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The Economics of Tractor Ownership and Use in the Nepal Terai

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FOREWORD

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The Ministry of Food and Agriculture appreciates the efforts of Dr. Shao-er Ong and Dr. Veit Burger, the A/D/C staff in Nepal, and of Dr. Ram Prakash Yadav, the Executive Director of APROSC, in making the publication of this Research Paper Series possible.

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THE ECONOMICS OF TRACTOR OWNERSHIP AND USE IN THE NEPAL TERAI

Ganesh B. Thapa and James A. Roumasset*

ABSTRACT

This study was designed to compare labor use, cropping intensity, percent hired labor and yields among non-mechanized and various categories of mechanized farms in the Terai Region of Nepal. In addition, the analysis examines the farmer's choice of mechanization with a risk-neutral model in which farmers are assumed to maximize the expected value of accounting profits. Farmers, representing four mechanization strata, namely tractor owning, tractor hiring, hand tractor owning and traditional bullock operated farms, were selected from Parsa and Chitwan districts for this purpose.

The results of the econometric analysis show the statistically sigificant association of a high level of mechanization with high cropping intensities, high yields per hectare, high labor use (except in land preparation), a high percent of hired labor and a low labor input for the land preparation operation. Since good quality land also can lead to these results, and a high shadow price for family labor and a low shadow price of capital lead to a high percentage of hired labor and also mechanization, the correlation between mechanization and these results may be partly spurious.

Two interrelated risk-neutral models in which farmers are assumed to maximize the expected value of accounting profits were developed and tested. The results of the tractor use model relating M (the actual mechanization index of each farm) to M* (optimum mechanization index to achieve maximum expected profits) revealed that M* explained the actual mechanization choice of farmers with a high degree of accuracy.

INTRODUCTION

The impact of farm mechanization on labor use, cropping intensity and yield is a subject of continuing controversy in developing countries. It is generally agreed that the tractor is a highly capital intensive form of mechanization with significant potential for displacing labor. Tractorization has also been controversial in the case of Nepal, where the average size of land holding is small (1.23 ha), agricultural land is fragmented and population density is high per unit of cultivated land. Proponents of mechanization believe, however, that tractorization increases labor absorption through higher cropping intensities. It is also purported to help farmers achieve timeliness in the performance of farm operations.

The introduction of four wheel tractors and pumpsets in the mid-sixties marked

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the beginning of farm mechanization in Nepal. Growth of mechanization has resulted largely from the efforts of the government and government-owned corporations. The tractor population increased rapidiy during the latter half of 1960s. The pattern of farm machinery is shown in Table 1. Credit to purchase this machinery was made available by the Agricultural Development Bank. These funds contributed significantly to the rapid increase in the number of tractors and pumpsets. The increasing trend in the use of farm machinery has generated a number of studies to assess the benefits and impact of farm machinery.

Table 1 : Number of tractors, hand tractors and pumpsets in Nepal, 1965-75.

Year	Type of Machinery		
	4-Wheel Tractor	Hand Tractor	Pumpset
1965-66	111	—	—
1966-67	57	—	10
1967-68	73	—	40
1968-69	195	—	100
1969-70	358	—	1,130
1970-74	1,061	100	—
1974-75	195	300	2,032
Total	2,050	400	3,312

Source: Agricultural Development Bank, Nepal.

An earlier study of farm mechanization in the Nepal Terai reported that tractor and pumpset use increased cropping intensity, labor absorption per hectare, labor productivity and net profits(ADB/N, 1973). Pudasaini (1976) reported that cropping intensity, yields, income and employment were higher on mechanized than traditional farms but the much greater use of cash inputs and higher education levels associated with mechanized farms made it difficult to attribute yield and income effects solely to machinery. He further observed that tractors could not be clearly linked with any on-farm labor displacement. Pumpsets were found to raise farm employment and tractor ownership allowed large farms to achieve higher cropping intensities. Similar to the experience of other countries in South Asia, tractor studies have not been conclusive in showing that tractors raise cropping intensity or yields, increase labor absorption or provide timeliness in the performance of farm operations.

This paper reports the findings of an econometric analysis designed to document relationships between mechanization and labor use, percent hired labor, cropping intensity and yields and to explain these relationships using the economic concept of expected profitability. It also reports the results of a decision model based on expected profit maximization to explain farmer's choice of mechanization.

The paper is organized as follows:

First, the selection of study area, sampling and survey methods and some characteristics of the sample farms are discussed. Then two distinct

models used in the study and their results are presented in two parts. Part one discussed the results of econometric models employed to compare input use, cropping intensity and productivity among non-mechanized and various categories of mechanized farms. Part two develops a model which is appropriate for explaining the mechanization choice and discusses the results of an empirical application of the model to explain the choice of 150 rice farmers in Nepal. Then follows some policy implication of the study. The last section is a summary of the paper.

METHODOLOGY

Because they embody a relatively high degree of mechanization, Parsa and Chitwan districts of Nepal were selected for analysis in this study. Both districts are early adopters of mechanical technology. Four-wheel tractors are more popular in Parsa whereas Chitwan has the largest number of hand tractors in the country. According to the Agricultural Development Bank, the tractor population in Parsa in 1978 was around 200 or roughly ten percent of the total tractors in the country. Chitwan had 58 hand tractors in 1978 which is more than fourteen percent of the national hand tractor population.

