The Economic Journal of Nepal, Vol.12, No.2, Issue 46, April-June 1989 (c) DOE-TU

Are Tractorized Farms More Efficient than Traditional Ones ?

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INTRODUCTION

Tractorization is a capital intensive innovation. A school of thought identified as substitution view argues that tractorization is not profitable in developing economies where wages are low and capital is scarce relative to labour. Under this view as reflected by Binswanger, tractors and bullocks are seen as two different power sources which technically are perfect substitutes and the switch from animal power to tractor power is primarily guided by factor prices or factor scarcities. If the opportunity cost of labour (measured either by wage rates or by man/land ratios) and the cost of maintaining bullocks become sufficiently high, it will make sense to shift to tractors. The argument seems to be reinforced by the fact that farm mechanization in the developed countries has taken place primarily as a result of high and rising wage rates. This school of thought advocates tractorization at a future date in the developing world when wages rise to higher level.

Despite the evidence from the developed world, the regular spread of tractorization in low labour wages countries, such as India, Pakistan, and Nepal, raises doubt about the validity of the argument and suggests that tractors have been privately profitable at the prices and incentive structures under which they were bought. However, if wages are not high, what are the sources of private profitability ? Of the many probable sources identified by the other school of thought known as the Net Contributor view; increased yields and cropping intensity, timeliness of farm operations, displacement of less productive bullocks, deeper tillage, and increased efficiency could be listed as the important ones. Under this view, speedy power is crucial to agricultural production almost regardless of factor prices. According to Binswanger more sophisticated substitution view, which takes into account the output effect of cost changes, agrees with the net contributor view that production effects are possible; but it would insist that such productivity responses to tractors, at the farmer's level, are only possible if the tractor does indeed reduce production costs. Tractors can be an important engine of growth, provided that animal power costs and wage rates are rising.

While important income distribution and social profitability issues are also associated with tractorization, this paper addresses two questions pertaining to the source of private profitability of tractor ownership. Does tractorization facilitate in timeliness of farm operations ? Are tractorized farms more efficient than traditional ones ?

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DATA AND ANALYTICAL APPROACH

Two sets of data from two different time periods are used in this paper. Also, a combination of tabular analysis, production function and profit function approaches are utilized in analysing the data. The first set of data utilized for tabular analysis and production function approaches was gathered in connection with the other study carried out by the author. In the study, five different types of farms - traditional, tractor owning, tractor and pumpset owning, tractor hiring, and pumpset owning - were identified. A simple size of 20 or 21 was randomly chosen from each of the specified types of farms, and a total of 103 farmers of Bara district were interviewed to gather necessary data for the period November 1974 to December 1975. The production function utilizes data on rice and wheat only since these are the most important crops of the district and over 50 percent of the total tractor power was used in cultivating these two crops.

Similarly, the estimation of profit function in this study is based on the data collected by interviewing 200 wheat farmers of Bara district for 1979 wheat season. Again the data utilized here represents only a fraction of the total data collected in connection with other study conducted by the author. The results obtained from the use of two sets of data from two different time periods and analyzed by adopting two different models should permit us to assess whether the results obtained are stable with regards to changes in time and analytical tool.

TABULAR ANALYSIS

A look at the selected characteristics of the traditional and tractorized farms show that they differ with respect to the education of the operator, land holdings, cultivated area, area owned(Table 1). Tractorized

Table 1
General Characteristics of Sample Farmers

Characteristics	Traditional	Tractor owning	Tractor Hiring	Tractor and Pumpset Owning
Education (yrs)	3.8	7.0	6.7	7.9
Farming experience (yrs)	19.1	15.9	13.2	13.2
Land holdings (ha.)	5.9	32.1	9.4	25.0
Cultivated area (ha.)	5.3	21.1	6.2	21.6
Owned area (ha.)	3.9	29.6	9.3	24.5
Leased area (ha.)	0.4	2.5	0.0	0.5
Area Tenanted (ha.)	1.6	0.0	0.1	0.0
Land fragments/area cultivated (no)	1.2	0.4	1.5	0.5

Source: Pudasaini, 1976

farms are operated by farmers with higher education than the traditional ones. Tractorized farmers, particularly those owning tractors, had larger holdings and cultivated areas than the latter. While 90 percent of the tractorized farmers were full owners of land, only 40 percent of traditional farmers were full owners. The problem of land fragmentation was much severe among taditional farmers than the tractor owning categories. The use of modern inputs per hectare per year was much higher in tractorized farms (Rs. 652) than in traditional ones (Rs. 63).

