APPLICATION OF MULTIVARIATE PROBIT ANALYSIS TO AN ADOPTION MODEL OF NEW AGRICULTURAL PRACTICES[1]

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1. INTRODUCTION

Society cannot benefit from agricultural research if research results are not adopted by farmers. It is therefore important that the process of adoption and diffusion of new technologies in agriculture is clearly understood.

Traditionally, the adoption-duffusion of new technologies has primarily been the subhject of rural sociologists, including Rogers (23), Jones (19) and Dobyns (12). Basically, their studies focussed on the impact of "interaction", or communication between people, and socio-cultural resistance to innovation, and on the temporal and spatial patterns of diffusion. Their aim was to provide some insight on how these characteristics determine the communication techniques which are most effective in accelerating the adoption-diffusion process.

In contrast, the focus of economists has been on how economic variables, such as the profitability of new technologies and the asset position of farmers influence the rates of adoption and diffusion. Griliches' study on hybrid corn (15) and his subsequent exchanges with sociolgists, Rogers (22), Braden and Straus (4), and Havens (18), brings out the contrast between the approaches of economists, and sociologists as well as the role of economic and socio-cultural factors in the adoption process.

According to Branden and Straus "congruence", or familiarity, with a technique or input is the critical factor in explaning the rate of adoption; and according to Havens and Rogers "interaction", or communication, between people is the important factor. In reply to these propositions, Griliches (14,16) argued that even if congruence and interaction are important, there is no basis for excluding profitability as a factor for explaining the rate of adoption. In fact, he pointed out that the profitability approach can be broadened by allowing for differences in information, risk preference, etc., bringing it closer to the sociological approach.

Research results have shown that both economic and sociological factors are important determinants of adoption rates under different conditions. An anthropologist's - D.Smock's - study in Nigeria (25) indicates that when the expected returns from new agricultural practices is large, profitability is the major determinant of adoption; otherwise non-economic factors appear to be more important. Ajaegbu (1) pointed out that education, ethnic group, migrat-

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ion and status seem to influence adoption of new practices in Southwest Nigeria. Similarly, "higher" caste farmers in India, who tend to be more educated and participate more in community affairs, were found to be faster adopters than the "lower" caste, less educated and less participatory farmers (2).

Although several researchers have reported on positive farmer response to price incentives in many late developing countries (5,13,20,), Krishna (20) found that non-price factors such as availability of irrigation water for cotton bajra, the level of yields for rice, and the amount of rainfall for non irrigated crops were more important than price in determining acreage planted and supply response of Punjab farmers in India. In general, however, cost of the new farm practices are important in determining farmer response. Furthermore, the price elasticities of different groups of commodities and the degree of market orientation of farmers are important considerations. For example, price elasticities of supply are generally higher for cash crops than for subsistence crops.

Without making judgement as to whether economic or noneconomic factors are more important in influencing farmers' rate of adoption of new technologies, this paper uses multivariate probit analysis to examine the relationship between adoption of sociological and economic variables. It focusses specifically on newly introduced wheat variaties and chemical fertilizer within the Gonde extension area of the Chilalo Agricultural Development Unit (CADU) in Ethiopia.[2]

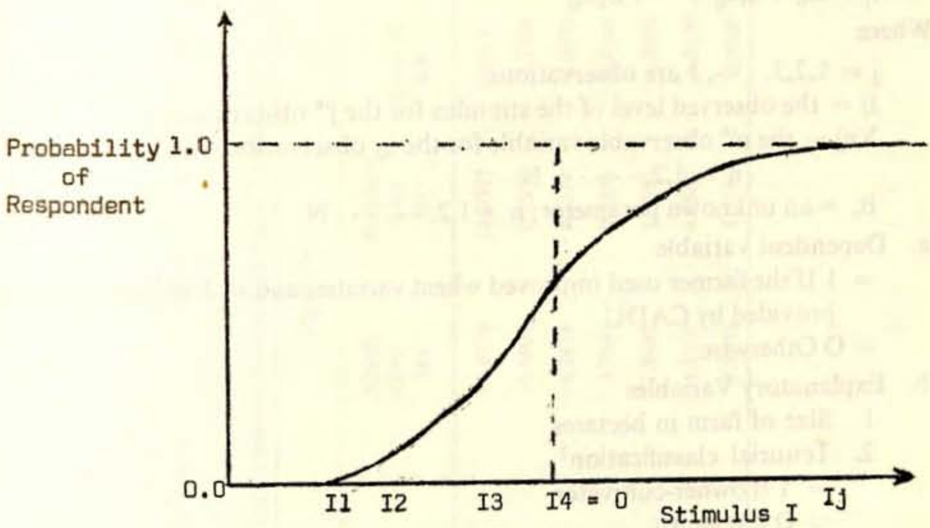
2. METHODOLOGICAL CONSIDERATIONS[3]

In a standard linear regression model, the dependent variable represents some measurable factor, but the explanatory variables may include quantitative as well as qualitative factors. The qualitative factors are usually incorporated into a regression model through the use of "dummy" variables. But in relationships where the dependent variable is dichotomous, certain specifications of the classical regression model are violated, and ordinary least squares estimates of some standard statistics, such as t-ratios, are incorrect.

