A comparison of factors affecting adoption of improved coffee management recommendations between small and larger farmers in Uganda

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ABSTRACT

The economies of developing countries continue to be dominated by the agricultural sector. In Uganda agricultural commodities contribute over 80% of total export earnings, of which coffee alone contributed 70% in 1997 (World Trade Organization, 1997). One of the major constraints to increasing production and quality is the generally low standard of management adopted by smallholder farmers who produce the bulk of Uganda's coffee. Previous studies of coffee-based farming systems indicated that most research recommended agronomic practices such as proper spacing, clean weeding, use of manure, pruning, stumping, and pest/disease control are not widely adopted by farmers.

This study attempts to identify factors that may explain differences in adoption between poor (small) and larger farmers. The results indicate that Education, farm size, and frequency of contacts with extension staff are statistically significant (at alpha=10%) for poor farmers, but not for richer farmers. Cropping system and off-farm employment are better predictors for high income farmers. The model predicts that high income farmers are about twice as likely to adopt soil conserving measures than poor farmers. The predicted probability of pesticide use is very low for both groups of farmers.

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Introduction

The economies of developing countries continue to be dominated by the agricultural sector. In Uganda agricultural commodities contribute over 80% of total export earnings, of which coffee alone contributed 70% in 1997 (World Trade Organization, 1997). In view of the vital role of coffee, a substantial proportion of the budget has been invested in research and extension geared towards boosting production and quality.

One of the major constraints to improving coffee yields and quality is the generally low standard of management adopted by smallholder coffee farmers who produce the bulk of Uganda's coffee. A recent survey of coffee-based farming systems (Ngambeki et al., 1992) indicated that most research recommended agronomic practices such as proper spacing, clean weeding, use of manure, pruning, stumping, and pest/disease control are not widely adopted by farmers. A need therefore arose to identify and measure the relative importance of the various factors that influence the behavior of coffee farmers in making decisions to adopt recommended coffee agronomic practices in the various farming systems.

Objectives

The objective of this study is to identify social, demographic, and economic factors that are likely to predict the adoption behavior of small farmers compared to larger farmers and to estimate the marginal effect of key factors on the probability of adoption. The study is aimed at testing the hypothesis that low income farmers are less likely to adopt soil conservation practices and use of pesticides compared to richer farmers.

Background

In order to boost declining yields and low bean quality, "clonal coffee", a line of *Robusta* clones with higher yield, and superior pest and disease resistance was released in 1991 as part of an attempt to provide farmers with a better alternative to the traditional *Robusta* varieties. The new clones also have bigger berries, and mature in 18 months compared to the 24-30 months required by traditional *Robusta* coffee.

A complimentary package of agronomic practices was also recommended to farmers along with the clonal varieties to ensure that the potential yield is realized. In addition, a substantial amount of resources has been invested under the "Farming Systems Support Programme (FSSP)" to promote adaptive research, multiplication and distribution of planting materials, and improvement of agricultural extension services so as to enhance adoption of this new technology.

In a wide sense adoption studies are intended to analyze the process of farmer decision making in deciding to adopt new technologies. Such studies usually involve identification of factors which constrain or enhance adoption, spatial and temporal patterns of adoption, when various types of farmers adopt, the level at which a technology is applied by farmers (stepwise adoption), and which farmers don't adopt and why. The concept of “adoption” in this study is used to refer to the decision by farmers to use or not to use agricultural technologies irrespective of the levels at which the technologies are used.

The results of adoption studies can be used by policy makers, researchers, extensionists, and even the public sector for example commercial firms interested in assessing the impact of technologies such as new seeds, fertilizers, and agro-chemicals. The goals of the research will thus differ depending on the intended clientele. The results of this study are focused mainly on the interests of research institutions and policy makers, namely: i) to identify potential factors limiting adoption of research recommendations, and ii) to identify differences between different groups of research clientele that can be utilized in the design and dissemination of technologies.