Pattern of Tractor Use

A total of 930 hours of tractor power was utilized by tractor owners for various purposes annually. Almost 60 percent of tractor time was used in rice and wheat cultivation, 18 percent for transportation, 10 percent for rental work and the remaining hours were used in other crops and activities. The level of tractor use in on-farm activities was positively related to own crop area served by farmers, while the rental work done was inversely related to it. This was particularly true of tractor owners who cultivated only upto 24 hectares. This indicates that the tractor owners with smaller land holdings were aware of the reality that they must employ tractors in higher rental use if their investment was to be profitable. On the other hand, tractor use for personal transportation purposes such as input procurement, output disposal, movement of personal effects exhibited no clear relationship with the size of crop area served.

Motivation for Using Tractor

Compatibility with planting reasons is achieved and hard land preparation work is greatly eased if tractors are used, even if only for one or two passes of plowing. Improved quality and better timeliness of land preparations were mentioned as the first reasons for using tractors by 38 percent of the tractor owner, while almost the same percentage mentioned the difficulty in maintaining bullocks as the key motivational factor. The remaining users reported labour shortage, ease and speed as the other motivational factors. In terms of planting schedule, 62 percent of rice growers and 91 percent of wheat farmers reported that they were able to plant the crops earlier than their neighbours after acquiring tractor while only 14 percent of them were able to do so before availing tractor power.

Tractor owning farms employed 27.4 man-days (18 percent) more of human labour per hectare per year than traditional farms. They had higher cropping intensity and higher yield (rice 59 maunds per hectare and wheat 65 maunds per hectare) than traditional farmers (rice 46 maunds and wheat 53 maunds per hectare). Income per hectare or per man/days of labour was also higher in tractorized farms than in traditional ones.

Bullock Use

One of the clear impact of tractorization can be seen both in the significant reduction of bullock use and reduction in the number of bullocks maintained. Bullock use per hectare per year was 59.9 days, 58.8 days, and 9.8 days lower in tractor owning, tractor and pumpset owning, and tractor hiring farms than in traditional ones. Besides, the number of bullocks maintained by tractor owning farmers and tractor and pumpset owning farmers after tractorization of their farm operations was 73.7 percent and 63 percent lesser respectively (Table 2). Lower degree of displacement of bullock labour and lower reduction in the number of bullocks

Table 2
Number of Bullocks Maintained by Mechanized Farmers Before and After Tractor Use

Farm Type	Before	After	Decrease	
			No.	Percent
Tractor Owning Farm	11.4	3.0	8.4	73.7
Tractor and Pumpset Owning Farm	10.0	3.7	6.3	63.0
Tractor Hiring Farm	3.7	3.5	0.2	5.4

Source: Pudasaini, 1976.

(5.4 percent) was observed in tractor hiring farms. The lower displacement of bullock labour in tractor hiring farms relative to the tractor owning categories is reasonable since the former uses insignificant amount of tractor power annually as compared to the latter. Consequently, disposal of slow and less efficient bullocks appears to be one source of private profitability of tractor ownership.

PRODUCTION FUNCTION APPROACH

Farm income is a function of farm production and productivity which, in turn, is a function of the level of technology and proper allocation of resources. Improvements in technology - biological, chemical and mechanical - increases production efficiency, thus, shifts the production function upward whereas proper allocation of resources enables producers to take advantage of the best possible alternatives.