Although classical linear regression models and linear probability functions are frequently used to approximate relationships with dichotomous dependent variables, the techniques have several serious limitations. The disturbances exhibit heteroscedasticity, and are dependent on the unknown expected values of the dependent variable.[4] Furthermore, the predicted values of the dependent variable may sometime be greater than 1 or less than 0 even though probability values never exceed 1 or fail below 0. Probit analysis is a procedure that takes account of hetroscedasticity of the disturbances and restricts prediction to values between 0 and 1. In the probit model, the probability of observing a response, in this case whether a farmer used improved inputs or not, is defined in terms of the level of an unobserved index, and the standard cummulative normal distribution is used to transform the index into probability values.

The relationship between the index and the probability, as shown in Figure 1, follows a sigmoid curve. Index I may take on any value between - ∞ , and + ∞ , but the transformation ensures that all corresponding probability values lie between zero and unity. The stimulus I, which cannot be observed, is defined as a linear combination of observable variables.

Figure 1: Relationship Between the Probability of Response and the Level of Stimulus.



3. ANALYTICAL MODEL

The following analysis is based on data that were collected from 92 farmers from the Gonde Extension area of CADU. These include 53 participants and 39 non-participants of the diffusion of innovations in CADU. The analysis is based on the hypothesis that the variables of farm size, land ownership, credit availability, membership in local organizations, extension contact and literacy were significant variables in an explanatory model of farmers' decision to adopt improved agricultural practices recommended by CADU. Some explanatory variables, such as crop prices migration and labour supply, which, on *a priori* theoretical considerations, would be thought of as being relevant could not be included due to lack of satisfactory information.[5] The multivariate probit model is formulated as follows to estimate the parameters involved in these relationships using maximum likelihood estimation.[6]

$$I_j = B_o + B_1 x_{1j} + \text{- -} + B_n x_{nj}$$

Where

$j = 1,2,3, \text{- - -}, J$ are observations

Ij = the observed level of the stimulus for the j^{th} observation,

Xnj = the n^{th} observable variable for the j_{th} observation,

$n = 1,2, \text{- - - - -}, N$

B_n = an unknown parameter; $n = 1,2, \text{- - - - - -} N$

a. Dependent variable

= 1 If the farmer used improved wheat variaties and/or fertilizer provided provided by CADU

= O Otherwise

b. Explanatory Variables

1. Size of farm in hectares
2. Tenurial classification[7]
   = 1 If owner-cultivator
   = O If tenant
3. Cash Availability for Downpayment
   = 1 If yes
   = O Otherwise
4. Membership in Local Organizations
   = 1 If yes
   = O Otherwise
5. Extension contact[8]
   = O If farmer lives within 5 kms. of the extension center (very close)
   = 1 If farmer lives 5-10 kms. away from the extension center (close)
   = 2 If farmer lives more than 10 kms. away from the extension center (far.)
6. Literacy[9]
   = 1 If farmer can read and write
   = O Otherwise

Table 1: Probit Estimates for the Determinant of Adoption of Fertilizer and Higher Yielding Wheat Varieties by Farmers in Gonde Extension Area of CADU, 1970

Dependent Variable: Whether farmer used fertilizer and/or improved wheat seed Yes = 53; No = 39

Explanatory variables	Equation I Coeffi-cient (a)	Equation I Standard error (b)	Equation I Ratio of a/b	Equation II Coeffi-cient (c)	Equation II Standard error (d)	Equation II Ratio of c/d
Constant	10.8719	12.2002	0.8911			
1. Farm Size	0.5601	0.2032	2.7564	0.5653	0.1981	2.8536
2. Tenurial classfication	-4.2878	4.1314	-1.0378	-0.4990	0.4470	-1.1163
3. Cash availability for downpayment	0.7864	0.9654	0.8146	1.4805	0.8769	1.6883
4. Membership in local associations	1.8698	1.5033	1.2438	1.0726	1.0050	1.0673
5. Extension contact	-4.9569	4.0869	-1.2129	-2.1516	-0.7454	-2.8865
6. Literacy	3.9855	4.1516	0.9600	2.3411	1.3117	1.7848

4. EMPIRICAL RESULTS

Results of the estimated probit model are summarized in Table 1. The difference between Equation I and Equation II is that in Equation II the constant term, whose coefficient was not significantly different from zero at the 0.10 level in Equation I, is excluded; thus forcing the response curve (Fig. 1) to pass through the origin. The equation performed well using the likelihood ration test.[10]

The ratio of the coefficient to its standard error has a standard normal distribution for large sample size $(n > 30)$. Since the signs of the coefficients were hypothesized, a one-tailed test of significance is followed in the analysis. The signs of the coefficients are consistent with hypothesized relationships, and are significantly different from zero at levels ranging from 0.15 to 0.025.