No similar studies on coffee have been previously conducted in Uganda. However studies conducted in other countries have shed some light on the factors at play. Ngatia and Kabaara (1976) in Kenya observed that resource constraints, ignorance, extension influence, seasonality, off-farm employment, and conditions attached to rural credit were major determinants of adoption of coffee production recommendations. Also in Kenya, Njagi (1980) observed that availability of cash, access to inputs on credit, risk aversion, and availability of manure affected adoption of soil fertility management recommendations. Kamau (1980) reported that adoption of weed control recommendations was influenced by availability and cost of labour, and cash flow constraints, and that adoption of pruning recommendations was influenced by labour availability, opportunity cost of labour, ignorance, and risk aversion. Other more general studies like one by Green and Ng'ong'ola (1993) conducted on Malawi reported crop type, farming system, crop variety, credit access, off-farm income, and availability of regular labour as the main factors affecting adoption of fertilizer recommendations. Kebede et. al (1990) on the other hand observed that farm size, farm income, family size, access to information, and education as having significant effect on adoption of fertilizer, single-ox, and pesticide technologies in Ethiopian crop production systems.

A survey of relevant literature indicates that most previous studies have focused on broad farming systems, covering several crops. Some like Ngatia and Kabaara (1976), Njagi (1980), and Kamau (1980) have focused on only a few technologies. Such information is useful in identifying potential constraints in similar cultural, socioeconomic, and agroecological settings. This study utilizes some of the findings of these studies in an effort to understand and explain differences in adoption behavior between poor and rich farmers. Rather than taking an aggregate view of the overall sub-sector, this study seeks to highlight relationships that may help explain why various socioeconomic groups of farmers exhibit differential adoption of various technologies. The approach used is to group farmers on the basis of total household income into low and high income groups.

Methodology

The data was collected through a formal survey in six districts in Central, Eastern, and Western Uganda (table 4). Using a multistage random sampling procedure, in each district four parishes were selected from two sub-counties (one parish is approximately 25 square kilometers). Stratification criteria used were: i) Type of coffee grown (*Robusta* or *Arabica*), ii) Accessibility from the main marketing centers, and iii) Farming system (Banana-Coffee, Maize-Millet). A sample of 240 farmers was randomly selected, 40 farmers from each district.

Theoretical Model

The study employs a logit model (Amemiya, 1981). In adoption studies, the use of probability models is conceptually preferable to conventional linear regression models because parameter estimates from the former overcome most weaknesses of linear probability models, namely: they provide parameter estimates which are asymptotically consistent, and efficient. The logit model was preferred to the probit model because of its simplicity. The general model is a binary choice model involving estimation of the probability of adoption of a given practice (Y) as a function of a vector of explanatory variables (X):

$$\text{Prob}(Y=1) = F(b'c) \qquad (1)$$

$$\text{Prob}(Y=0) = 1 - F(b'c) \qquad (2)$$

Where Y_i is the observed response for the i^{th} observation of the response variable Y. $Y_i = 1$ for an adopter, and $Y_i = 0$ for a non-adopter), and X is a set of explanatory variables such as age, sex, income, and farm size, which determine the probability of adoption (P) of a given technology. The function F may take the form of a normal, logistic, or other probability function. The logit model uses a logistic cdf to estimate P as follows:

$$P(Y=1) = \frac{e^{b'c}}{1+e^{b'c}} \qquad (3)$$

$$P(Y=0) = 1 - \frac{e^{b'c}}{1+e^{b'c}} = \frac{1}{1+e^{b'c}} \qquad (4)$$

The Probability model is a regression of the conditional expectation of Y on X giving:

$$E[y|x] = 1\{F(b'c)\} + 0\{1 - F(b'c) = F(b'c) \qquad (5)$$

Since the model is non linear, the parameter estimates are not necessarily the marginal effects of the various explanatory variables. The relative effect of each explanatory variable on the probability of adoption is obtained by differentiating equation (3) with respect X_{ij} resulting in equation 6.

$$\frac{dP_i}{dX_{ji}} = \left(\frac{e^{b'c_i}}{(1+e^{b'c_i})^2} \right) b \quad = \quad F(b'c)[1 - F(b'c)]\beta \tag{6}$$

The method of estimation used is maximum likelihood. Each observation is treated as a single draw from a Bernouli distribution. Assuming independence of the Y_is, L is the joint likelihood function for a sample of n observations (7).

