Farmer Characteristics, Ecological Zones and Adoption Decisions: A Tobit Model Application for Maize Technology in Ghana

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Resumé

Dankyi, A. A., Andah, K. Moris, M. M. & Fosu, Y. *Caractéristiques paysannes, Zones écologiques et décisons adoptives: Une application du Model Tobit pour la technologie du maïs au Ghana.* L'objectif de ce papier était d'esayer l'hypothèse que les caractéristiques paysannes et les zones écologiques où les paysans cultivent la terre affectent considérablement les décisions adoptives de la technologie du maïs. La zone écologique où les paysans cultivent le maïs comme une variable explicative pour l'adoption des variétés du maïs amélioré était inclue parce que les premières études sur le maïs au Ghana ne l' ont pas considéré en analysant les facteurs qui affectent l' adoption de la technologie du maïs. De plus, ces études n'ont utilisé aucune dépendante de variable du model limiteé pour analyser les facteurs qui affectent des décisions adoptives et l'intenssté d'usage. Dans un échantillon de 420 cultivateurs de maïs au Ghana sondé en 1997, un model de TOBIT était utilisé pour essayer l' hypothèse que les caractéristiques paysannes et les zones écologiques dans lesqueles les paysans cultivent le mas influencent la superficie du terrain mise sous condition de la culture du maïs amélioré. Les résultats montrent que la vulgarisation, les zones écologiques de culture, genre, la tenure de terre, la superficie entière du maïs affectent considérablement la superficie cultivée à la variété du maïs amélioré. La superficie du ménage n'est pourtant pas considérable malqré le fait qu' elle soit positivement alliée.

Mots clés: Tobit, technologies améliorées, décisions adoptives, zones écologiques, caractéristiques paysannes.

Abstract

The objective of this paper was to test the hypothesis that farmer's characteristics and ecological zones where farmers farm significantly affect the adoption decisions of maize technology. The ecological zone where farmers cultivate maize as an explanatory variable for the adoption of improved maize varieties was included because earlier studies on maize in Ghana have not considered it in analysing factors affecting maize technology adoption. Furthermore, these studies have not used any limited dependent variable model to analyse the factors affecting adoption decisions and the intensity of use. In a sample of 420 Ghana

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maize farmers surveyed in 1997, a TOBIT model was used to test the hypothesis that farmer's characteristics and the ecological zones in which farmers cultivate maize influence the size of the field put under improved maize cultivation. The results show that extension contact, ecological zones where farmers' farm, gender, land tenure and total maize area significantly affect the area planted to improved maize varieties. Household size is, however, not significant although it is positively related.

Keywords: Tobit, improved technologies, adoption decisions, ecological zones, farmer characteristics.

Introduction

The use of discrete choice models such as LOGIT, PROBIT and TOBIT in explaining adoption are well documented (Shiverly, 1997; Nichola and Sanders, 1996; Adesina and Badu-Forson, 1995; Adesina and Zinnah, 1993). These studies have variously used farm, farmer characteristics and or farmer perceptions to explain the adoption process.

Since the earlier work of Rogers (1962), several attempts have been made to explain the factors of adoption. Generally, three main issues for explaining adoption decisions can be identified. The economic constraint, the innovation-diffusion and the "adopter perception" (Adesina and Zinnah, 1993).

The economic constraint model (Aikens *et al.,* 1975) argues in favour of the distribution patterns of resource endowments as the major determinants of adoption. The innovation-diffusion model, pioneered by Rogers(1962) believes that access to information is the main determining factor in adoption decisions. The 'adopter perception' model suggests that the perceived attributes of innovations are the key determinants of adoption behaviour (Kivlin and Fliegel, 1966; 1967).

In many of these studies, ecological zones in which farmers farm are not included as some of the explanatory factors affecting the adoption of improved technologies. Farmers in different ecological zones may adopt improved technologies differently because of the environment in which they live. If technologies developed are not compatible with the conditions prevailing in the ecological zones, adoption may be low. Thus the type of improved crop varieties and other technologies developed may be in response to the environmental conditions prevailing in the ecological zones. Similarly, adoption of the technologies may be due to the same conditions.

The study seeks to contribute to the literature on TOBIT models on Ghana agriculture and technology adoption. It is to open up the inclusion of ecological zones as some of the important factors explaining adoption in future adoption studies.