The negative coefficient associated with tenurial classification and extension contact (or distance from extension center) indicate that the probability of a farmer using CADU provided farm input will decrease as the distance between the extension center and the farm increases (or as the number of extension contacts decreases), and if the farmer is a tenant and not an owner-cultivator. The position coefficients associated with the other explanatory variables indicate that the probability of adoption increases with farm size, availability of cash for downpayment, membership in local associations and literacy. But the relationship between the rate of adoption and membership in local associations and the literacy level was found to be not as strong as was originally hypothesized, indicating that literacy and participation in local associations are not as strong as farm size and extension services in influencing the rate of adoption of innovations in the Gonde Extension Area of CADU.

Since the level of awareness of the input provided by CADU, and their income raising potential is very high among all categories of farmers in the study area[11], one wonders why the rate of adoption is relatively lower for the smaller and/or tenant farmers. There are several possible explanations. First, assuming that farm size is an appropriate proxy for income, it is very likely that the smaller farmers face more problems in securing cash to make the downpayments that CADU requires before the improved inputs are given to each farmer. Second, CADU requires that tenants have signed lease agreement with their landlords in order to be eligible for credit. But landlords might refuse to sign the lease clause prepared by CADU since it is primarily designed to protect the tenants against their landlords by ensuring that they pay a "fair" rent. Third, there might be lack of incentive on the part of tenants to adopt the new practices due to the prevailing share-cropping arrangements in the area. This point begs further clarafication.

Table 2: A comparison of the share of Benefits Between Landlords and Tenants under Alternative assumptions about yields and product sharing (per hectare)**

Wheat yield Increases (%)	Tenant paying one-third of His Gross output and Bearing all Costs		Tenant paying one-half of His Gross Output and Bearing all Costs	
	Net Return to tenant (Eth. $)	Net Return to Landlord (Eth. $)	Net Return to Tenant (Eth. $)	Net Return to Landlord (Eth. $)
20	-50.00	13.33	-70.00	20.00
40	-36.67	26.67	-50.00	40.00
60	-10.00	40.00	-30.00	80.00
80	16.67	53.33	-10.00	80.00
100	43.33	66.67	10.00	100.00

** For this analysis the average yield for unfertilized local wheat is assumed to be 10 quintals per hectare (7,8) and the average farm gate price is assumed to be Eth. $20.00 per quintal, which is the avergae price CADU paid to farmers participating in its marketing activities in 1970.

Within the CADU project area, as in most parts of Ethiopia, rental payments by tenants to landlords range from one-third to one half of their gross output, while bearing all variable costs of production. Table 2 shows why tenants might be reluctant to adopt the new technologies because there is some risk associated with taking the inputs provided by CADU on credit, if in fact risk aversion is an important consideration by tenant farmers.

The incremental production costs which include the costs of fertilizer, improved seeds, extra labour input, and other associated costs, were estimated by CADU's Agricultural Engineering Section (7). It is assumed that the farmers follow CADU recommended rates of seed and fertilizer application.

Under the assumption that the tenant receives the most favourable sharecropping arrangement available in the CADU project area by paying only one-third of his gross produce as rent, about 80% increase in yield is necessary to make the venture profitable to the tenant. If on the other hand, he pays one-half of his produce as rent and gets no compensation for part of his costs, about 100% increase in yields is necessary.[12]

In order to demonstrate the effect of the explanatory variables on farmer's adoption of new methods, the predicted changes of the stimulus level I (i.e. the rate of adoption) have been computed for selected hypothetical changes of the explanatory variables. The results are presented in Table 3. For example the probability that either a tenant or an ownercultivator used inputs provided by CADU was practically nil in 1969 if he cultivated only 3 hectares of land, had no cash to pay downpayments for credit, was not a member of any local organization, had very little extension contact, and was illiterate. On the other extreme, the probability that either a tenant or an owner-cultivator used inputs provided by CADU in 1969 was about 99% if he cultivated at least 10 hectares of land, had cash for downpayments, had frequent extension contacts, and was literate.

The change in probability corresponding to a specified change in the stimulus level is not always the same (as is the case with the standard linear regression) because the transformation from the stimulus I to probability is non-linear. The effect of a change in I depends on which part of the sigmoid curve (Figure 1) is relevant. The effect becomes larger as I gets closer to zero.