$$L = \prod_{i=1}^{n} P_i^{y_i}(1-P_i)^{1-y_i} = \prod_{i=1}^{n} \; b'c_i)]^{y_i}[1-[F(b'c_i)]^{1-y_i} \tag{7}$$

$$\ln L = \sum_{i=1}^{n} y_i \ln F(b'c_i) + \sum_{i=1}^{n} (1-y_i)\ln[1-F(b'c_i)] \tag{8}$$

$$\frac{d \ln L}{db} = \sum_{i=1}^{n} \left[\frac{y_i f_i}{F_i} + (1-y_i)\frac{-f_i}{1-F_i} \right] X_i \tag{9}$$

Taking the log of L and maximizing with respect to β we obtain the first order condition in (9) where f_i is the pdf and F_i is the cdf of y respectively. The solution of (9) gives $\hat{b}$ the maximum likelihood estimator.

The underlying economic theory on factors that are thought to influence the decision to adopt is based on the understanding that farmers are rational. They form an impression of the potential costs and benefits of a candidate technology usually through their own research either by experimenting with the technology or through analysis of secondary information from early adopters and key informants in the community. In economic theory the farmer is thought to optimize an objective function such as expected utility or net present value of benefits from adopting a given technology. Unfortunately these variables are unobserved by the researcher (latent). The fact that most adoption studies are done ex-ante makes the measurement problem more difficult. Even in the ex-post situation correct measurement of these variables is problematic due to difficulties in estimating the farmer's perceptions of utility or profit, his/her level of risk aversion, and the weights he/she puts on profitability, risk, and subsistence requirements. The adoption decision variable is therefore cast in a framework that predicts the probability of adoption as a function of proxy factors that are likely to predict the expected values of the farmer's objective function. Suppose a latent response variable U can be represented as a linear function of a set of regressors, Z, where $\in$ is unobserved random.

$$U = Z\beta + \in \qquad (10)$$

Variation, and Z is a vector of idiosyncratic, environmental, and technology variables. Let y represent the choice that a farmer makes, where: y = 1 iff $U \geq 0$; y = 0 otherwise. In case of the logit model, we assume that the error terms are distributed logistically, and P(y=1) is derived as in equation 1 above.

Model specification

A logit model of adoption is estimated for two types of management practices: (1) Soil conservation practices (Mulching, Grass bands, Cover crops, Furrows, Contour cultivation, and Water basins), and (2) Pesticides (insecticides and fungicides). Each dependent variable is regressed on 12 explanatory variables as outlined in Table 4 in the appendix. The major factors believed to influence adoption of research recommendations are derived largely from the literature, namely: geographical location, age, gender, education, labour availability, income/wealth, accessibility to markets, and access to information. The model used in the study is specified as $Y_{ij} = f(\beta' X)$ = f(age, sex, education, income, off-farm employment, coffee sales, district, accessibility, farm size, labor demand, cropping system, and information).

Previous studies have not included a cropping system variable in the adoption model. By cropping system" we mean: "intercrop or pure stand". All farmers in the sample grew either *Robusta* or *Arabica* coffee of various varieties and a range of staple food and cash crops. Coffee is grown both as a pure stand and intercropped with a variety of annuals and perennials including bananas, maize, millet, grain legumes, and various root crops. Intercropping is a very common practice, and it is believed to influence adoption of certain agronomic practices such as mulching, weeding, pesticides, and use manure. Due to the purported complementarity between various crops and coffee, intercropping is believed to augment returns to land and labour, and due to its positive effect on food security. It is believed that intercropped fields are more likely to be better managed compared to pure stands when the above conditions hold.

Over 90% of the coffee acreage in Uganda is accounted for by *Robusta* coffee produced in the lowlands, and 10% is *Arabica* coffee which is produced at high elevations in Mbale, and on the slopes of Mt. Rwenzori. One sixth (16.5%) of the sample were *Arabica* coffee farmers while the rest were *Robusta* coffee farmers. The sample consisted of 18% *Arabica* farmers and 72% *Robusta* farmers.