Farm mechanization brings forth a change in the level of technology directly and also through inducing biological and chemical innovations. Since the agricultural production function combines land, labour, capital and technology in a manner supervised by the farmer acting in his role as a manager, change in the level of technology has two important mutually reinforcing influences on the level of production. Firstly, it has the potential of raising the productivity of the existing set of conventional inputs of agricultural production. This potential emerges from the complimentary relationship it has with conventional inputs. Secondly, with the marginal productivity of conventional inputs raised, there develops an incentive for the increased application of the existing stock of conventional inputs. Increase in labour productivity in agriculture depends on relative use of complimentary inputs, namely land and capital, their respective productivity. With the limited physical land and abundant labour, growth of agriculture via increase in labour and land productivities ultimately depends on the rate and efficiency of capital investment in agriculture. Production function reflects the notion that the physical quantity of output depends on the quantities of productive services or inputs employed in the production process and the efficiency with which they are utilized.

In order for estimating the contribution of various inputs to rice and wheat production and assessing relative efficiency differences between traditional and tractorized farms a log - linearized Cobb-Douglas type function was estimated by pooling data for all the specified types of farms:

$$LnY = lna + \sum_{i=1}^{5} bi\ lnXi \qquad (1)$$

where, Y = gross value of the total production of rice and wheat per farm in rupees X1 = land in bighas, X2 = human labour in man/days, X3 = bullock labour in days, X4 = tractor use in hours, and X5 = expenses on fertilizer in rupees.

Since the specified types of farms differed from each other in terms of tractor or pumpset use, they can be expected to differ from each other in terms of efficiency. Consequently, the following model with shift dummies was also estimated.

$$\ln Y = \ln A + \sum_{i=1}^{5} bi\ \ln xi + \sum_{j=2}^{5} djDj \qquad (2)$$

where, D2 = 1 if tractor owners, 0 otherwise
D3 = 1 if tractor and pumpset owners, 0 otherwise
D4 = 1 if tractor hirers, 0 otherwise
D5 = 1 if pumpset owners, 0 otherwise

Tractors and bullocks are substitutes for a range of operations and one of the impacts of tractorization is replacement of bullocks. But, farmers maintain a few bullocks and use them in cultivation even after tractorization as an insurance against risk of tractor breakdown. To determine whether tractor and bullocks are substitutes and whether bullocks are used redundantly, the following function introduction slope dummies (SD) was also estimated.

$$\ln Y = \ln A + \sum_{i=1}^{5} bi\ \ln Xi + \sum_{j=2}^{5} dj\ Dj + \sum_{X=2}^{3} C_x\ SD_k \qquad (3)$$

where, (D2 x ln X4) = SD2 = bullock labour slope dummy for tractor owners

(D3 X ln X4) = SD3 = bullock labour slope dummy for tractor and pumpset owners.

RESULTS

The parameters of the estimated equations 1, 2 and 3 are presented in Table 3. The regression coefficients from equation (1) show that land (X1) and human labour (X2) were the most important factors in the production of rice and wheat since their coefficients are significantly positive and have larger magnitude than coefficients of any other factors. Similarly, the positively significant coefficients for tractor (X4) and fertilizer (X5) shows that these resources positively contributed to the total

Table 3
Production Function Estimates

Independent Variables		Regression Coefficients in Equations 1	2	3
X1	Land	0.629 (9.5)	0.634 (9.5)	0.623 (9.5)
X2	Human Labour	0.197 (2.5)	0.194 (2.8)	0.144 (2.1)
X3	Bullock Labour	0.017 (8.9)	-0.023* (1.1)	0.124 (2.0)
X4	Tractor Use	0.058 (2.8)	0.033* (1.1)	0.054 (1.8)
X5	Fertilizer	0.054 (4.0)	0.035 (2.1)	0.034 (2.1)
Shift Dummies				
D2	Tractor Owner	--	0.251* (1.2)	1.053 (2.5)
D3	Tractor and Pumpset Owner	--	0.345 (1.7)	1.332 (3.2)
D4	Tractor Hirers	--	0.135* (1.2)	0.114* (1.0)
D5	Pumpset Owners	--	0.254 (2.1)	0.246 (2.1)
Slope Dummies				
SDB2		--	--	-0.148 (2.1)
SDB3		--	--	-0.195 (2.8)
Intercept		6.756 (19.0)	6.812 (19.0)	6.313 (17.0)
R^2 (adjusted)		0.91	0.91	0.92
Number of observations		103	103	103

