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A TOBIT ANALYSIS OF THE ADOPTION AND USE RATES OF FERTILIZER ON WHEAT IN THE EASTERN TARAI OF NEPAL

Promotion of modern wheat varieties and fertilizer have stimulated wheat production in Nepal. More than 80 per cent of the wheat area is now planted to modern varieties (MV). Wheat production increased by 40 per cent or nearly 3.5 per cent annually between 1970 and 1980.[1] The Sixth Development Plan (1980-1985) aims to increase wheat production by a further 25 per cent, or about 4.5 per cent annually.[2] While increased wheat output may result from area expansion, the greatest increase is anticipated from greater inorganic fertilizer use, and where feasible, expansion in the irrigated area.[3]

National avernge wheat yields are about 1.3 t/ha., higher in the Tarai and the Hills (1.3 t/ha.) than in the Mountains (1.0 t/ha). Wheat hectareage fertilized and associated application rates are not known. Per hectare consumption of inorganic fertilizer on all crops in 1979-80 was about 13 and 16 kg./ha. in the Hills and Tarai respectively.[4] This is less than 10 kg. nutrients per hectare, low by Asian standards.

This paper reports an analysis of factors influencing adoption of inorganic fertilizers on MV wheat. The study area was Sunsari and Morang districts of Kosi Zone situated in the Eastern Tarai of Nepal where MV wheat adoption has been widespread. The area is also a target for land reform, infrastructural development and extention of modern farming methods.

METHODOLOGY

In reviewing many statistical methods used to analyse adoption behavior, Feder *et al.*[5] criticise the frequent use of bivariate analysis as not providing insights into the relationships between adoption and adoption determinants. Ordinary and generalised least squares regression are also limited when the dependent variable is not normally distributed—as is usually the case in adoption behaviour.[6] Feder *et al.* thus recommended the use of

1. Asian Development Bank and His Majesty's Government of Nepal: Nepal Agriculture Sector Strategy Survey, 2 Vols., Manila, December 1982.
2. His Majesty's Government of Nepal: The Sixth Plan 1980-85: Part I (Summary), National Planning Commission, Kathmandu, January 1981 (English translation).
3. Asian Development Bank and His Majesty's Government of Nepal: *op.cit.*
4. *ibid.*
5. G. Feder, R. Just, and D. Zilberman: Adoption of Agricultural Innovations in Developing Countries: A Survey, World Bank Staff Working Paper No. 542, Washington, D.C., U.S.A., 1982.
6. *ibid*, pp. 40-46.

probit and logit models as a more defensible approach. An extensive review of these limited dependent variable models is found in Amemiya.[7]

The probability of modern variety[8] and fertilizer[9] adoption have been analysed using probit and logit models. However, it is also relevant to predict the use rates by the adopters, when the dependent variable is continuous, as are fertilizer application rates. Under these circumstances the tobit model or 'hybrid probit' described by Tobin[10] is superior. The tobit model provides (*a*) an estimate of the probability that a specific farmer will be an adopter, and (*b*) for adopters, the level of fertilizer use.[11]

Based on multivariate tobit analysis procedures, the equations for estimating factors influencing adoption and fertilizer rates are:

$$I = b_0 + b_1X_1 + b_2X_2 + \dots + b_nX_n = f(X_i) \qquad \dots(1)$$

$$\text{and } y = g\,(I) \qquad \dots(2)$$

$$\text{where } y = 0 \qquad \text{if } I < I^* \qquad \dots(3a)$$

$$y = I - I^* \qquad \text{if } I \geqslant I^*. \qquad \dots(3b)$$

I is an index reflecting the combined effect of the X factors which hinder ($b_i < 0$) or promote ($b_i > 0$) fertilizer use. I^* is the critical value of an index and is distributed as an N $(0, \sigma^2)$ variable while y is the amount of fertilizer used.[12] If I is less than the critical value I^*, the farmer is a non-adopter so $y = 0$ (equation 3*a*). If I exceeds the threshold I^* the farmer is an adopter and y is positive. The value of y is related to the difference between the index level I and the critical value, I^* (equation 3*b*).