Information on farm production, labor use, costs, etc. were collected through personal interviews with four categories of farmers, namely tractor owning, tractor hiring, hand tractor owning and non-mechanized bullock operators. Since tractor owning farmers are likely to own relatively large holdings compared to other types of farms, a size-adjusted sampling procedure was used. This procedure minimizes the confounding effect of farm size and makes comparison of non-mechanized and mechanized farms more meaningful.

In Parsa district, villages with high tractor populations were identified and information describing the names of farmers, land holding size, irrigation type and machine ownership were collected. Farms were listed according to farm size for three irrigation strata : pumpset irrigation, canal irrigation and rainfed. From each list, a tractor owning farm was selected at random and a tractor hiring and a bullock operated farm of the nearest farm size were also chosen. This procedure was repeated to select 18 canal irrigated, 3 pumpset irrigated and 12 rainfed farms from each mechanization stratum. The proportion of farms in each irrigation stratum was determined on the basis of a pretest done in the study area.

A different sampling technique was used in Chitwan district because of a lack of secondary information. Village groups with high hand tractor populations were first identified. From each village group (a village group consisted of 2 to 3 neighboring villages) hand tractor owning farms were selected at random. Other types of farms were then chosen in the vicinity of the hand tractor owning farms.

A total of 150 farms were selected and interviewed for the study. Enumerators were hired for the purpose of interview.

Age, educational attainment, farm size and other selected characteristics of the sample farms are presented in Table 2 by mechanization type. Tractor owning farms are four to six times larger than farms in other categories. Tractor hiring, hand tractor

owning and non-mechanized farms do not differ appreciably in this respect. Farms also differ considerably in terms of educational attainment by farmers. Tractor and hand tractor owning farmers had two to three times the number of years of schooling compared to tractor hiring and traditional farmers. Farms do not differ much in other characteristics.

Table 2 : Characteristics of 150 sample farms, Parsa and Chitwan, 1977.

Characteristics	Tractor owner	Tractor hiring	Hand tractor owner	Bullock only
Number of farms	41	41	20	48
Age of the farmer	39.27	41.05	42.40	43.48
Year of schooling	5.81	2.73	7.05	1.92
Number of adults engaged in farming	3.68	3.54	3.80	3.46
Farm size (ha)	17.69	4.67	4.53	3.01
Number of bullocks/farm	3.71	2.54	1.90	2.60

Source : Field survey.

RESULTS OF ECONOMETRIC MODELS

Mechanization and Patterns of Input Use

A covariance model was used to compare total labor use, labor use in specific farm operations, levels of hired labor and other inputs in rice production among non-mechanized and various categories of mechanized farms. This method is superior to one-way analysis of variance because it incorporates corrections for differences in other factors such as irrigation, variety and farm size when comparing input use among these farms.

In this method, the dependent variable e.g. total labor in mandays is regressed against a set of independent variables which explain the variation in the dependent variable. In the model shown below, independent variables include a continuous variable, farm size in hectares and dummy variables for variety, irrigation and mechanization characteristics.

The following model was used for the analysis: [1]

$$L = b_0 + \sum_{i=1}^{3} b_i M_i + \sum_{j=1}^{2} b_{3+j} I_j + b_6 V + B_7 F + \sum_i \sum_j b'_{ij} M_i I_j + \sum_i b'_i MV + E \qquad (1)$$

1 A further improvement in the model can be done by including other current inputs or prices including wage rates.

Where L=labor input in specific farm operations (mandays per hectare)

F=farm size in ha

V=variety dummy where V=1 for modern variety, O=Otherwise

M=mechanization dummy which takes a value of unity if the farm belongs to mechani-zation group i where i= 1-3

M_1=1 for hand tractor owning farm, O othersise

M_2=1 for tractor owning farm, O otherwise

M_3=1 for tractor hiring farm, O otherwise

Reference group : non-mechanized farm

I =irrigation dummy which takes a value of unity if the farm belongs to j^{th} irrigation group where j= 1-2

I_1=1 for pumpset irrigation, O otherwise

I_2=1 for canal irrigation, O otherwise

Reference group: rainfed farm

E=error term

The coefficients, b_1 to b_3 measure group differences between mechanized and non-mechanized farms. b_1 indicates the additional ($b_1 > 0$) labor input employed by hand tractor owning farm compared to non-mechanized farms.

This model allows for non-additive effects which measure the interaction of mechanization and irrigation as well as variety on labor use. For example, b_{11} (the coefficient of $M_1 I_1$) measures the interaction of hand tractor and pumpset irrigation on the level of labor input. The significance of interaction terms was tested by fitting a constrained version of the above model (which contains no interaction terms):

$$L = b_o + \sum_{i=1}^{3} b_i M_i + \sum_{j=1}^{2} b_{3+j} I_j + b_6 V + b_7 F + e \qquad (2)$$

The set of restrictions $b_{ij} = O$ and $b'_i = O$ were tested by comparing the computed F-statistics with the tabulated F-value. The F-statistics was computed on the basis of the residuals from the estimating equations (1) and (2).

The F-tests showed that interaction effects between mechanization and irrigation as well as variety are statistically insignificant for regressions explaining variations in land preparation labor, level of fertilizer and other cash expenses.

The results of constrained models are presented in Tables 3-4. Mechanized farms report significantly lower levels of labor use for land preparation. Tractor owning, hand tractor owning and tractor hiring farms employed 15, 11 and 7 fewer mandays per hectare than non-mechanized farms. In contrast, mechanized farms reported higher levels of total hired labor and higher labor use for harvest and threshing operations compared to non-mechanized farms. Increased employment in these tasks more than balanced the

lower level of labor used in land preparation on the mechanized farms. These farms reported higher total labor use by 6 to 12.5 mandays compared to bullock operated farms.