5. CONCLUSIONS

Because the statistical properties of the multivariate probit regression technique permits quantification of the relationship between a dichotomous dependent variable and quantitative as well as qualitative explanatory variables, it was possible to show that the rate of adoption of new technologies in agriculture is closely related to both sociological and economic factors.

The conclusions of the empirical analysis are somewhat limited in that it was not possible to consider the effects of some explanatory variables, such as migration and marketing policies, on the adoption rate that, on *a priori* considerations, were thought to be important. Nevertheless, the analysis has shown that the profitability of an innovation is a necessary, but not a sufficient, condition for its adoption by peasant farmers.

In fact the analysis suggests that government policies and programs should encourage the establishment of self-help group organizations, provide intensive extension services, promote functional literacy for adults in rural areas, abolish the prevailing land tenure system and create rural credit and input distribution institutions in order to influence the speed and direction of adoption of new agricultural practices favourably.

Table 3: Estimated Probabilities of Adopting CADU Provided Fertilizer and Higher Yielding Wheat Varieties by Hypothetical Combination of Farmer Characteristics, Gonde Extension Area, CADU, 1970.

	Tenant				Owner-Cultivator			
Tabie 3	Cultivating 3 ha.		Cultivating 10 ha		Cultivating 3 ha.		Cultivating 10 ha.	
Hypothetical Combination of Farmer Characteristics*	Cumulative probability index	Estimated Probabilities	Cumulative probability Index	Estimated Probabilities	Cumulative probability Index	Estimated probabilities	Cumulative probability Index	Estimated probabilities
I	-5.76	0.00	-1.83	0.04	-5.26	0.00	- 1.30	0.10
II	0.88	0.81	4.82	0.99	1.38	0.91	5.32	0.99
III	3.43	0.98	7.37	0.99	3.93	0.99	7.87	0.99
IV	-2.54	0.01	-1.40	0.09	-2.04	0.02	1.90	0,96
V	0.02	0.51	3.96	0.99	0.52	0.70	4.46	0.99

* Hypothetical Combination of Farmer characteristics:

I = Farmer has no cash to make downpayments; he is not member of local associations; he lives 10-15 Kms. away from the extension center; and he is illiterate.

II = The same as case I but he lives within 5 Kms. of extension center and is literate

III = Farmer has cash available to make downpayments; he is a member of at least one local association; lives within 5 Kms. of extension center; and is literate

IV = Farmer has no cash to make downpayments; he is a member of a local association; he lives 5-10 Kms away from extension center; and he is illiterate

V = Farmer has cash available to make downpayments; he is not a member of local associations; lives within 5 kms. of extension center; he is illiterate.

FOOTNOTES

1. The information used for this study, which was gathered by John Toborn in 1970, was made available to this writer by the Planning and Evaluation Unit of CADU while conducting field research for his Ph.D. dissertation in 1972/73.
2. CADU which was initiated in 1967, is the first integrated regionally oriented rural development project in Ethiopia consisting of a package of integrated projects which cut across different socio-economic sectors but are concentrated in one particular region, CADU's aim is to overcome economic stagnation and to ease social problems in the Chilalo region by increasing productivity, employment and income.
3. For a detailed disucssion of probit theory, the multivariate probit regression methods, and the statistical properties of probit regression coefficients, see D.J. Finney, *Probit Analysis,* 2nd edition, Cambridge University Press, 1952, and J. Tobin, „The Estimation of Relationships with Limited Dependent Variables," *Econometrics* 26:24-36, 1958.
4. A.S. Goldberger, *Econometric Theory*, Wiley, 1964, pp. 248-251.
5. Observations on all variables included in the analysis were made in 1970 in the Gonde extension area (CADU) and pertain to the year 1969.
6. The probit regression analysis was performed using a computer programme written by Roger Selly, Department of Agricultural Economics, Cornell University.
7. There was no information on farmers who own part and rent part of the land they cultivate.
8. No information was available on the number of times a farmer visited or was visited by an extension agent. However, a close scrutiny of the data and the organizational set-up of CADU's extension progeram indicate a close relationship between the distance of a cultivator's farm from the extension center and the impact of the extension service.
9. Perhaps a broader categorization of literacy would have been more relevant to incorporate non-formal educational possibilities, but the information available is only in these two categories.
10. A.M. Mood and F.A. Graybill. *Introduction to the Theory of* Statistics, 2nd edition, Mc Graw-Hill, 1963, pp. 297-301.
11. Over 97 % of the sample farmers were aware of the inputs provided by CADU on credit and believed that yields are higher when these inputs are used (29).
12. Most tenants pay an extra one-tenth as land tax, if included in this analysis, this would have worsened the tenant's position.

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