The Marginal Productivity of Inputs and Agricultural Production in Nepal

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In Nepal, agricultural technology has been relatively stagnant and farmers have been forced to apply more and more of their traditional inputs to production on the land. Since there are few alternative economic opportunities, it is possible that the marginal products of these inputs may be zero. A modified form of a VES production function is applied to cross-sectional data on Nepalese farmers in order to test this proposition.

I

In the rural areas of many less developed countries, the farmers are constrained to use traditional inputs[1] within the context of a traditional technology.[2] As rapid population growth occurs, farmers in these areas are forced to use land of poor quality and, in the absence of innovation, to apply the traditional technology in a more intensive manner. Thus one would expect the marginal productivity of the traditional inputs to be driven to very low levels, possibly even to zero.

The idea of zero marginal productivity for an input is not a new idea in economics. Of course, the model of dualistic development constructed by Arthur Lewis assumed that the marginal product of labour in the traditional sector is driven down to zero [6], perhaps even to a negative level.[3] This part of his model created a great deal of controversy at both the theoretical and empirical levels. At the theoretical level, many economists found it hard to understand why labour whose marginal product was zero or very close to zero would be paid a positive wage. Of course, if one includes only economic variables and assumes that the farmer is a profit maximizer then it is difficult to understand why anyone whose marginal

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[1] By traditional inputs we mean the use of inputs such as bullocks, farm-produced manures, etc.

[2] The term traditional technology is drawn from the work of Theodore Schultz [9].

[3] It should be pointed out that when Lewis discussed the possibility of labour's marginal product being zero, he was referring to the marginal product of a labourer, not to a man-hour of labour. More specifically, the marginal product of an individual labourer may be zero while the marginal product of a man-hour of labour may be positive. For a detailed discussion of the importance of such a distinction, see A. K. Sen [10].

product is zero or close to zero would be hired at a positive wage. However, if indeed there are few alternative opportunities and if the well-being of family members is a factor in the utility function of the farmer, then it is logical to argue that individual family members whose marginal product is very low or zero would be employed by the head of the family with the effective wage exceeding marginal productivity.

In an agricultural sector characterized by traditional technology, it is also likely that the marginal productivity of other traditional inputs would be driven to low levels, although it is unlikely that they would be zero or negative. This would occur if there were few alternative uses for the traditional inputs and if rapid population growth were forcing a more intensive application of traditional technology in a land-scarce agricultural sector.

A previous analysis of the situation in agriculture in Egypt, conducted by one of the authors of this paper, did seem to show that the marginal product of labour was indeed negative [1]. This was attributed to the lack of alternative opportunities for labour, scarce land, rapid population growth, and stagnant technology. The purpose of this paper will be to determine whether the marginal products of inputs used in Nepalese hill agriculture are very close to zero or possibly even negative. In order to do this, a relatively new form of production function will be estimated for cross-sectional data drawn from the Nuwakot District in Nepal. In this region, as in much of Nepal, traditional technology dominates and rapid population growth has forced an increasingly intensive application of traditional technology.

The second section will present a brief discussion of the characteristics of the Nepalese agriculture and the characteristics of the Nuwakot District. In addition, the data source and method of collection will also be discussed. In Section III, the modified VES production function to be estimated will be discussed in some detail. In Section IV, the results of the estimation will be presented and discussed, while Section V will summarize the paper.

II

Nepal can be divided into three major ecological and topographical zones: the mountains in the north, the hills in the middle, and the plains in the south. Situated at an altitude exceeding 3000 metres, the mountain region is mainly rugged and barren and accounts for 34.4 percent of the total area. The hill region, lying between 900 and 3000 metres, contains agricultural land and good pasture and occupies 44.2 percent of the total area. The terai region, below 300 metres, is mostly flat and accounts for 21.4 percent of the total area.

Nepal is one of the least developed countries of the world. The per capita income of US $ 120 is among the lowest for less developed countries. It has a population of 13 million and a population density of 1500 per square kilometre of

arable land. The pressure of population is severe in the hills and mountain areas where food deficiencies persist for one to seven months [3, p. 399].