Table 3 : Differences in land preparation labor, post-production labor, total labor and hired labor expenses by level of mechanisation, (rice).

Independent variables	Dependent variables			
	Land preparation labor (days/ha)	Post-production labor (days/ha)	Total labor (days/ha)	Hired labor expenses (Rs/ha)
Intercept	23.54	32.95	120.56	557.58
Farm size	-0.28 (-0.72)	-0.64 (-0.79)	-0.57 (-0.36)	-0.45 (-0.40)
M_1 Hand tractor own	-11.08** (-11.27)	15.01** (7.16)	10.48** (2.60)	271.75** (9.41)
M_2 Tractor own	-15.18** (-15.72)	15.38** (7.16)	14.80** (3.74)	238.81** (8.42)
M_3 Tractor hire	-6.90** (-8.71)	10.27** (6.08)	14.43* (4.44)	154.83** (6.65)
I_1 Pumpset irrigation	0.41 (0.40)	6.37** (3.01)	12.27** (4.24)	58.10* (1.99)
I_2 Canal irrigation	0.23 (0.30)	2.15 (1.49)	6.12* (2.2[illegible])	22.97 (1.16)
V Improved variety	-1.21* (-1.94)	6.11* (4.60)	4.30* (1.68)	19.93 (1.09)
R^2	0.76	0.54	0.29	0.53
Adjusted R^2	0.74	0.52	0.26	0.50
F-statistic	62.65	23.63	8.40	22.70

Figures in parentheses are 't' statistics.

* significant at 5% level

** significant at 1% level

The effect of farm size on labor use and level of other inputs such as fertilizer was negative and insignificant. Irrigation had a positive effect on labor use and the level of other inputs

Table 4 : Differences in level of fertilizer, other cash expenses and cropping intensity by level of mechanisation, (rice).

Independent variables	Dependent variables		
	Level of fertilizer (kg N/ha)	Other cash expenses (Rs/ha)	Cropping intensity (%)
Intercept	22.26	55.13	123.72
Farm size	-0.34*	0.15	-0.71
	(-1.72)	(0.25)	(-1.22)
M_1 Hand tractor own	20.54**	26.44*	48.16**
	(4.08)	(1.72)	(3.26)
M_2 Tractor own	27.92**	54.98**	27.21*
	(5.65)	(3.65)	(1.87)
M_3 Tractor hire	9.92**	22.30*	36.59**
	(2.45)	(1.80)	(3.07)
I_1 Pumpset irrigation	17.52**	18.07	6.10
	(3.45)	(1.16)	(0.41)
I_2 Canal irrigation	5.14	39.70**	11.80
	(1.50)	(3.79)	(1.17)
V Improved variety	14.63**	10.22	6.29
	(4.59)	(1.05)	(0.67)
R^2	0.40	0.25	0.12
Adjusted R^2	0.37	0.22	0.08
F-statistic	13.40	6.89	2.87

Figures in parentheses are 't' statistics.

* significant at 5% level

** significant at 1% level

In the co-variance model specified earlier, with the exception of irrigation characteristics, land quality measures such as soil fertility, topography, rainfall etc. have not been included. If land quality and tractor use are positively correlated, the effects of omitted variables are partially captured by the estimates of the mechanization variables leading to an upward bias in these coefficients.

Mechanization and Cropping Intensity:

Comparison of average statistics shows that machine using farms had higher cropping intensities compared to non-mechanized farms (see Table 5). Hand tractor owning farms reported the highest cropping intensity (180%) followed by tractor hiring (167%) and tractor owning (150%)farms and non-mechanized farms had a cropping intensity of 130%. Since these mean values do not segregate the effects of factors such as varieties, irrigation, and farm size from the effect of mechanization, the co-variance analysis

specified earlier was used to compare cropping intensities among farms (Table 4). The results show that mechanized farms had higher cropping intensities compared to non-mechanised farms. However, the coefficient of determination (R^2) was low for the regression equation explaining differences in cropping intensity. When the number of educated adults in the family was used as a proxy for the management variable, the R^2 improved marginally and the coefficient of this variable was significant at the 20% level.

Mechanization and Productivity:

Table 5 shows that mechanized farms had higher yields per hectare compared to traditional bullock operated farms. A generalized (linear logarithmic) production function with dummy variables for mechanization was estimated which allowed a comparison of productivity among non-mechanized and various categories of mechanized farms.

Table 5 : Average statistics of sample farms by mechanization type for one rice crop (per hectare).

Operation	Tractor owner	Tractor hiring	Hand tractor owner	Bullocks only
Number of farms	41	41	20	48
1. Land preparation labor (m-days)	7.4	15.9	11.9	23.6
2. Weeding labor (m-days)	33.4	31.6	33.2	28.0
3. Other pre-harvest labor (m-days)	48.4	46.2	40.6	39.5
4. Harvesting ; Threshing labor (m-days)	53.9	48.4	53.0	38.9
5. Total labor (m-days)	143.2	142.2	138.6	127.0
6. Hired labor as percent of total labor	95	86	95	74
7. Hired labor expenses (Rs/ha)[a]	822.44	739.90	800.85	572.38
8. Level of fertilizer (kg N/ha)	58.3	43.9	54.1	31.0
9. Other cash expenses (Rs/ha)	143.93	106.48	113.52	78.24
10. Yields (Kg/ha)	2409	2030	2345	1568
11. Cropping intensity (%)[b]	149.6	167.5	179.8	129.6