Data

The model utilizes data from a farm household survey conducted between 1994 and 1995 using a formal questionnaire. The dependent variables, i.e. decision to adopt either a soil conservation method or pesticide use are measured as a dichotomous choice (yes or no). A farmer is considered to have adopted soil conservation or pesticide use if he/she has used the practice as a routine task for at least two years. Details on how each dependent and explanatory variable is measured and coded are presented in table 4 in the appendix.

Results and Discussion

The following discussion is focused on identifying and comparing factors that can be used to explain differences in adoption of soil conservation practices and use of pesticides in coffee production. Results for low income farmers are compared with those for high income farmers.

The parameter estimates for the logit model are presented in Table 1a. Although the parameters themselves are not an indication of the marginal effects of the various factors on the probability of adoption by the two groups of farmers, some salient differences may be pointed out. *Robusta* coffee has a significant effect on adoption of soil conservation practices by both low and high income farmers. Education, farm size, and number of contacts with extension staff are statistically significant (at alpha=10%) for poor farmers, but not for richer farmers. On the other hand, cropping system and off-farm employment are better predictors for high income farmers.

Pesticide use, especially fungicides and insecticides is known to be more prevalent in *Arabica* coffee production because *Arabica* is more prone to pest and disease pressure. It is therefore not surprising that both dummies for *Arabica* coffee and the main *Arabica* producing district, Mbale, are significant at 5% level in the model. As in the case of soil conservation, education and farm size are significant predictors of adoption for low income but not for high income farmers. There is also an apparent trend suggesting that the number of extension visits is a common predictor for adoption of both soil conservation and pesticide practices.

Overall the model predicts that high income farmers are as much as twice likely to adopt soil conserving measures than poor farmers (table 2). The predicted probability of pesticide use is close to zero as would be expected because most Ugandan coffee farmers do not use pesticides (Ngambeki et. al., 1992).

The preceding discussion tells us little about whether these factors affect the probability of adoption positively or negatively. Such knowledge would shed more light on the differences between the two groups of farmers and the possible implications for policies that ultimately affect farm size, farmer education, and provision of extension services. In terms of marginal effects, the results presented in table 3 suggest that number of extension visits has a positive and highest marginal effect on adoption of both soil conservation and pesticide use for poor farmers, and it has no effect on conservation by richer farmers. Also market access, and farm size have positive effects on the probability of adoption for the poor, but no significant effect for richer farmers. On pesticide use, the results indicate very low (approximately zero) marginal effects of both explanatory variables, confirming the same trend as in the parameter estimates in table 1. Overall, it can be observed that the model predicted higher and more significant marginal effects for poor farmers compared to richer ones.

Conclusion

The analysis of adoption of soil conservation practices and use of pesticides among low income compared to high income farmers revealed that analyzing adoption by income group can reveal several differences that would otherwise be masked in a more aggregated study. The results of this study suggest that some longstanding beliefs about poor access to extension services, education, and land by poor farmers, might explain some of the differences in adoption rates between the poor and the rich. A major finding of this study is that these three characteristics have the largest potential impact on the probability of adoption of soil conservation measures and use of pesticides by poor farmers.

The model predicts that high income farmers are about twice as likely to adopt soil conserving measures than poor farmers. The predicted probability of pesticide use is very low for both groups of farmers. This finding is in line with the low incidence of pesticide use observed in previous studies.

Table 1a: Parameter estimates for Adoption Model of Soil Conservation Practices

	Low (Income<100,000 Ushs)			High (Income>100,000 Ushs)		
Variable	Parameter	S.E.	Pr > Chi-Sq	Parameter	S.E.	Pr > Chi-Sq
INTERCPT	-3.1597	2.7492	0.2504	-0.7128	1.1089	0.5204
Robusta	-4.0000	2.1053	0.0574	-2.1426	0.9146	0.0192
D1 (Mubende)	1.0362	1.1532	0.3689	2.2686	0.8259	0.006
D5 (Masaka)	5.3025	1.5164	0.0005	1.0914	0.7373	0.1388
D6 (Mbale)	1.6324	1.9228	0.3959	1.2376	1.0714	0.248
Income				-3.37E-07	5.90E-07	0.5675
Coffee Sales	0.000032	0.000059	0.5812			
Market accessibility	0.2205	0.4267	0.6054			
Education	0.2354	0.1216	0.0529	0.0941	0.0811	0.2463
Farm Size	0.0544	0.0303	0.0723			
Labour (Mandays)	-0.2133	0.1994	0.2848	-0.1453	0.0785	0.0641
Intercropping				1.7847	0.7675	0.0201
Off-Farm Employment	-2.338	1.7838	0.19	-0.9552	1.4826	0.5194
Extension visits (No.)	1.3561	0.6884	0.0488			