Improved maize technologies in Ghana

The Ghana Grains Development Project (GGDP) was established in 1979 by the joint effort of the Governments of Ghana and Canada. Funds were provided through the Canadian International Development Agency (CIDA). The primary objective of the Project was to develop and extend to Ghanaian farmers improved maize and grain legume technologies. The executing agencies of the Project were the Crops Research Institute (CRI) in Ghana and the International Centre for Maize and Wheat Improvement (CIMMYT) in Mexico. Other collaborators were International Institute for Tropical Agriculture (IITA), the Ministry of Food and Agriculture (MoFA) and the Grains and Legumes Development Board (GLDB). The backstopping of maize breeding programme was provided by CIMMYT.

Prior to the establishment of the GGDP, several improved maize varieties were available in Ghana but there was little interest among farmers to grow them. Adoption of improved maize technologies was not widespread and national maize production declined particularly, in the late seventies. Under the GGDP, the national maize research programme was reorganized. Working closely with farmers, the GGDP released, beginning in 1984, a series of improved maize varieties and planting recommendations such as fertilizer and planting practices. By the end of the Project in 1997, it had released nine open-pollinated and three hybrid maize varieties, some of which are quality-protein maize and streak resistant. The hybrid maize varieties were released in 1997. The maize varieties developed by the GGDP are summarized in Table 1.

Ghana has four main ecological zones and somehow, maize cropping systems and production technologies differ among these zones. Beginning from the coast is a stretch of savannah known as the coastal savannah. Maize may be planted as a monocrop or as an intercrop with cassava in this zone. The rainfall is bimodally distributed and the annual rainfall is about 800mm. The productivity of maize is generally low because soils are light in texture and low in fertility.

Moving inland and next to the coastal savannah zone is the forest zone. As the name implies, there are several trees. The soils are heavy and loamy and are more fertile than the other ecological zones. It has two rainfall seasons. The major season occurs between March and July and the minor season is between September and October. The annual rainfall averages about 1500mm. Maize is usually intercropped with plantain, cassava and or cocoyam in this zone.

Table 1. Improved varieties released by the Ghana Grains Development Project.

Name	*Year released*	*Days to maturity*	*Grain texture*	*Grain colour*	*Yield (kg ha^{-1})*	*Streak resistant to streak*	*CIMMYT germplasm*
Aburotia	1984	105	dent	White	4.6	No	Tuxpeno PBC16
Dobidi	1984	120	dent	White	5.5	No	Ejura(1) 7843
Kawanzie	1984	95	flint	Yellow	3.6	No	Tocumen(1)7931
Golden Crystal	1984	110	dent	Yellow	4.6	No	Not available
Safita-2	1984	95	dent	White	3.8	No	Pool 16■
Okomasa	1988	120	dent	White	5.5	Yes	EV8343-SR■
Abeleehi	1990	105	dent	White	4.6	Yes	Ikenne 8149-SR■
Dorke Sr■■	1990	95	dent	White	3.8	Yes	Pool 16-SR■
Obatanpa■■	1992	105	dent	White	4.6	Yes	Pop 63-SR
Cidaba■■	1997	110	--	White	4.9	Yes	Not available
Mamaba■■	1997	110	--	White	5.1	Yes	Not available
Dadaba	1997	110	--	White	4.8	Yes	Not available

■ Developed jointly by CIMMYT/IITA.
■■Quality protein maize.
Source: Compiled by the authors from various GGDP Reports, 1979 - 1998.

Maize may be planted in both the major and minor seasons. In the case of the minor season, maize is planted as a monocrop.

Further north of the forest zone is the transition zone. This zone has deep and friable soils. There are fewer trees than the forest zone and therefore, mechanized equipment are often used especially for land preparation. The zone has a bimodal rainfall with an annual average of about 1300mm. The transition zone is noted for commercial maize production in Ghana.

The Guinea savannah zone covers most northern part of Ghana. Temperatures are usually high and the zone has uni-modal rainfall which occurs between May and September. Soils are light and low in fertility. Maize is mostly planted on fields around the compound or in the bush farther away from homes. Maize may be planted as a monocrop or as intercrops with millet, sorghum and or cowpea. Animal and tractors are often used to cultivate maize.

A nation-wide survey of maize farmers was conducted by the CRI and CIMMYT between November, 1997 and March 1998 to assess the adoption of maize technologies in Ghana. Using a 3-stage clustered and randomized sampling procedure, 420 maize farmers were selected. The results of the adoption survey from the ecological zones are summarized in Table 2. It is seen that about two-thirds of maize area in the coastal savannah, transition and Guinea savannah is put under improved

Table 2. Area under improved maize technologies in Ghana.