[a] 1 US $ = Rupees 12

[b] $$\text{Cropping intensity} = \frac{\text{Area under different crops in a given year}}{\text{Total cultivated physical area in that year}} \times 100$$

The production function was expressed as :

$$Y = b_o N^{b_1} L^{b_2} C^{b_3} F^{b_4} e^{b_i M_i + b_i + {}_j I_j + b_{i\,j} M_i + b_i MV + b' V + E} \quad (3)$$

Where Y=yields / ha

b_o=intercept or efficiency term

b_i=partial regression coefficient of the ith input

N=nitrogen in kg/ha

L=labor input in mandays/ha

C=cash inputs in Rs/ha

F=farm size in ha

V=variety dummy as defined earlier

M_i=mechanization dummies as defined earlier

I_j=irrigation dummies as defined earlier

The results of the production function model are given in Table 6. F-tests revealed that the interaction terms were again insignificant.

Table 6 : Results of production function model, 150 rice farms, Parsa and Chitwan districts, 1977.

Independent variables	Unit	Dependent variable Yield in quintals/ha	
Intercept		0.85	(1.03)
N Fertilizer	Kg/ha	0.02	(1.02)
C Other cash expenses	Rs/ha	0.01	(0.20)
L Labor	mandays/ ha	0.38*	(2.08)
F Farm size	ha	-0.03	(-0.93)
M_1 Hand tractor own	D	0.37**	(5.35)
M_2 Tractor own	D	0.37**	(5.65)
M_3 Tractor hire	D	0.14**	(3.01)
I_1 Pumpset irrigation	D	0.11*	(1.81)
I_2 Canal irrigation	D	0.05	(1.35)
V Improved variety	D	0.27**	(7.76)
R^2		0.61	
F-Statistic		20.61	

Figures in parentheses are 't' statistics.

D=Dummy variable

* significant at 5% level

** significant at 1% level

1 Quintal = 100kg

Fertilizer and cash expenses have positive partial elasticities, i. e. a one percent increase in any of these inputs would result in an increase in yield by a percentage equivalent to the partial elasticity for that particular input. For example, Table 6 shows that labor has a partial elasticity of 0.38 which means a one percent increase in labor results in 0.38 percent increase in rice yield. The coefficient of irrigation and variety are also positive and significant.

Farm size was negatively associated with yields. Other studies have shown an inverse relationship between farm size and productivity, particularly for family farms. Small family farms usually have better land quality and low shadow price[2] for family labor. For commercial farms, however, farm size is often positively correlated with yields per hectare (Uy, 1979). Large farms may mechanize because of economics of scale in the operation of machinery. This helps reconcile the finding that larger mechanized farms have higher yields per hectare with inverse relationship between farm size and productivity.

RESULTS OF TRACTOR USE MODELS BASED ON EXPECTED PROFIT MAXIMIZATION

In the econometric model discussed in part one, mechanization was assumed to be an exogenous variable and included as one of several independent variables in determining dependent variables like yields, cropping intensity and labor. The main purpose of this part is to develop and test a model based on expected profit maximization in order to explain tractor use by farmers. In this model, mechanization is treated as an endogenous variable which seems consistent with the observation of other studies (Binswanger and Ruttan 1978). In other words, we want to test a model which explains why some farmers mechanize while others do not.

Decision models based on expected profit maximization were developed and tested to predict tractor ownership and explain the observed choice of mechanization by individual farmers. The basic approach was first developed by Roumasset (1973; 1976) to explain fertilizer use by Filipino farmers and the methodology was further simplified to improve its applicability (Roumasset, 1978). In this model, the returns to different production techniques under three states of nature (good, medium and bad seasons) are estimated and an optimal rate of input use which maximizes expected profits is predicted for each farm. A second step is to measure how well the predicted level of input use explains the actual inputs used by farmers.

Two extensions were developed in order to apply the expected profit approach to the mechanization problem. First, since it is difficult to quantify and measure mechanical power used in farm tasks, a mechanization index based on housepower-hour per hectare was developed. The procedure for computing the index is shown in Table 7. Secondly, an attempt was made to link the long-term investment decision with the short-term production decision. Roumasset's (1976) earlier use of the model dealt with a

2 The shadow price is the opportunity cost of an input when employed in alternative uses.

Table 7 : Computation of mechanization index* : A hypothetical example.

Operation (per hectare)	Tractor power				Bullocks (1 pair)				Human labor		
	Proportion of work done by tractor	Hours	Horse power	Horse power hours	Proportion of work done by bullocks	Hours	Horse power	Horse power hours	Hours	Horse power	Horse power hours
First ploughing	1.0	2	32	64	0	0	0	0	2	0.1	0.20
First harrowing	1.0	1.75	32	56*	0	0	0	0	1.75	0.1	0.18
Second harrowing	0	0	0	0	1.0	48	1.0	48	48	0.1	4.80
Third harrowing	0	0	0	0	1.0	48	1.0	48	48	0.1	4.80
Puddling	0.5	2	32	32	0.5	24	1.0	12	26	0.1	2.60
Total				152				108			12.58

Mechanization index, $M = \frac{\text{Sum of horsepower hours from mechanical (tractor) power}}{\text{Sum of horsepower hours from mechanical power + sum of horsepower hours from non-mechanical (bullock and human labor) power}}$

$$M = \frac{152}{152+108+12.58} = \frac{152}{272.58} = 0.5576$$

***Assumptions:** (1) A pair of bullock is equivalent to one horsepower

(2) A human laborer is equivalent to 0.1 horsepower

(3) The horsepower from human labor includes hours worked by tractor operator and bullock operator

production process which was independent of the investment decision. According to neo-classical economic theory with perfect rental markets for capital goods, investment and production decisions are independent. In less than a perfect market, these decisions are no longer independent. Since mechanization is a key part of farm investment, two interrelated models were developed to link the investment decision with the production decision.