The Nepalese economy is predominantly an agricultural economy. This sector accounts for 69 percent of the national product, 90 percent of the employment, and 80 percent of the export trade [11, p. 263]. Hill agriculture in Nepal is characterized by small fragmented land holdings, low productivity, and traditional technology. The average size of landholdings in the hills is less than one hectare. Maize and millet are the major crops grown in the hill areas. Other crops are rice, wheat, potatoes, barley, oilseeds, soya bean, and vegetables. Over the 1967–77 period, the yield for maize in Nepal declined from 1.81 metric tons to 1.79 metric tons per hectare [11, p. 263]. For other crops as well, yield increases have been sluggish or non-existent.

The problem of low productivity is very serious in the hills where, in certain areas, productivity has deteriorated over time. This is because the pressure of population growth has forced an extension of farming to marginal land that should never have been brought under cultivation. This, together with the deforestation of land in the hills and mountains, has contributed to the loss of topsoil and, in some areas, the loss of arable land due to soil erosion.

Hill agriculture in Nepal is characterized by traditional technology. The most abundant input is labour, with bullocks being used mainly for ploughing the land. The use of improved seeds and chemical fertilizers is very limited owing to high transportation costs, unavailability of farm credit, and the unavailability of the inputs themselves.

The specific area in the hill region that this study concentrates on is the Nuwakot District, which lies in the middle hills of Nepal. The district is one of the 75 administrative and 50 hill-region districts of Nepal. The district lies from 15 to 35 miles northwest of the nation's capital, Kathmandu. It has 50 village panchayats (local administrative units), each containing 250 to 1000 households and 1,000 to 5,000 people. In 1974-75 the total land area in the district was 2227 square miles and the population density was 3332 persons per square mile.

The data for this study came from a 1974-75 survey [2] of 600 farm families from six village panchayats representing the full range of climate, soil types, and altitude of the Nuwakot District. The households in the sample owned either upland or lowland or both. The main crops grown in the upland were maize and millet and in the lowland paddy and wheat.

The technology used in this district is basically traditional in nature. Land is the most limiting factor of production with average landholding per family of only 0.47 hectares. In addition, it would seem that there are few alternative opportunities available to farmers. Thus this district has the characteristics which would lead one to think that the marginal products of traditional inputs to land would be very low,

perhaps zero or negative in the case of labour. In order to determine whether this is so, a relatively new form of production function will be estimated. The characteristics of this function will be discussed in the following section.

III

In order to analyse the marginal products of traditional inputs in the Nepalese agriculture, a modified VES production function [8] will be used. An example of the basic form of the VES function that will be employed is

$$Y \quad = \quad A[X_1 - \gamma X_2]^{\alpha}[X_2 - \delta X_1]^{1-\alpha}, \tag{1}$$

$$\text{if } [X_1 - \gamma X_2] \text{ and } [X_2 - \delta X_1] > 0,$$

$$0 \text{ otherwise},$$

where X_1 and X_2 represent two inputs, Y represents output, $A > 0$, $0 < \alpha < 1$ and it is expected that γ and $\delta > 0$. This is slightly different from the traditional VES function, since to a limited degree negative marginal products (and a negative elasticity of substitution) are allowed.[4]   This difference is due to the use of the constraint that $(X_1 - \gamma X_2)$ and $(X_2 - \delta X_1) > 0$ (or equivalently $\gamma^{-1} > X_2/X_1 > \delta$) instead of the more usual constraint that $((1-\alpha + \gamma \alpha \delta)/\gamma > X_2/X_1 > (\alpha + \delta(1-\alpha)\gamma)/\delta$. However, this modification has the advantage of providing a simple test for input congestion (if the marginal product of an input is negative, congestion is indicated).

The modified VES function used in this paper is, like all VES functions, weakly disposable.[5]   Weak disposability[6] is indicated by the parameters γ and δ being greater than zero. This characteristic means that if both inputs increase proportionately, *ceteris paribus,* output will *not decrease,* and if one input increases, *ceteris paribus,* output *may decline.* This is in contrast to a strongly disposable function where if both inputs increase proportionately, *ceteris paribus,* output *will increase,* and if one input increases, *ceteris paribus,* output will *not decrease.* Clearly

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[4] The elasticity of substitution can as a result also become negative. However, since the marginal product of both inputs cannot be negative at the same time, a positive elasticity of substitution implies that one is operating in the efficient portion of the isoquant.

[5] For a good discussion of weak disposability and a proof that the VES function is weakly disposable, see R. Färe and L. Jansson [4] and R. Färe and Bong Joon Yoon [5].

