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

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

where 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 and were therefore estimated. The marginal effect can be derived by differentiating equation (1) with respect to x_i [14]:

$$\frac{\partial Y_i}{\partial x_i} = \left[\frac{\lambda \beta' x_i}{(1 + \lambda \beta' x_i)^2} \right] \beta_i = F(\beta' x_i) [1 - F(\beta' x_i)] \beta_i = \phi(\beta' x_i) \beta_i \quad (4)$$

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:

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

where = adoption of fertilizer (=1 if adopted, 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 access, 0 otherwise).

The choice of variables in the model is based on intuition and literature [6, 11, 15, 16, 17 18, 19, 20, 21, 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

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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	-

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123 There is no consensus among researchers regarding the sign of many of the variables
 124 influencing adoption decision as findings reported by many research scientists often differ.
 125 While the reason for the variations may or may not be due to methodological differences, it is
 126 important to state that since the socio-cultural and economic settings of farmers vary,
 127 empirical results across different geographical regions are likely to show some variations.

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

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

141 It has been shown that the cultivated area has a positive influence on farmers' adoption of
 142 chemical inputs [26, 27, 28]. According to [29], the positive influence of farm size on
 143 adoption may be attributed to economies of scale effects or the ability to bear the risks
 144 associated with adoption of new technology. However, as shown by [6], farm size decreases
 145 the adoption of fertilizer by farmers. The influence or sign of farm size is therefore
 146 indeterminate.

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

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

153 Household size is expected to have a negative influence on adoption. This is due to the
 154 reliance on family labour for farming by rural households. An increase in household size is
 155 likely to increase the household labour supply which can substitute for agrochemical input
 156 thus reducing the financial burden of the household.

3. RESULTS AND DISCUSSION

The results of the study and discussion of the main findings are given in the following section. 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 results.

3.1 Characteristics of the respondents

We provide a brief description of the characteristics of the respondents involved in the study. About two-thirds of 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. This shows that there are a number of farmers who do not get access to services (the mass spraying of cocoa farms and extension service) even though these exercises are free. The average farm size was 7.8 acres, which shows that the farmers 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.

Table 2: Descriptive statistics of respondents

Variable	Mean	Std. Dev.	Minimum	Maximum
Adoption of fertilizer	0.62	0.49	0	1
Farm size	7.76	5.76	2	32
Farm income	1937	2029	204	10200
Extension contact	0.36	0.81	0	3
Access to mass praying	0.69	0.47	0	1
Age	47.6	11.0	25	65
Household size	9.99	2.94	3	23

A comparative analysis of the main characteristics of the respondents shows that 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 bigger farm size as well as greater access to finance and the government mass cocoa spraying program. However the mean difference was not significant. Adopters however had fewer contact with extension 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
Access to mass praying	0.73	0.63	-0.89
Age	45.6	50.7	2.01 ^{**}
Household size	9.56	10.7	1.63

3.2 Determinants of fertilizer adoption by cocoa farmers

Table 4 is a presentation of the maximum likelihood estimates of the parameters of the probit model of adoption of fertilizer 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 percentage of the variables that were correctly classified. This shows that the explanatory variables included in the model are relevant and jointly explain the adoption decision of farmers. The results show that factors that tend to significantly 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.

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*	-

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

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 adoption of fertilizer 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 very experienced cocoa farmers are less likely to adopt fertilizer in cocoa production. The result is consistent with [25] who reported a positively significant influence of age on fertilizer adoption by Ghanaian cocoa farmers. On the contrary, [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 familiarity with farming and a reliance 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 by way of caring for 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 decrease in the probability of adopting fertilizer by 0.024. 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

229 purchase chemical fertilizers may still expect to obtain some output by virtue of their large
230 acreage if they manage to maintain basic agronomic practices.

231 Farm income exhibited a positive and highly significant relationship with adoption of cocoa
232 fertilizer, implying that as farm income increases, so does the probability of adoption of
233 fertilizer by farmers. A unit increase in farm size increases the probability of adoption of
234 fertilizer by 0.37. It is reported that there are an estimated 350,000 cocoa farms in the
235 country operated by smallholder farm families who derive about 70 – 100% of their annual
236 household incomes from cocoa [30]. Since cocoa production is the mainstay of smallholder
237 producers, it is expected that an increase in farm income will enhance adoption of
238 technology. An increase in farm income is a motivation to farmers produce more while it
239 also enables farmers to afford productivity-enhancing technologies.
240

241 **4. CONCLUSION**

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243 The study employed a probit model to analyse the determinants of fertilizer adoption by
244 Ghanaian cocoa farmers and found that farmers' age, farm size and farm income were the
245 critical determinants of adoption. The implications of the findings are that younger farmers
246 are more likely to embrace technological change in cocoa production and efforts to
247 encourage them to increase production can improve Ghana's cocoa output level.
248 Furthermore, farmers with bigger farm sizes showed less likelihood of adoption, which could
249 be attributed to the high cost involved in applying fertilizer on a large farm, compared to a
250 small farm. This shows that farmers with very low incomes are likely to be non-adopters.
251 This point is buttressed by the high significance of the income variable in the model. Farmers
252 are thus more likely to adopt fertilizer when their incomes increase. Efforts to enhance the
253 productivity and incomes of cocoa farmers will therefore go to enhance adoption of fertilizer
254 to spur further productivity growth.

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