Risk preferences were omitted for two reasons: a previous test of the model (Roumasset, 1973; 1976) suggested that risk preferences do not help explain actual input use. Furthermore, due to the necessary level of approximation in estimating a stochastic production function, the inclusion of risk preference would only be a minor refinement.

A. **The Tractor Use Model:** In explaining tractor use, we assume farmers wish to maximize expected accounting profits. Accounting profits differ from nominal profits in that market prices are replaced by opportunity costs and shadow prices. For example, if a farmer uses his own family's labor, nominal profits can be converted to accounting profits by subtracting the opportunity cost of family labor. For our purpose, six production techniques were defined on the basis of varying levels of inputs used in the production process. Tractor owning, tractor hiring and bullock operated farms were each assumed to employ two production techniques based on the level of fertilizer used. The six techniques were :

A– tractor own, low level of fertilizer

B– tractor own, high level of fertilizer

C– tractor hire, low level of fertilizer

D– tractor hire, high level of fertilizer

E– bullock operated, low level of fertilizer

F– bullock operated, high level of fertilizer

A group of farmers and experts in each village were asked about the level of inputs used and the expected yields under each production technique for three states of nature: good, medium and bad. These states refer to no damage, moderate damage, and major damage to crops caused by pest and weather problems. By asking how many years out of ten the farmer expected the season to be good, medium or bad, expected yields corresponding to the three states of nature could be computed. In each village, farmers were stratified into three economic groups on the basis of soil type, variety grown, irrigation availability and mechanization level.

In order to determine expected accounting profits corresponding to each production technique, opportunity costs and shadow prices were used instead of market prices. The computation of shadow prices is explained below.

For tractor owners and hirers, who usually have large farms and employ a high degree of hired labor, the hired wage rate (Rs. 6 per day) was taken as the shadow price of labor. The wage a farmer must pay to hired labor and the wage that family members earn outside differ if transportation costs are taken into account. Therefore, in the case of bullock operated farms where the family prepares the land, the shadow price for labor in land preparation was assumed to be eighty percent of the wage rate, a figure

believed to fall between the buying and selling price for labor in the market.

Since farmers would have to borrow from money lenders for additional expenditures at roughly 25 percent per year, this figure was taken as the shadow price of capital. This is the cost to the farmer of borrowing an additional rupee at the margin. Since the output price (rice) fluctuates every year, an average price was computed by assigning weights (0.5, 0.3 and 0.2) to the price of three preceding years. This average price was assumed to be the shadow price of output. The shadow prices of labor, capital, output and tractor use are presented in Table 8.

Table 8 : Shadow prices of labor, capital, output and tractor use.

Shadow price of	Tractor owner	Tractor hirer	Bullock operator
Labor	Hiring wage rate (Rs. 6/day)	Hiring wage rate (Rs. 6/day)	Eighty percent of hiring wage rate
Capital	Interest rate charged by money lenders (25 percent per year)		
Output (rice)	Average price computed by assigning weights (0.5, 0.3 and 0.2) to the prices of three preceding years. (Rs. 1.64/kg)		
Tractor use	Eighty percent of actual hiring rate	Actual hiring rate (Rs 45/hour)	Not applicable

The expected profit maximizing levels of mechanization (M_1^* and M_2^*) were computed for each farm group (which included sample farms from each village). M_1^* is the mechanization index corresponding to a production technique which maximizes expected profits on a tractor owning farm. For example, in Table 10, mechanization indices of techniques A and B belonging to tractor owning category are 0.8920 and 0.9884 respectively. Since technique A has higher expected profits than technique B, M_1^* is equal to 0.8920.

M_2^* refers to the mechanization index corresponding to a production technique that maximizes expected profits on a tractor hiring farm. In Table 10, techniques C and D belonging to tractor hiring category have mechanization indices of 0.9000 and 0.8309 respectively. Since technique D has higher expected profits than technique C, M_2^* is equal to 0.8309.

Table 9 : Computation of expected profits and mechanization index under different production techniques on a representative irrigated rice farm, Maniyari village, Nepal, 1977.

Inputs per hectare	Price per unit	Production techniques (a) A Units	A Value (Rs)	B Units	B Value (Rs)	C Units	C Value (Rs)	D Units	D Value (Rs)	E Units	E Value (Rs)	F Units	F Value (Rs)
(1) Tractor (32 hp) use for land preparation (hrs)	For A & B: Rs 36/hr For C & D: Rs 45/hr	7.5	270	8.5	306	6.7	302	7	315	—	—	—	—
(2) Bullock use for land preparation (days)	Rs 15/day	3	45	—	—	6	90	5	75	18	270	18	270
(3) Labor use (days)													
(i) land preparation	For A, B, C, and D: Rs 6/day. For E and F: Rs 4.8/day	4	24	4	24	7	42	7	42	20	96	20	96
(ii) Other labor	Rs 6/day	96	576	100	600	91	546	93	558	79	474	81	486
(4) Chemical fertilizers													
(i) Urea (kgs)	Rs2.44/kg	54	132	98	239	54	132	65	159	33	80	33	80
(ii) Complesal (kgs)	Rs 2.27/kg	100	227	175	397	75	170	150	341	50	114	125	284
(5) Other chemicals													
(i) metacid (ml)	Rs 15/50 ml	200	60	200	60	200	60	200	60	—	—	—	—
(ii) B.H.C. (kgs)	Rs 2/kg	20	40	20	40	20	40	20	40	20	40	20	40
(6) Seed (kgs)	Rs 2.2/kg	60	132	60	132	60	132	60	132	60	132	60	132
(7) Land rent (Rs)	Rs 38/ha	—	38	—	38	—	38	—	38	—	38	—	38
(8) Irrigation fee (Rs)	Rs 60/ha	—	60	—	60	—	60	—	60	—	60	—	60
Total costs			1604		1896		1612		1826		1304		1486