The probability that a farmer is an adopter is calculated as:

$$\text{Prob.}\,(y > 0|I) = \text{Prob.}\,(I \geqslant I^*|I) = F(I/\sigma) \qquad \dots(4)$$

where F (z) is the value of the standard normal cumulative distribution at (I/σ). The associated expected value of y for adopters is:

$$E(y|I) = I[F(I/\sigma) + \sigma\,(f(I/\sigma)] \qquad \dots(5)$$

where f (z) is the value of the standard normal density distribution at (I/σ).[13]

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7. T. Amemiya, "Quantitative Response Models: A Survey", *Journal of Economic Literature*, Vol. XIX, No. 4, 1981, pp. 1483-1536.
8. See, for example, John Gerhart: The Diffusion of Hybrid Maize in West Kenya, Abridged by International Maize and Wheat Improvement Center (CIMMYT), Mexico City, 1975 and P. B. Malla: Logit Analysis of Technology Adoption by Rice Farmers in Dhanusha District, Nepal, A/D/C-APROSC Research Paper Series No. 22, Kathmandu, 1983.
9. See, for example, A. O. Falusi, "Multivariate Probit Analysis of Selected Factors Influencing Fertilizer Adoption among Farmers in Western Nigeria", *Nigerian Journal of Economic and Social Studies*, Vol. XVI, No. 1, 1974, pp. 3-16, and Malla, *op.cit.*
10. James Tobin, "Estimation of Relationship for Limited Dependent Variables", *Econometrica*, Vol. 26, No. 1, 1958, pp. 24-36.
11. Arthur S. Goldberger: Econometric Theory, John Willey and Sons, Inc., New York, 1964.
12. *ibid*, pp. 252-253.
13. *ibid*, p. 253.

Estimates of the partial regression coefficients of equation (1) and sigma (σ) are derived via maximum likelihood techniques. The b_is are asymptotically efficient, unbiased and normally distributed. Thus, an analog of the t-test may be applied as a test for significance. The significance of all or a sub-set of coefficients included in the analysis is tested using a log likelihood ratio test statistic which follows a Chi-square distribution.[14] The algorithm used to solve the tobit model reported was programmed by Avery.[15]

DATA SET

In 1980 crop production in the Eastern Tarai was dominated by rice and wheat which accounted for 64 and 16 per cent respectively of the total cropped area.[16] The dominant cropping pattern is rice in the monsoon season and wheat in winter. Few crops compete with rice. However, in winter, oilseeds, maze and jute compete with wheat.

This study uses part of a data set primarily collected to examine the adoption and productivity of MV rice.[17] Of the 177 farms surveyed, 128 grew wheat, all of the modern variety, RR 21. About two-thirds of the owners and one-third of the tenants interviewed applied inorganic fertilizer to their wheat. The quantity of fertilizer used was typically 2-3 and 1-2 bags/ha. for the owner and tenant adopters respectively. The dominant fertilizer was 20-20-0, thus the rate of nutrient application of the owners and tenants who applied fertilizer was in the range of 40-60 and 20-40 kg./ha. respectively. Owners reported wheat yields of the order of 1.6 t/ha. and tenants, 1.3 t/ha.

Mean values of continuous variables included in the fertilizer adoption study, and hypothesized signs, given equation (1), are listed in the upper panel of Table I. Discrete (dummy) variables included in the model are listed in the lower panel of the table. These variables were included in the study because (*a*) they are frequently found to be significant determinants of adoption,[18] and (*b*) from an operational view point they were the variables collected. Other variables such as the farmer's perception of the riskiness of fertilizer use[19] and those more sociological in nature[20] may influence

14. Robert S. Pindyck and Daniel L. Rubinfeld: Econometric Models and Economic Forecasts, McGraw-Hill Book Company, New York, 1981.
15. Robert B. Avery: CRAWTRAN: Quantitative Dependent Variable Program User's Manual, Carnegie-Mellon University, New Haven, Connecticut, March 1980.
16. Asian Development Bank and His Majesty's Government of Nepal: *op.cit.*
17. The survey and the study area are described by J.C. Flinn, B. B. Karki, T. Rawal, P.Masicat and K. Kalirajan: Rice Production in the Tarai of Kosi Zone, Nepal, IRRI Research Paper Series No. 54, International Rice Research Institute, Manila, Philippines, 1981; B. B. Karki: The Impact of Modern Rice Varieties on Farm Income and Income Distribution in Eastern Nepal, A/D/C-APROSC Research Paper Series No. 12, Kathmandu, 1981 and Tilak Rawal: An Analysis of Factors Affecting the Adoption of Modern Varieties in Eastern Nepal, A/D/C-APROSC Research Paper Series No. 11, Kathmandu, 1981.
18. Feder *et al.*: *op.cit.*
19. Ramesh P. Sharma: Uncertainty and Subjective Beliefs in the Adoption of Modern Farming Techniques: A Case Study of Nepalese Farmers, A/D/C-APROSC Research Paper Series No. 5, Kathmandu, 1980.
20. J. A. Ashby, "Technology and Ecology: Implications for Innovative Research in Peasant Agriculture," *Rural Sociology*, Vol. 47, No. 2, 1982, pp. 234-250.