The figures in parenthesis are "t" values.
*Not significant at even 10 percent level.

production of rice and wheat. However, contrary to expectation, the coefficient for bullock labour is negative. This might be due to incomplete specification of equation (1) since it was estimated by pooling the data for all five specified types of farms together without including variables that could take into account existing differences among the types of farms in terms of mechanization and other factors. Thus, equation (2), which included shift dummies to account for the difference, should provide better outcome. The results from this equation supports the finding that land and human labour were the most important resources and also maintains that expenditures on fertilizers positively contributed to rice and wheat production. But, unlike (1), it (2) shows that the contribution of bullocks was not negative but significantly different from zero.

While it is a marked improvement over a significantly negative bullock coefficient, it does not seem to be truly believable not to have positive contribution of bullocks in the case of traditional farmers or pumpset owners or tractor hirers since bullocks were the most important source of power for their land cultivation. Nonetheless, it is plausible to have redundant use of bullock in the case of tractor owners and tractor and pumpset owners if they do not dispose of the larger numbers of bullocks they were maintaining before acquiring tractors. Equation (3), which includes slope dummies was better specified to take care of even this problem. As usual, the results from equation (3) also maintain that land and human labour were the two most important factors in the production of rice and wheat. Similarly, it supports that the contribution of tractor labour and fertilizer was positive. But, unlike earlier equations it shows that bullock labour positively contributed in the case of traditional farmers, pumpset owners, and tractor hirers while the contribution of bullocks was negative in the cases of both tractor owners (B4 - SDB2 = -0.024) and tractor and pumpset owners (B4 - SDB2 = -0.071), suggesting redundant bullock use in the two latter types of farms.

The coefficients for all shift dummies are positive indicating that mechanized farms are technically more efficient than traditional ones. The coefficient of the dummy for tractor and pumpset owners is larger in magnitude than that for tractor owners or pumpset owners alone. This suggests that a mechanization strategy that combines better land preparation facility (tractor) with irrigation (pumpset) is likely to be more efficient than either of them alone. The coefficient of the shift dummy only for tractor hirers is insignificant and smaller in magnitude than the coefficients of the shift dummies of both tractor owners and tractor and pumpset owners, respectively. This leads to the suggestion that (1) availability of adequate and speedy tractor power facilitates in timeliness of farm operations and improve efficiency but (2) occasional use may not significantly improve efficiency of the users relative to the traditional farmers. Evidently, most of the farm operations, such as land preparation, threshing, input and output transportation involving tractor use, occur during a particular period of the year, during which the owners and hirers need tractor service. Clearly, tractor owners give first priority to their own farm work and rent them out only when they are finished with their cultivation. Consequently, the tractor hirers do not get tractor service at the right time and in adequate quantity and are unable to reap as much benefit as tractor owners in terms of efficiency resulting from timeliness. However, one must be cautious in attributing higher efficiency in the case of tractor owners and tractor and pumpset owners solely to tractor and/or pumpset because (1) these farmers had larger land holdings, (2) were generally better educated, and (3) were users of larger quantities of other improved inputs as compared to tractor hirers or traditional farmers. Despite these facts, it must be recognized that it would have been extremely difficult for the bigger farmers to complete their farm operations in time without tractor labor. Thus, timeliness and, in turn, efficiency resulting from tractor ownership cannot be completely ruled out as a source of private profitability even after other factors are accounted for.