[6] Mathematically, for a production function ϕ with inputs X_1 and X_2 to be weakly disposable $\phi(\lambda X_1, \lambda X_2) > \phi(X_1, X_2)$ for all $\lambda > 1$. In contrast, for a strongly disposable function, $\phi(X_3, X_4) > \phi(X_1, X_2)$ if $X_3 > X_1$ and $X_4 \geqslant X_2$ or $X_3 \geqslant X_1$ and $X_4 > X_2$.

if the parameters γ and δ are both equal to zero, then the VES function reduces to the traditional, strongly disposable Cobb-Douglas function. Figure 1 illustrates this point with the use of unit isoquants. The isoquant GH is strongly disposable, i.e. if X_1 is increased, then, *ceteris paribus,* output will not decrease. Thus the marginal products only asymptotically approach zero. In contrast, the weakly disposable isoquant IJ is asymptotic to the rays OA and OB (not a vertical or horizontal line) and hence has marginal products that are zero and within the range set by the rays OA and OB becomes negative. The slope of ray OB is δ and the slope of ray OA is γ^{-1}
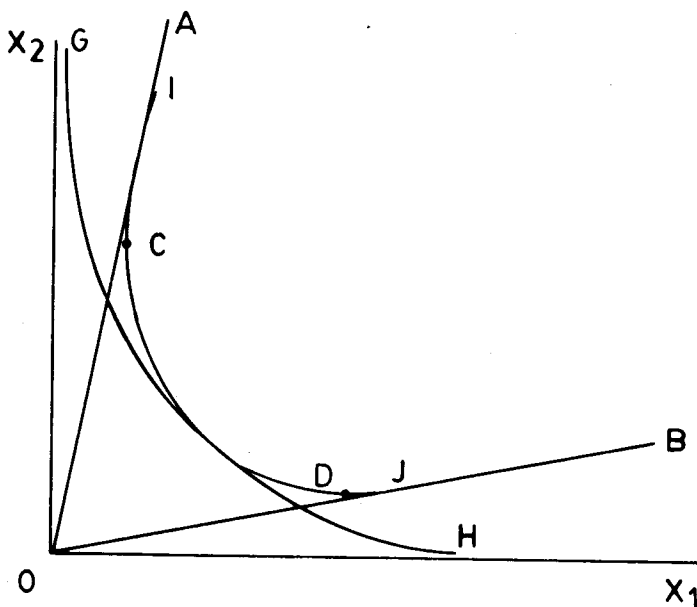

Figure 1

Two brief digressions seem appropriate. Firstly, in allowing for weak disposability, it is important to remember that what is being modelled is not the *desired* relation between inputs and output but the *observed* relation. Hence, if production in the area of negative marginal products is detected (above point C or to the right of point D) there should be no inference that this is of the producers' choice, but only that congestion has occurred (which may be due to factors outside of their control). Secondly, if producers are operating on a weakly disposable production function, this does not necessarily imply that the marginal product of some input is negative — operation between points C and D on isoquant IJ is the locus

of points where both marginal products are positive — but rather that it is possible for congestion to occur. It clearly depends on where, on the isoquant, production is occurring.

The function discussed above includes only two inputs. Within the context of agricultural production in Nepal, the function must incorporate four inputs; land, labour, bullocks, and fertilizer. Thus the form of the VES function actually estimated for Nepal can be written as

$$Y \quad = \quad A(L - \alpha_1 N - \alpha_2 B - \alpha_3 F)^{\beta_1} \, N^{\beta_2} \, B^{\beta_3} \, F^{(1 - \beta_1 - \beta_2 - \beta_3)} \quad (2)$$

$$\text{if } (L - \alpha_1 N - \alpha_2 B - \alpha_3 F) \geqslant 0,$$

$$0 \text{ otherwise,}$$

where Y, L, N, B, and F represent output, land, labour, bullocks, and fertilizer respectively. This function allows for the possibility of congestion with respect to fertilizer, labour, and bullocks. In other words, it allows for the possibility that too much of these inputs may be applied to land. Thus it allows for the possibility of zero or negative marginal products for labour, fertilizer, or bullocks. This would seem to be an appropriate specification for the situation in Nepal in the light of the discussion in the previous section.