[a] Production techniques:
A – Tractor own, low level of fertilizer
B – Tractor own, high level of fertilizer
C – Tractor hire, low level of fertilizer
D – Tractor hire, high level of fertilizer
E – Bullock operated, low level of fertilizer
F – Bullock operated, high level of fertilizer

Source : Field Survey

Table 10 : Expected yields, profits and mechanization index on a typical irrigated rice farm, Maniyari village, Nepal, 1977.

Item	Probability level of individual states of nature (out of ten)	Production techniques					
		A	B	C	D	E	F
(1) Yields (kgs/ha)							
(i) Good season	3	1860	2100	1770	1960	1320	1440
(ii) Medium season	4	1500	1680	1440	1590	1140	1200
(iii) Bad season	3	1020	1140	960	1020	900	960
(2) Expected yields[a] (kgs/ha)		1464	1635	1395	1530	1158	1245
(3) Expected revenue[b] (Rs/ha)	Price of rice: Rs 1.64/kg	2401	2681	2288	2509	1899	2042
(4) Expected profits[c] (Rs/ha)		797	785	676	689	595	556
(5) Mechanization index		0.8920	0.9884	0.8000	0.8309	0.0000	0.0000

[a]Expected yields, $E(Y) = Y_j P_j$ where Y_j = Yield in the jth season

P_j = Probability of the jth season

e.g. E(Y) in technique A = 1860 (0.3) + 1500 (0.4) + 1020 (0.3)
= 1464 kgs/ha

[b]Expected revenue, E (R) = Price per unit output × Expected yields

e.g. E (R) for technique A = 1.64 × 1464
= Rs 2401/ha

[c]Expected profits = Expected revenue − Total costs

e.g. Expected Profits for technique A = Rs 2401 − Rs 1604
= Rs 797/ha

[d]Mechanization index, $M = \frac{A}{A+B+C}$

where A = No. of hours of tractor use for land preparation times tractor horsepower

B = No. of hours (1 day = 8 hours) of bullock use for land preparation X horsepower equivalent of a pair of bullocks (a pair of bullocks = 1 hp)

C = No. of hours (1 day = 8 hours) of human labor used for land preparation X horsepower equivalent of a human laborer (1 human laborer = 0.1 hp)

e.g. M for technique A = $\frac{7.5 \times 32}{(7.5 \times 32) + (3 \times 1 \times 8) + (4 \times 0.1 \times 8)}$ = 0.8920

M^* = the level of mechanization which maximizes expected profits on a tractor owning farm.

e.g. M corresponding to technique A, 0.8920 is M_1^* in the above example.

M_2^* = the level of mechanization which maximizes expected profits on a tractor hiring farm.

e.g. M corresponding to technique D, 0.8309 is M_2^* in the above example.

B. The Tractor Ownership Decision Model : In an ordinary investment model, the sum of net present value of benefits forms the basis for the investment decision. This model cannot be used independently to predict tractor ownership by Nepalese farmers because the Agricultural Development Bank (ADB) which is the source of tractor loans, also influences ownership decisions. Ownership depends on two separate decisions. The farmer has to buy a tractor on the basis of economic returns he expects to obtain from ownership of machine. In addition, however, the bank must choose farmers who meet their basic requirements for tractor ownership (all tractor owners in the sample area obtained their tractors through ADB loans). In order to predict tractor ownership in Nepal, we need to model both the demand and supply sides which are represented by farmers and the bank respectively.

The Model : The farmer will own a tractor if:

i) the sum of the present value of net benefits from ownership of tractor is positive, and

ii) the farmer can meet the bank requirement for a tractor loan.

Net Benefits : The benefits of tractor ownership comprise the sum of net rents obtained from use of the tractor on the family's own farm, the sum of net rents obtained by hiring out to others and the sum of differences in expected profits between tractor owning and tractor hiring farms.

The present value of net benefits was computed by subtracting discounted costs from discounted benefits for each tractor owning, tractor hiring and bullock operated farm included in the sample. For tractor owning farms, the actual hours of tractor use and actual costs incurred in the operation and maintenance of tractor were computed in calculating net benefits. Net benefits from tractor ownership in the case of tractor hiring and bullock operated farms were computed on the assumption that if they owned tractors, they would use an average number of hours of tractor services and would hire out the tractors an average number of hours annually. These average figures were computed from the actual hours of tractor use by the tractor owners.

The annual sum of net rents on the farmer's own farm was computed by multiplying the total number of hours of tractor use on the farm and in transporting inputs and produce by the per unit net rental charge. The annual sum of net rents from tractor use on other's farms was computed by multiplying the total number of hours the tractor was hired out by the contract rate. In summing the net rents over the years it was assumed that net rents would be identical for each year.