Table 1b: Parameter estimates for Adoption Model of Pesticide use

	Low (Income<100,000 Ushs)			High (Income>100,000 Ushs)		
Variable	Parameter	S.E.	Pr > Chi-Sq	Parameter	S.E.	Pr > Chi-Sq
INTERCPT	-10.832	3.8611	0.005	-1.2146	1.2153	0.3176
D4 (Mukono)				0.6117	0.9877	0.5357
D6 (Mbale)				1.6461	0.6977	0.0183
Arabica	5.7966	2.1173	0.0062			
Coffee Sales	0.000073	0.000094	0.4408			
Education	0.3323	0.1737	0.0557			
Intercropping	0.91	1.406	0.5175			
Farm Size	0.0756	0.0418	0.071	0.0307	0.03	0.3056
Labour (Mandays)	-0.1387	0.291	0.6335	0.0905	0.0692	0.1906
Extension visits (No.)	1.4193	0.9808	0.1479	-1.6475	0.8722	0.0589

Table 2: Estimated probabilities of adopting soil conservation and pesticide use (at mean characteristics)

	Low Income	High Income
Soil Conservation (mulching, trenches)	-0.2531012	0.4707531
Pesticide application	-0.0024874	-0.0349884

Table 3: Marginal effects of explanatory variables at mean characteristics

	Low Income	High Income
	Soil Conservation measures	
Income	-	0.00000
Coffee Sales	0.00001	-
Market accessibility	0.0450	-
Education	0.0481	0.0205
Farm Size	0.0111	-
Labour (Mandays)	-0.0436	-0.0316
Extension visits (No.)	0.2770	-
	Pesticide application	
Coffee Sales	0.00000	-
Education	0.0029	-
Farm Size	0.0006	0.0017
Labour (Mandays)	-0.0012	0.0050
Extension visits (No.)	0.0122	-0.0908

APPENDIX

Table 4: Description of variables in the model

Variable Name	Type[0]	Comment
Soil Conservation Practices (Mulching, Grass bands, Cover crops, Furrows, Contour cultivation, and Water basins)	B	1= if farmer uses any one or combination; 0=none
Pesticide use (Insecticide, Fungicide, or Herbicide Application)	B	1 = Yes, 0 = No
Income (Total household)	C	
Coffee sales per year	C	
Location (district dummy)	D	1=Mubende, 2=Luweero, 3=Mbarara, 4=Mukono, 5=Masaka, 6=Mbale
Age of household head	C	
Accessibility to Markets (Distance in kilometers to nearest market)	D	1 = <5 km, 2 = 5-10 km, 3 = 10-15 km, 4 = 15-20km, 5= >20 km
Coffee Type (Dummy)	B	*Robusta* or *Arabica*
Credit Access	B	1 = Yes, 0 = No

0 B = Binary, D = Discrete (more than two levels), C = Continuos

Table 4: Description of variables in the model (continued)

Variable Name	Type[0]	Comment
Education of HH Head (Years)	C	None
Farm Size (Acres)	C	1 = Yes, 0 = No
Information (Number visits with extension staff in a year)	D	1 = Fellow farmers
		2 = Demonstration, DFI, etc.
		3 = Extension staff
		4 = Radio/TV
		5 = Farmer training course
		6 = Publications
		7 = Formal Training
Labor availability (man days)	C	Total number of man days of family and hired regular labor per season
		Adult (over 18 yrs) = 1.0, Child = 0.5).
Cropping System	B	1 = Mixed Cropping , 0 = Pure Stand
Off-Farm Income	B	1 = Yes, 0 = No
Sex of HH Head	B	1 = Male, 2 = Female

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