Ecological zone	*Improved maize (%)*	*Fertilizer (%)*	*Row planting (%)*
Coastal savannah	74	38	59
Transition	68	42	66
Guinea savannah	60	32	68
Forest	33	9	44
All zones	54	26	55

Source: 1998 CRI/CIMMYT/CIDA survey.

maize varieties compared to about a third in the forest zone. Fertilizer adoption is however, low. Just about a third of maize area is fertilized in the coastal, Guinea savannah and the transition zones. In the forest zone, about a tenth of the maize area is fertilized. This is not surprising as forest soils are relatively more fertile compared to savannah soils and soils of the transition zone. If the actual numbers of farmers who adopt improved maize technologies are analyzed, the same pattern of adoption as the area under improved maize technology is followed. For example, in Table 3, the percentage of farmers who adopted improved maize technologies on at least, part of their fields show that adoption is relatively high among farmers in the coastal savannah, transition and Guinea savannah zones and much lower in the forest zone. These differences again show how important ecological zones are in the adoption of the improved technologies.

The mean household size is 10.1 and the average extension contact with maize farmers is 2.3. Results from Table 4 show that farmers who have more contact with extension adopt improved technologies. This shows that extension plays a role in the adoption of improved technologies and may be an important explanatory variable in adoption patterns and decisions.

Gender issues in technology development, transfer and adoption are important if equity is to be realized. From a total sample of 420 farmers, 75% were males and 25% females. This suggests that there are more men farmers in maize production than women farmers and this is consistent with findings from other maize studies (Tripp, *et al.*, 1987; GGDP, 1990). Despite this proportional difference, the improved maize technologies developed in Ghana are gender-neutral and it is expected that both sexes will adopt the technologies equally. However, results from Table 5 show that the proportion of men who adopted

Table 3. Proportion of farmers adopting improved maize technologies in Ghana.

Ecological zone	*Improved variety (%)*	*Fertilizer (%)*	*Row planting (%)*
Coastal savannah	69	29	65
Transition	68	29	59
Guinea savannah	66	36	73
Forest	38	9	39
All zones	54	21	53

Source: 1998 CRI/CIMMYT/CIDA survey.

Table 4. Influence of extension contact on maize technology adoption.

Technology	*Number of extension contacts*		*Significance level*
	Adopter	*Non-adopter*	
Improved variety	3.3	1.1	<.001
Fertilizer	4.0	1.9	<.001
Row planting	3.3	1.2	<.001

Source: 1998 CRI/CIMMYT/CIDA survey.

Table 5. Gender and technology adoption.

	Adopters		
Technology	*Female* (%)	*Male* (%)	*Significance*
Improved maize	39	59	<.001
Row planting	38	59	<.001
Fertilizer	16	23	NS

Source: 1998 CRI/CIMMYT/CIDA survey.

improved maize and row planting is significantly greater than their women counterparts. In the adoption of fertilizer, however, there is no difference. This further suggests that male farmers are more likely to adopt improved maize technologies than their female counterparts.

The model

A TOBIT model developed by James Tobin (1958) was used to determine the factors of adoption of improved maize in Ghana. Mathematically, the TOBIT model (Gujarati, 1995) can be expressed as : $Yi = \beta_i + \beta_2 X_{2i} + \mu_{2i}$

If Right Hand Side > 0

= 0, *otherwise*

Where,

Y_i = Limited dependent variable

X_{2i} = explanatory variable

β_{2i} = Disturbance term

β_1 = Intercept

μ_2 = Coefficient of the explanatory variable, X.

The Tobit model measures not only the probability of adoption but also the intensity of adoption. Rahm and Huffman (1984) developed a general model where farmers are assumed to make adoption decisions based on utility maximization.

Define t_1 = New technology

t_2 = Farmer technology

The underlying utility function which ranks the preference of the i^{th} farmer is given by: $U(H_{ti}, N_{ti})$.

This means that utility is a function of H_{ti} a vector of farm specific attributes such as farm size, and N_{ti} which are technology-specific characteristics such as taste.(1)

$Uti = \alpha Fi(Hti, Nti) + eti$

Where, $t = 1,2$; $i = 1..., N$.

The utilities are random and the i^{th} farmer adopts the new technology, ($t = 1$) if $U_{1i} > U_{2i}$ or if the non-observable random variable $y^* = U_{1i} - U_{2i} > 0$.