In short, one of the factors for the regular spread of tractorization in low wage and capital scarce economies, such as Nepal, seems to be the contribution of tractors to timely completion of farm operations. Through timeliness and, most probably, deep and thorough land preparation and replacement of less productive bullocks, tractors have contributed to increasing efficiency of tractorized farms. A mechanization strategy combining both tractors and pumpsets leads to higher efficiency than with either of them alone since it permits to combine timeliness of farm operations with better irrigation and other input package.

PROFIT FUNCTION ANALYSIS

Certain characteristics make profit function model methodologically more flexible than and statistically superior to the production function model. Of the attributes, two may be worth referring in the context of this paper. A restricted normalized profit function model, which is a function of the quantities of fixed factors and the prices of variable inputs and in which profit and factor demand functions are generally jointly estimated, yields statistically consistent estimates while a production function estimated by OLS may result in a simultaneous equation bias and inconsistency. Also, it takes into account differences in technical efficiency, allocative efficiency and effective prices, and permits to test efficiency differences between groups such as tractorized vs bullock operated traditional farms.

The Normalized Restricted Profit Function

The normalized restricted profit function is assumed to be a function of the normalized prices of variable inputs (hired labor, bullock, and fertilizer), the quantities of fixed inputs (land, family labor, capital), and environmental variables (education, age, extension).

The following specification of the normalized restricted profit function (4) and input demand function (5-7) for hired labor (NH), bullock (B) and fertilizer (F) for wheat are estimated.

(4) $$\ln \pi^* = \ln A^{*W} + \delta^T D^T + \alpha_N^* \ln pn + \alpha_B^* \ln p_b + \alpha_F^* \ln p_f + \beta_L^* \ln L + \beta_N^* \ln NF + \beta_k^* \ln k + \beta_A^* \ln A + \beta_E^* \ln E + \beta_X^* \ln X$$

(5) $$-\frac{P_n \cdot NH}{\Pi^*} = \alpha_N^{*T} DT + \alpha_N^{*W} DW$$

(6) $$-\frac{P_b \cdot B}{\Pi^*} = \alpha_B^{*T} DT + \alpha_B^{*W} DW$$

(7) $$-\frac{P_f \cdot B}{\Pi^*} = \alpha_F^{*T} DT + \alpha_F^{*W} DW$$

where, Π^* is a restricted profit normalized by the wheat price. The restricted profit is the difference between total wheat revenue (P.Y) minus the cost of variable inputs of hired labour, fertilizer and bullock. Y is wheat output in quintals. Py is wheat price per quintal. The variables Pn. Pb. and Pf are respectively price of labour, bullock and fertilizer normalized by wheat price L is the market value of land under wheat cultivation in rupees. NF is manyears of available family labour. K is capital (12 percent of the total value of tools, equipments and machinery) in rupees. A is farm operators age in years. DT is 1 if farmer using tractor in wheat production and zero otherwise. DW is 1 if farmer not using tractor in wheat production and zero otherwise. X is number of extension contacts in wheat crop season. E is number of years of schooling of wheat farm operators. Superscripts T and W denote tractorized and non-tractorized (traditional bullock operated) wheat farmers respectively.

Test of Profit Maximization and Relative Efficiency

Economic efficiency consists of two components: technical and allocative (price) efficiency. Farmers are allocatively efficient if they maximize profit (i.e. equate marginal value products of variable inputs to their respective opportunity costs) and the maximization of profit is referred to as absolute allocative efficiency in this paper. The hypothesis that both tractorized and non-tractorized farmers are absolute allocative efficient is tested by imposing restriction (8) in (4-7).

(8) $$Ho: \alpha_N^* = \alpha_N^{*T} ; \alpha_B^* = \alpha_B^{*T} ; \alpha_F^* = \alpha_F^{*T}$$

$$\alpha_N^* = \alpha_N^{*W} ; \alpha_B^* = \alpha_B^{*W} ; \alpha_F^* = \alpha_F^{*W}$$

The hypothesis (8) can be rejected if either one of the group fails to maximize profits. Thus, the hypothesis is that the tractorized farmers are absolute allocative efficient.