TABLE I—SAMPLE CHARACTERISTICS OF VARIABLES INCLUDED IN TOBIT MODEL OF FERTILIZER ADOPTION AND USE RATES ON WHEAT, EASTERN TARAI OF NEPAL, 1979

Variable			Mean value	Expected sign
Panel A: Interval scale variables				
Farm size (ha.)			3·83	>0
Wheat area (ha.)			1·14	>0
Family labour (persons)			2·67	>0
Education (years)			5·47	>0
Extension visits/year			9·63	>0
Fertilizer transport cost (Rs/bag)			1·51	<0
Irrigation (per cent)			69·33	>0
Panel B: Dummy variables				
Tenure status	Owners	= 1	98	>0
	Tenants	= 0	30	
Credit users	Users	= 1	62	>0
	Others	= 0	66	
Fertilizer adopter	Adopter	= 1	77	—
	Others	= 0	51	
Sample size (n)			128	

fertilizer use. However, as data were not collected on these factors they were not included in the analysis.

RESULTS AND DISCUSSION

The estimated partial regression coefficients for the tobit model of fertilizer use on MV wheat are listed in Table II. The model, significant at the one per cent level based on the log likelihood test, correctly predicted nearly 84 per cent of the adopters and non-adopters. As postulated, variables other than fertilizer transportation cost were positively associated with fertilizer use.

The farmer's wheat area, fertilizer transport cost and the percentage of wheat area irrigated were associated at the 5 per cent level or better with fertilizer adoption, while tenure status was significant at the 10 per cent level. However, access to credit, the farmer's formal education, intensity of extension contact, and size of the farm-family labour force were not. Coefficients in Table II are difficult to interpret directly because they have different units of measurement and because they are indices. Thus, the probability of adoption and associated fertilizer use rates for a range of farm situations are reported in Table III.[21]

The probability that a farmer will adopt fertilizer, and the quantity he will apply per hectare is influenced by the farmer's resource base (tenure and farm size) and via transportation cost, to the location of the farm with respect to the fertilizer supply point (Table III). Indeed, fertilizer adoption is more sensitive to fertilizer transport cost than to tenure, *per se*. This cost

21. The basis for estimating these figures is illustrated in the Appendix.

TABLE II—TOBIT REGRESSION COEFFICIENTS OF DETERMINANT OF ADOPTION AND EXPECTED QUANTITY OF FERTILIZER USED ON MV WHEAT, SOUTHERN KOSI ZONE OF NEPAL, 1979

	Variable	Coefficient	Standard error	Asymptotic t-value	Significance level[a] (per cent)
b_0	Constant	—252·4258	71·4849	—3·5311	5
b_1	Wheat area	164·5180	12·1636	13·5254	5
b_2	Wheat irrigated	1·0182	0·5315	1·9156	5
b_3	Family labour	8·8598	9·9036	0·8946	NS
b_4	Education	6·4254	4·3133	1·4897	NS
b_5	Extension	1·5961	1·2546	1·2722	NS
b_6	Fertilizer transport cost	—68·5532	19·7054	—3·4789	5
b_7	Tenure	88·9671	65·1391	1·3658	10
b_8	Credit users	30·7398	34·6408	0·8874	NS
σ	Sigma	145·6028	6·1491	23·6786	5
— 2 times log likelihood ratio[b]			195·60**		
X^2 distribution for degrees of freedom			8		
Cases predicted correctly			83·6 (per cent)		

a. Significance levels based on one-tailed t-tests, given hypothesized signs of partial regression coefficients, see Table I.

b Significant at one per cent level.

NS = Not significant.

TABLE III—PREDICTED PROBABILITY OF ADOPTION AND EXPECTED AMOUNT OF FERTILIZER USED BY MV WHEAT GROWERS EASTERN, TARAI OF NEPAL, 1979

Tenure:	Owners				Tenants			
Wheat area[a]:	Large		Small		Large		Small	
	Prob.[b]	kg./ha.	Prob.[b]	kg./ha.	Prob.[b]	kg./ha.	Prob.[b]	kg./ha.
Irrigated								
LTC[c]	90	131	68	131	76	82	44	64
HTC[d]	64	59	32	40	40	28	14	14
Rainfed								
LTC[c]	73	75	41	57	50	39	20	21
HTC[d]	37	25	12	11	17	9	4	3

a. 'Large' and 'small' wheat hectareage was arbitrarily set at 1.50 and 0.75 ha. respectively. Over 80 per cent of the wheat acreage was 1.50 ha. or less.

b. Predicted probability in per cent.

c. LTC = Low transporation cost per 50 kg. bag of fertilizer, set at Re. 1.00 /bag.

d. HTC = High transportation cost set at Rs. 3.00/50 kg./bag.

was used as a proxy for farm specific fertilizer cost as in principle, fertilizer price is uniform at all rural co-operative supply points in the study area. Higher fertilizer costs decrease both the expected adoption rate and quantity of fertilizer applied.