The probability that y*>0, the farmer adopts the new technology, can be written as a function of the independent variables:(2)

$Pi = \Pr(yi > 0) = \Pr(U1i > U2i)$

$= \Pr[\alpha 1\, Fi(H_{ti}, N_{ti}) + e1i \;\; \alpha 2 Fi(H_{ti}, N_{ti}) + e2i]$

$= \Pr[e1i - e2i > Fi(H_{ti}, N_{ti})(\alpha 2 - \alpha 1)]$

$= \Pr(Ui > Fi(H_{ti}, N_{ti})\beta) = Fi(Xi\beta)$

Where

Pi = Probability function.

$\mu_i = e_{1i} - e_{2i}$, is a random disturbance term.

$\beta = \alpha_2 - \alpha_1$, is a vector of parameters to be determined.

X = (n x k) vector of explanatory variables.

$F(X_i\beta)$ = Cumulative distribution function for the disturbance term, μ_i, evaluated at $X_i\beta$.

The dependent variable (Yi) is the proportion of maize area under improved varieties. The dependent variable is censored because information on the regressand is available only for some observations. TOBIT model can, therefore, be used.

Empirical model

The empirical model is based on the national data collected during 1997 cropping season through a CRI/CIMMYT maize survey of Ghana conducted in 1998. The estimated empirical model was developed using farm and farmer specific characteristics. The dependent variable is "area planted to improved maize varieties (MVAREA)". The definitions of the other variables in the model are given in Table 6. In the model, the forest zone was not included because as shown

Table 6. Variables in the empirical model.

Dependent variable:	
MVAREA	Area planted to improved maize.
Independent variables:	
EXTVISIT	Number of contacts with extension agents in 1997. It is measured as a continuous variable.
HHSIZE	Total household size. Measured as a continuous variable.
ZONECS	Coastal Savannah ecological zone. It is measured as a binary Variable: 1 if maize is planted in Coastal Savannah zone, 0 if planted elsewhere.
ZONETR	Transition ecological zone. It is measured as a binary variable: 1 if maize is planted in the transition zone and 0 if planted elsewhere.
ZONEGS	Guinea Savannah ecological zone. It is a binary variable: 1 if maize is planted in the Guinea Savannah zone, 0 if planted elsewhere.
GENDER	Sex of farmer. It is a binary variable: male = 1 and female = 0.
TENURE	Ownership of land under maize cultivation. It is a binary variable: 1 if land is owned, 0 if any other land arrangements.
MZAREA	Total area of maize for the farmer and is measured as a continuous variable.

earlier in Table 3, the adoption of improved maize varieties in this zone was relatively smaller than the other ecological zones.

Results

The results from the above model show that extension contact, planting maize in the coastal savannah, transition, Guinea savannah zones, gender, land tenure and maize area are all significant at 95% level and are positively related to area planted to improved varieties (Table 7).

The significant level of extension contact is noteworthy because it is mainly through contacts with extension workers that many farmers learn about improved varieties and acquire them. This finding confirms the result that improved maize adopters had three times as many contacts with extension during a 12-month period of the 1997 cropping season. Thus extension plays a role in the promotion of adoption of improved technologies.

The ecological zones are important factors explaining adoption. All the three zones are significant with positive coefficients. Thus the area put under improved maize is likely to be bigger if farmers are in the transition, coastal and the Guinea savannah. Size of household is however, not significant but it is positively related to the dependent variable, area under improved maize.

Results of marginal analysis on the same factors results show that all the factors are significant except size of household (Table 8). The coefficients of the equation give indication of the marginal change. For example, one standard

Table 7. Estimated results of improved maize adoption using farmer, farm specific variables and ecological zones, Ghana.

Variable	*Coefficient*	*Standard error*	*b/St. Er*	*P[I z I > z]*	*Mean of X*
Constant	-4.88674	0.5985	-8.165	0.0000	
EXTVISIT	0.14602	0.36953E-01	3.952	0.0001	2.3000
HHSIZE	0.17974E-01	0.26549E-01	0.677	0.4984	10.1047
ZONECS	2.28518	0.45684	5.002	0.0000	0.2000
ZONETR	2.62006	0.49790	5.262	0.0000	0.1500
ZONEGS	1.42237	0.49998	2.845	0.0044	0.2000
GENDER	1.02497	0.43278	2.368	0.0179	0.7500
TENURE	0.88860	0.37861	2.347	0.0189	-1.6523
MZAREA	0.65899	0.51433E-01	12.813	0.0000	3.7049
		Disturbance standard deviation			
Sigma	3.06781	0.15564	19.713	0.0000	

Log of likelihood function - 694.7732.