(9) $$Ho: \alpha_N^* = \alpha_N^{*T}; \alpha_B^* = \alpha_B^{*T}; \alpha_F^* = \alpha_F^{*T}$$

and that the non-tractorized wheat farmers are absolute allocative efficient

(10) $$Ho: \alpha_N^* = \alpha_N^{*W}; \alpha_B^* = \alpha_B^{*W}; \alpha_F^* = \alpha_F^{*W}$$

are also tested separately to distinguish whether the tractorized or the non-tractorized farmers fail to maximize profits. As discussed earlier, the profit function approach permits testing of a relative economic efficiency difference between the tractorized and non-tractorized wheat farmers by taking into account the differences in technical efficiency, allocative efficiency and in effective prices. The hypothesis of equal relative economic efficiency of tractorized and non-tractorized farmers can be tested by statistically assessing whether tractor dummy variable (δ^T) in (4) is equal to 0:

(11) $$Ho: \delta^T = 0$$

Since higher economic efficiency of tractorized farmers can emanate from their being technically and/or allocatively more efficient than the non-tractorized farms, the hypothesis of the equal relative allocative efficiency:

(12) $$Ho: \alpha_N^{*T} = \alpha_N^{*W}, \alpha_B^{*T} = \alpha_B^{*W}, \alpha_F^{*T} = \alpha_F^{*W}$$

and that of the equal relative allocative and technical efficiency:

(13) $$\delta^T = 0 \quad \text{and}$$

$$\alpha_N^{*T} = \alpha_N^{*W}; \alpha_B^{*T} = \alpha_B^{*W}; \alpha_F^{*T} = \alpha_F^{*W}$$

are also tested to determine whether the higher relative economic efficiency of the tractorized farms emanate from their being allocatively and/or technically more efficient than the non-tractorized farms.

Since the issue of returns to scale has important policy implications the hypothesis of constant returns to scale:

(14) $$Ho: B_L^* + B_K^* + B_N^* = 1$$

is tested to determine if the returns to scale in wheat farming is constant or not.

Profit Maximization and Relative Efficiency

The F-ratios computed for testing hypothesis of absolute allocative efficiency (profit maximization) and constant returns to scale are reported in Table 4. The hypothesis that the tractorized wheat farmers are absolute price efficient, that the non-tractorized farmers are absolute price efficient, and that both the tractorized and non-tractorized farmers are absolute price efficient, are not rejected.

Table 4
Tests of hypotheses of absolute allocative efficiency and constant returns to scale of tractorized and non-tractorized wheat farms

Hypothesis	Computed F-ratios	Critical F-ratios at 5 percent level of significance
Absolute price efficiency of tractorized farms	F(3.783) = 0.517	F(3,∞) = 2.60
Absolute price efficiency of non-tractorized farms	F(3.783) = 0.401	F(1,∞) = 3.84
Absolute price efficiency of both tractorized and non-tractorized farms	F(3.783) = 1.419	F(6,∞) = 2.10
Constant returns to scale	F(1.783) = 0.012	

Table 5
Tests of hypotheses of relative economic efficiency of tractorized and non-tractorized wheat farms

Hypothesis	Computed F-ratios	Critical F-ratios at 5 percent level of significance
Equal relative economic efficiency	F(3.783) = 5.09	F(1,∞) = 3.84
Equal relative allocative efficiency	F(3.783) = 2.38	F(3,∞) = 2.60
Equal relative allocative and technical efficiency	F(4.783) = 2.94	F(4,∞) = 2.37

The tests indicate that both the tractorized and non-tractorized wheat farmers were able to maximize profit in the sense of equating the marginal value products of variable inputs (hired labour, bullock, and fertilizer) to their respective opportunity costs in wheat production in the 1979 wheat season (January-April 1979). Since both tractorized and non-tractorized farmers were able to maximize profits, the tests imply that tractors do not necessarily improve the allocative efficiency of farmers. Also, the hypothesis of constant returns to scale is not rejected at 1 or 5 percent level indicating that wheat production in Bara District can be increased proportionately by increasing all the inputs by a given proportion.