The probability of fertilizer use on wheat increases with increasing farm size. Similarly, farmers with irrigation are more likely to apply fertilizer (and at higher rates) than those without access to irrigation. At the extreme, an owner farming a large area of wheat, located close to the fertilizer supply point, has a 90 per cent probability of fertilizer adoption. Alternatively, a tenant with a small rainfed parcel of wheat and remote from the supply point is unlikely (P 5 per cent) to apply fertilizer.

CONCLUSIONS

Factors influencing the adoption and use rates of fertilizer on MV wheat in the Tarai of South-eastern Nepal were examined via a multivariate tobit regression model. This model was chosen because its assumptions are consistent with the limited dependent variable nature of fertilizer adoption. The analysis provided estimates of (*a*) the probability of fertilizer adoption and (*b*) the quantity of fertilizer used by the adopters.

Factors significantly related to fertilizer use on MV wheat were the area under wheat, extent of irrigation, fertilizer transport cost and operator's tenure status. Owner farmers with larger areas of wheat were more likely to use fertilizer and at higher rates than tenants with smaller wheat areas. However, whether the farmer used formal sources of credit, his years of schooling, and the intensity of extension visits were not. This unexpected result may be partly due to the fact that owners tended to farm larger holdings than tenants, and were better educated.[22] Thus the impact of these variables on fertilizer adoption may have been partly accounted for in the size and tenure variables.

Fertilizer adoption was sensitive to the cost of fertilizer procurement, implying that farmers in the area are responsive to fertilizer price as reflected in procurement plus delivery costs. Thus, the re-allocation of fertilizer supply points to reduce fertilizer delivery costs to farmers should promote fertilizer use on wheat. However, without further information on the costs of such an operation, it is premature to speculate which set of fertilizer price/distribution policy options would be most effective.

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22. See Tilak Rawal: Analysis of Factors Affecting Adoption of Modern Varieties in Southern Bel of Kosi Zone, Nepal, Unpublished M.Sc. Thesis, University of the Philippines at Los Banos, October 1979.

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APPENDIX

Calculation of Probability of Fertilizer Adoption and Use Rates on MV Wheat

The predicted probabilities listed in Table III were calculated for 'typical' farm situations. For example, consider an owner ($X_7 = 1$), with a 'large' area of wheat ($X_1 = 1.5$), which is fully irrigated ($X_2 = 100$), low transport cost ($X_3 = 1.0$), who does not use credit ($X_8 = 0$), with other variables (family labour, education, extension) held at their mean values as listed in Table I

The index value for this farmer is (equation (1) and Table II) :

$$I = -252{\cdot}42 + 164{\cdot}52(1{\cdot}50) + 1{\cdot}02(100{\cdot}00) + 8{\cdot}86(2{\cdot}67) + 6{\cdot}43(5{\cdot}47) + 1{\cdot}60(9{\cdot}63) - 68{\cdot}55\ (1{\cdot}00) + 88{\cdot}97(1) + 30{\cdot}74(0) = 190{\cdot}76.$$

Thus, $I/\sigma = 190{\cdot}76/145{\cdot}60 = 1{\cdot}31$.

The probability that this farmer will use fertilizer is obtained by evaluating the area under the standard cumulative distribution at F(1·31). Using 'Z' tables from a statistical textbook, F(1·31) = 0·90. Thus, there is a 90 per cent chance that the farmer described will apply fertilizer to his MV wheat.

The expected amount of fertilizer used on 1·5 ha. (equation 5) is

$$E(y|I) = 190{\cdot}76) = (190{\cdot}76)\ (0{\cdot}90) + (145{\cdot}60)\ ({\cdot}17) = 197{\cdot}25 \text{ kg.}$$

where $f(1{\cdot}31) = 0{\cdot}17$ is the value of the standard normal density function at $z = 1{\cdot}31$.

In this case the per hectare fertilizer use was 131 kg./ha. or about 52 kg. nutrients/ha.