Table 8. TOBIT marginal effect for factors of maize technology adoption.

Variable	*Coefficient*	*Standard error*	*b/St. Er*	*P[I z I > z]*	*Mean of X*
Constant	1.53086	0.4486	-3.413	0.0006	
EXTVISIT	0.45744E-01	0.2013E-01	2.273	0.0230	2.3000
HHSIZE	0.56307E-02	0.86928E-02	0.648	0.5171	10.1047
ZONECS	0.71588	0.26716	2.680	0.0074	0.2000
ZONETR	0.82079	0.31942	2.570	0.0102	0.1500
ZONEGS	0.44558	0.22961	1.941	0.0523	0.2000
GENDER	0.32109	0.16454	1.951	0.0510	0.7500
TENURE	0.27837	0.30610E-01	9.094	0.0000	1.6523
MZAREA	0.20644	0.72315E-01	2.855	0.0043	3.7049

deviation change in extension contact leads to a change of 0.46 or 46% change of area planted to improved maize varieties. Similarly, one standard deviation change of area planted to maize, changes the area planted to improved maize by 0.2 or 20%. The coastal and the transition zone have the highest marginal effect among the variables in the model. By the same token, a standard deviation change in Guinea savannah or transition zone changes the area under improved maize by 71% and 82%, respectively. This shows that the ecological zones where maize is planted are important variables to consider in the introduction and adoption of improved maize technologies in Ghana.

Conclusions

This paper examined the factors that affect the area that is planted to improved maize varieties and the marginal effect of these factors.

The ecological zones where farmers cultivate their maize affect the adoption of improved maize technologies. It is expected that future studies will include the ecological zones where farmers farm maize as some of the explanatory variables in adoption decision models.

The study also showed that access to extension services would increase the area planted to improved maize varieties. Thus the number of extension contact with maize farmers should be stepped up. Male farmers were more likely to plant larger areas to improved maize varieties than their women counterparts. This could partly be due to access to land or financial reasons. Thus female maize farmers should be given some support to expand their maize farms.

References

Adesina, A. & Zinnah, M. M. 1993. "Technology Characteristics, Farmer Perceptions and Adoption Decisions: A Tobit Model Application in Sierra Leone" *Agricultural Economics* 9:297-311.

Adesina , A. A. & Badu-Forson, J. 1995. "Farmers' perceptions and adoption of New Agricultural Technology: Evidence from Analysis in Burkina Faso and Guinea, West Africa. *Agricultural Economics* 13: 1-9.

Aikens, M. T., Haven's, A. E. & Flinn, W. L. 1975. "The Adoption of Innovations: The Neglected role of Institutional Constraints." Mimeograph. Dept. Of Rural Sociology, Ohio State University.

Feder, G. & Slade, R. 1984. "The acquisition of Information and the Adoption of New Technology." *Australia Journal of Agricultural Economics* 66(3): 312-320. Aug. 1984.

Gujarati, D. N. 1995. *Basic Econometrics* 3rd ed McGraw-Hill.

GGDP. 1990. A Study of Maize Technology Adoption in Ghana. Mexico City, Mexico: Ghana Grains Development Project.

Kivlin, J. E. & Fliegel, F. C. 1966. "Farmer's Perceptions of Farm Practice Attributes". *Rural Sociology* 31: 197-206.

Kivlin, J. E. and Fliegel, F. C. 1967. " Differential Perceptions of Innovations and rate of Adoption. *Rural Sociology* 32: 78-91.

Nichola, T. & Sanders, J. H. 1996. "A Probit Analysis of the Determinants of Adoption when inputs are rationed: The Gezira Experience with Hybrid Sorghum". *Science, Technology and Development* 14 (3):107-119.

Rogers, E. M. 1962. Diffusion of Innovations. Free Press. Glencoe. IL.

Shively, G. E. 1997. "Consumption Risk, Farm Characteristics and Soil Conservation Adoption among Low-Income Farmers in the Phillipines". *Agricultural Economics* 17:165-177.

Tripp, R., Marfo, K. A., Dankyi, A. A. & Read, M. D. 1987. Changing Maize Production Practices of Small-scale Farmers in the Brong-Ahafo Region of Ghana. Mexico City, Mexico: GGDP.