Similarly, the F-ratios computed for testing hypothesis of relative economic efficiency of tractorized and non-tractorized wheat farmers are presented in Table 5. The hypothesis of equal relative economic efficiency is rejected in favour of higher economic efficiency of tractorized wheat farms at 5 percent level. Tractorized farmers can attain higher economic efficiency by being allocatively and/or technically more efficient than non-tractorized farms. Thus, two more hypothesis are tested to determine whether the higher economic efficiency of the tractorized farms resulted from their being allocatively and/or technically more efficient than the non-tractorized farms. Of the two, the hypothesis of equal relative allocative and technical efficiency is rejected at 5 percent level. The further tests demonstrate that the tractorized and non-tractorized wheat farmers are equally price or allocative efficient but the former surpasses the latter in terms of technical efficiency. In other words, the tractorized wheat farms are more economic efficient relative to the non-tractorized farms. The higher relative economic efficiency of the tractorized farms emanates from their being technically (rather than allocatively) more efficient than the non-tractorized farms. The tests of absolute and relative efficiency hypotheses leads to the conclusion that tractors improved wheat production in Bara by helping farmers to shift their production function upward (technical efficiency) but not by enhancing their decision making ability (allocative efficiency).

The Parameters from Profit Functions

The parameter estimates based in the joint estimation of profit and input demand functions are reported in Table 4. The first column presents the parameters estimated by Zellner's seemingly unrelated regression method by imposing restriction that tractorized farms are absolute allocative efficient. The second column presents the estimates obtained by imposing the restrictions that non-tractorized farms are absolute allocative efficient. In the third column, the estimates derived by imposing linear constraints implied by the hypothesis that both tractorized and non-tractorized farms are absolute allocative efficient are reported. Lastly, in the fourth column, the parameters estimated by Zellner's method by imposing linear restrictions implied by constant returns to scale and absolute allocative efficiency of both types of farms is contained. The parameter estimates of the normalized restricted profit function must satisfy the conditions of monotonicity (decreasing) and convexity in the normalized prices of inputs and monotonicity (increasing) and quasiconcavity in the quantities of the fixed resources.

The parameter estimates of all factors, except for extension, have expected signs (Table 6) which suggests that the profit function model

Table 6
Estimates from the Joint Estimation of Profit and Input Demand Functions for Wheat

Profit Function		Seemingly Unrelated Regression Estimates With Restrictions*			
Variables	Parameters	1	2	3	4
Constant		-9.687	-9.625	-9.807	-9.789
		(1.137)	(1.268)	(1.052)	(1.042)
Land (L)		0.751	0.753	0.751	0.750
		(0.061)	(0.061)	(0.061)	(0.057)
F Labour (NF)		0.169	0.169	0.169	0.164
		(0.102)	(0.102)	(0.102)	(0.052)
Capital (K)		0.086	0.085	0.085	0.086
		(0.030)	(0.030)	(0.030)	(0.029)
Education (E)		0.077	0.077	0.076	0.077
		(0.073)	(0.073)	(0.073)	(0.070)
Extension (X)		-0.097	-0.093	-0.095	-0.095
		(0.077)	(0.077)	(0.077)	(0.077)
Age (A)		0.021	0.018	0.020	0.022
		(0.173)	(0.174)	(0.174)	(0.166)
H Labour (Pn)		-0.270	-0.329	-0.307	-0.306
		(0.070)	(0.184)	(0.056)	(0.056)
Bullock (Pb)		-0.379	-0.610	-0.495	-0.494
		(0.113)	(0.133)	(0.091)	(0.091)
Fertilizer (Pf)		-0.390	-0.209	-0.339	-0.338
		(0.108)	(0.129)	(0.086)	(0.086)
Tractor (TD)		0.312	0.267	0.225	0.224
		(0.129)	(0.124)	(0.109)	(0.108)
Input Demand Function					
Labour		-0.270	-0.290	-0.307	-0.306
		(0.070)	(0.076)	(0.056)	(0.056)
		-0.371	-0.329	-0.307	-0.306
		(0.093)	(0.084)	(0.056)	(0.056)
Bullock		-0.379	-0.414	-0.495	-0.494
		(0.113)	(0.125)	(0.091)	(0.091)
		-0.685	-0.610	-0.495	-0.494
		(0.153)	(0.133)	(0.091)	(0.091)
Fertilizer		-0.390	-0.424	-0.339	-0.338
		(0.108)	(0.117)	(0.086)	(0.086)
		-0.273	-0.209	-0.339	-0.338
		(0.143)	(0.129)	(0.086)	(0.086)