For those hiring tractors, the actual hiring rate (Rupees 45 per hours) was taken as the shadow price or net rental rate for tractor use. Since a tractor owner includes a profit margin and price for the risk of breakdown in the rental rate, the shadow price for tractor use for owners will be less than the actual hiring rate. Based on these criteria, the shadow price for tractor use by tractor owners was assumed to be twenty percent less than the actual hiring rate.

The difference in expected profits between a tractor owning and a tractor hiring farm is the benefit attributable to tractor ownership. The computation of expected profits in tractor owning and tractor hiring farms is shown in Table 9. Tractor owning

farms have two production techniques (A and B) and two techniques are defined for tractor hiring farms (C and D). In the example given in Table 10, technique A generates the highest expected profit (Rupees 797 per hectare) in the tractor owning category while technique D yielded the highest expected profit (Rupees 689 per ha) in the tractor hiring category. The differences in expected profits (Rupees 106.61 per hectare per crop) is a benefit attributable to tractor ownership. In computing the sum of the differences in expected profits over 10 years (life of the tractor) it was assumed farmers would obtain identical expected profits from two crops grown each year and the profits would not vary over the years for which the sum is computed.

Costs : The cost incurred by a tractor owner are : (a) fixed costs which include depreciation, taxes and insurance, interest on investment and labor costs, (b) variable costs which include expenditures on diesel, lubricants, oils, repairs and maintenance costs. These costs were computed on the basis of total hours of tractor use. The assumptions and procedures for the computation of these costs are presented in Table 11.

Table 11 : Assumptions and procedure in the computation of tractor costs.

Costs (32 HP Tractor)

(a) Initial cost : Rs 52, 000

(b) Interest, depreciation and wages :

(i) Interest : at 25% of initial cost on diminishing balance for 10 years

(ii) Depreciation : at 10% of initial cost each year

(iii) Wages : Driver's salary at Rs 12/day

(c) Working costs:

(i) Diesel consumption at 4 liters/hour at Rs 2.55/liter

(ii) Mobil oil at 7.5 liters/100 hours at Rs 14/liter

(iii) Gear oil at 2.4 liters/100 hours at Rs 20/liter

(d) Repair and Maintenance Costs : at 5% of initial cost per year

Costs (47 HP Tractor)

(a) Initial cost : Rs 80,000

(b) Interest, depreciation and wages:

(i) Interest : at 25% of initial cost on diminishing balance for 10 year

(ii) Depreciation : at 10% of initial cost each year

(iii) Wages : Driver's salary at Rs 12/day

(c) Working Costs:

(i) Diesel consumption at 4.5 liters/hour at 2.55/liter

(ii) Mobil oil at 7.5 liters/100 hours at Rs 14/liter

(iii) Gear oil at 2.4 liters/100 hours at Rs 20/liter

(d) Repair and Maintenance Costs : at 5% of initial cost/year

Assumption

1. The life of tractor is assumed to be 10 years.

Agricultural Development Bank Requirements : Farmers need to fulfill 3 basic requirements set by the Agricultural Development Bank to obtain a tractor loan:

1. the farmer should own at least 10 hectares of land, although if he owns only 3.35 ha of land, he can apply for a tractor loan if other member of his family own additiona l land which can be used to make up the deficit.

2. the farmer should be able to utilize the tractor for at least 750 hours annually.

3. the applicant should be able to deposit in cash at least 15 percent of the tractor price with the bank and mortgage his land as security against the remainder of the loan.

The ability of a farmer to utilize the tractor for the recommended number of hours depends on the size of his farm and the prospects of hiring out the tractor to other farmers. The number of hours of tractor use on a farmer's own farm is computed on the basis of actual size for each farm. The number of hours that a prospective tractor owner expects to hire out his tractor was based on the average number of hours actual owners are currently hiring out tractors. To determine if the sample farms satisfied the third requirement set by the bank, a cash balance was computed for each farm by subtracting total annual costs from total annual revenue. A farm which has a positive sum of discounted benefits and which meets all the requirements set by the bank was predicted to own a tractor.

Findings of the Ownership Model : The present value of net benefits was computed for all tractor owning (33), tractor hiring (33) and bullock operated (33) farms in the sample. Out of a total of 33 tractor owning farms, 26 had positive net benefits. For the remaining 7 farms, gross costs were greater than gross benefits.

Among tractor hiring farms, only 2 had positive net benefits. None of the bullock operated farms showed a positive benefit. Tractor owning farms showing negative net benefits utilized tractors less than the recommended annual number of hours, either because of small holdings or inability to hire out the tractor to others. Most of the tractor hiring and bullock operated farms had negative net benefits because of small holdings.

Whereas all tractor owning farms met the minimum land area requirement set by the bank, four utilized their tractors less than the required number of hours annually. As a result, these farms had negative net benefits. All tractor owning farms, however, had sufficient cash to deposit at least 15 percent of the tractor price with the bank upon approval of the tractor loan.

Only 18 of 33 tractor hiring farms and 9 of 33 bullock operated farms possessed the minimum farm area required by the bank. In addition, only 4 tractor hiring farms had sufficient cash on hand to meet the required bank deposit. Two of these 4 tractor hiring farms had positive net benefits. None of the bullock operated farms had adequate cash for the bank deposit.

Out of 33 tractor owning farms, the model predicted that 26 farms would buy tractors, would have positive net benefits and would meet all requirements set by the bank. The model predicted that only two of 33 tractor hiring and none of the bullock operated

farms would own tractors. Based on these results, we can conclude that the model is 91 percent accurate in predicting tractor ownership by farmers in the Nepal Terai.