The numbers in parentheses are standard errors of the estimates.

*The equations 1,2 and 3 are estimated by imposing hypotheses 9,10 and 8 respectively. The equation 4 is estimated by jointly imposing hypotheses 8 and 14.

estimated by imposing restrictions is well behaved. The estimates display that all inputs except extension have a positive contribution to wheat production. It demonstrates further that land, family labour, hired labour, bullock, fertilizer and capital are important inputs in wheat production. Education is also an important contributor to wheat production while operator's age (a proxy for experience) does not appear to be crucial. The coefficient for tractor dummy variable (DT) indicates that tractorized wheat farms are technically more efficient than the non-tractorized ones.

CONCLUDING REMARK

In the case of Bara District, Tractor Ownership allowed large farms to achieve and surpass cropping intensity levels otherwise associated with small bullock farms. It has also allowed them to almost fully eliminate bullocks. Tractor farmers reported deeper and quality land preparation and a higher degree of timeliness in farm operations. While on farm labour displacement did not seem to be large, this does not however imply that tractor do not displace labour from a broad societal point of view since the large amount of capital invested in tractors did not create as much employment as the pumpsets. Crop yields were higher in tractorized farms. But such farms were using higher levels of modern inputs, had better educated operators and contained less fragmented larger sized holdings. Consequently, it is difficult to attribute higher yields to tractorization alone.

Economic efficiency consists of two components: allocative and technical. Tractorized wheat farms were more efficient than traditional ones due to their higher technical efficiency while they were not significantly different from each other in terms of allocative efficiency. Among mechanized farms, those owning tractor and pumpsets were more efficient than those owning either tractor or pumpsets alone, indicating that a mechanization strategy combining speedy cultivation technology (tractor) and irrigation (pumpset) facility is better than one emphasizing on either alone. Tractor hiring farms were not significantly different from traditional farms in terms of even technical efficiency. Returns to scale in the wheat farms of Bara was unity indicating that a proportional increase in the use of a package of inputs would raise wheat output proportionately.

In the final analysis, the source of private profitability of tractor ownership in the case of wheat farms of Bara District appear to be (a) increased technical efficiency,(b) improved timeliness of operations and increased cropping intensity of large farms, (c) replacement of less efficient bullocks. In addition, tractorization may also have contributed somewhat to yield improvement through timely and quality farm operations and also through inducing increased use of improved inputs. Nonetheless, a majority of farms in Nepal are small and timeliness was not a very important premium for the second crop on small farms. Yield and intensity levels of small farms are also observed to be high even without tractors. Consequently, a mechanization policy that places only very limited emphasis on tractorization to enable a small number of larger farmers to achieve greater efficiency and much greater emphasis on irrigation facilities (pumpsets, tubewells etc.) that benefits a large majority of small farmers appear appropriate. The author in his paper "Farm Mechanization, Employment and Income in Nepal: Traditional and Mechanized Farming in Bara District" reflects that if the capital invested in tractors had been invested in additional irrigation facilities, labour requirement would have increased more. Considering the foregone opportunities for employment creation, as well as potential for on-farm displacement, investment on mechanization of irrigation facilities rates priority in the context of low wage (labour abundant), capital-scarce economies such as Nepal.

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