The Complete Model : The tractor ownership decision model makes use of expected profits computed for various farm types under different production techniques to predict tractor ownership. It is then possible to determine the implicit net rent of tractor use for each farm. The tractor use model employs this information in conjunction with the prices of other inputs and predicts tractor use. In testing this model, we compute an actual mechanization index M, and the mechanization index M* corresponding to the maximum level of expected profits. We then test the power of M* to explain the actual mechanization level , M.

The coefficient of determination (R^2) was computed by relating M to M* for all farms in the sample. The high coefficient of determination (0.91) showed that M* explained the actual mechanization choice of the farmer very well.

Thus, the extent of mechanization is accurately predicted by a risk-neutral model wherein farmers are assumed to maximise the expected value of accounting profits.

POLICY IMPLICATIONS

Subsidies to tractorization through cheaper institutional loans or other means brings about two seemingly offsetting effects. On the one hand, it leads to displacement of labor in operations done by tractors. On the other hand, it expectedly lowers the shadow price for farm operations done by tractor, like land preparation, and helps achieve higher cropping intensity, particularly in areas where timely land preparation is crucial. We cannot quantify which of the two effects is higher. However, the results of the tractor surveys conducted in South Asia fail to provide evidence that tractors are responsible for substantial increases in intensity and timeliness (Binswanger, 1978).

The results of this study lead to some policy implications. Since the farmers act as if they maximize expected profits, they are efficient, with respect to private shadow prices, in the use of mechanical (tractor) power. Therefore, to the extent that social prices are equivalent to private shadow prices, there is no need to correct farmer behaviour through artificial incentives like cheap loans for tractor purchase. Indeed, since the social shadow price of labor is less than the private one, government policy should discriminate against labor displacing technique.

Instead, social policy has encouraged more mechanization than in the market solution. The adoption of tractors and power tillers in Asia has been influenced by capital bias due to (a) market imperfections like subsidized interest rates on credit and market wages above than the opportunity cost for labor, (b) preference of decision makers like government administrators and experts for capital intensive technology and (c) institutional structure for society e.g. the preference of larger farmers for equipment that displaces labor and thus their dependence on hired laborers (Barker, 1977).

Some people argue that government subsidy such as subsidized interest rate or credit is essential for the successful introduction of a new technology like tractors on the

grounds that farmers underestimate the benefits of new techniques. Since tractors were introduced in Nepal more than a decade ago, this argument for subsidy no longer holds i. e. farmers are already aware of the benefits of tractors.

Another argument for subsidy is that the private shadow price of capital to farmers is greater than the social price. If this is true, then loans should not be earmarked for tractor purchase at such a low interest rate. Rather the credit program should cover a wide range of agricultural inputs. The Agricultural Development Bank should, therefore, phase out its subsidy on tractor loans and should focus its agricultural loan program on a broad range of inputs.

SUMMARY

The results of the econometric analysis revealed that mechanized farms had higher cropping intensities, higher yields per hectare, higher levels of labor use (except in land preparation), a higher percentage of hired labor and lower levels of labor in land preparation compared to non-mechanized farms. However, the regression estimates may exhibit bias because of omitted explanatory variables such as a measure of land quality (soil fertility, topography, etc.) and/or inaccurate measurement of variables. Considering the deficiencies in the data that mechanized farms use higher levels of inputs, the analysis is inadequate to conclude that the above results are solely a result of using machinery. We can only say that a high level of mechanization is normally associated with these findings.

Other studies have shown that good land quality leads to more intensive crop cultivation i.e., all tasks are carried out at higher levels, including use of higher levels of inputs such as chemicals and labor (Roumasset, 1976; Uy, 1979). This results in higher yields per hectare.

The attributes of good quality land may also account for higher cropping intensities. The availability of irrigation water offers great potential for increasing cropping intensity. Soil fertility is a determinant of cropping patterns in small farm agriculture where cash inputs are scarce or unavailable. Soil fertility also has an indirect effect on cropping intensity because a fertile soil provides a strong positive inducement for double cropping.

Thus better quality land leads to higher cropping intensity and more intensive cultivation. In turn, higher cropping intensity and more intensive cultivation increases the marginal benefits of mechanization.

Better quality land also leads to use of higher percentage of hired labor. With higher incomes for the operator as a result of new technology, the marginal utility of not engaging in hard labor is high relative to the marginal utility of additional income. Moreover, the new technology is more management intensive, so the operator allocates a greater proportion on his time to that activity (Roumasset and Smith, 1979; Smith and Gascon, 1979). The shadow price of family labor is higher relative to the shadow price of hired labor which makes the use of hired labor more attractive.

The above explanation indicated that even in the absence of mechanization, we would expect high cropping intensities, higher yields per hectare, increases in total labor and a high percentage of hired labor on farms with good quality land.

Similarly, a high shadow price for family labor and a low shadow price of capital lead to higher percentage of hired labor and also induce higher levels of mechanization.

Therefore, the correlation between mechanization and the results from the covariance analysis may be partly spurious, i. e., we can explain the relation between mechanization, specialization and intensification without postulating that mechanization causes those trends.

A risk neutral model wherein farmers are assumed to maximize the expected value of accounting profits, accurately predicted the extent of mechanization by farmers. The results of tractor use model relating M (actual mechanization index of the farm) to M* (optimum mechanization index for maximizing expected profits) showed that M* explained the actual mechanization choice of the farmer and there was no learning lag, i. e. farmers were readily aware of the benefits of using tractors. A tractor ownership decision model was found to accurately predict tractor ownership decisions by farmers.

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