IV

The data for estimating equation (2) is, as was discussed earlier, drawn from a survey of 600 farms conducted by Peter Calkins. Because of missing values for some farms, the actual number used in the estimation was 557. Land was measured in muri-matos (one muri-mato is equal to 1/80 hectare). Labour was measured in man-days, bullocks in days, and fertilizer in rupees. The output variable represents the sum of rice, maize, millet, and wheat production in kilograms.[7]

In order to estimate equation (2) it is assumed that it has an additive disturbance term U_t and that jointly the U_t's are independently and identically distributed with a mean of zero and a covariance matrix of $\theta^2 I$. Equation (2) was then estimated with the use of non-linear least squares. Since α_1 and α_3 were statistically insignificant, the terms involving α_1 and α_3 were dropped and the

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[7] These crops were chosen because they represent the bulk of agricultural production in this region.

equation was re-estimated.[8] The results are presented in Table 1. As can be seen, when a one-tailed t-test is used, all of the coefficients are highly significant. In addition, the estimation results imply that for the farmers in this sample the possibility of congestion exists only with respect to the use of bullocks.

Table 1

Results of the Estimation of Equation (2)

Parameter	Estimate	Asymptotic t-Ratio
A	24.24	9.50
α_2	.18	1.80
β_1	.45	8.74
β_2	.18	5.56
β_3	.24	4.88

$R^2 = .88$

In order to investigate the marginal products of each of the inputs for each of the farms, the derivatives of equation (2) with respect to land, labour, bullocks, and fertilizer must be calculated. Assuming that α_1 and α_3 are zero and taking the derivatives give

$$\frac{\partial Y}{\partial L} = A\beta_1 (L - \alpha_2 B)^{\beta_1 - 1} N^{\beta_2} B^{\beta_3} F^{1 - \beta_1 - \beta_2 - \beta_3} \tag{3}$$

$$\frac{\partial Y}{\partial N} = A(L - \alpha_2 B)^{\beta_1} \beta_2 N^{\beta_2 - 1} \beta_3 F^{1 - \beta_1 - \beta_2 - \beta_3} \tag{4}$$

$$\frac{\partial Y}{\partial B} = A\beta_1 (L - \alpha_2 B)^{\beta_1 - 1} (-\alpha_2) N^{\beta_2} B^{\beta_3} F^{1 - \beta_1 - \beta_2 - \beta_3}$$
$$+ A(L - \alpha_2 B)^{\beta_1} N^{\beta_2} \beta_3 B^{\beta_3 - 1} F^{1 - \beta_1 - \beta_2 - \beta_3} \tag{5}$$

$$\frac{\partial Y}{\partial F} = Y(L - \alpha_2 B)^{\beta_1} N^{\beta_2} B^{\beta_3} (1 - \beta_1 - \beta_2 - \beta_3) F^{-\beta_1 - \beta_2 - \beta_3} \tag{6}$$

The values of the coefficients from Table 1 were then substituted into equations (3), (4), (5) and (6). Then the quantity of each input used by each farm was substituted into the above four equations and the marginal products for all four inputs were calculated for each farm.

[8] The results of this earlier estimation are available from the authors upon request.

Given the results of estimating equation (2) presented in Table 1, it was of course not possible for the marginal products of land, labour, and fertilizer to be negative or zero. It was possible for congestion to occur with respect to the use of bullocks. However, when the calculations discussed above were undertaken, it was found that none of the inputs had zero or negative marginal products, i.e. no congestion had occurred.

In examining the marginal products more closely, it was found that the marginal products of both labour and fertilizer, although positive, were very close to zero for almost all of the farms in our sample. It must be remembered that much of th fertilizer used by these farmers is compost, not commercially produced chemical fertilizers. Thus fertilizer in the Nepalese agriculture is a traditional input as well as labour and bullocks. The marginal products for land and bullocks were much higher. The average products for all four inputs are presented in Table 2.

Table 2

Average Products for Four Inputs in the Nepalese Agriculture

Input	Average Product (Kilogram)
Land	35.83
Labour	5.69
Bullocks	89.16
Fertilizer	5.75

Thus it would seem that the Nepalese agriculture represents a form of traditional agriculture similar to that described by Theodore Schultz. The rapidly growing population, within the context of a stagnant technology, has forced the Nepalese farmers in this sample area to farm their land more and more intensively. This, combined with the fact that there are few other economic opportunities available, has forced these farmers to apply labour and traditional forms of fertilizer to the point where marginal products are approaching zero.

V

In this short paper, a brief review of the characteristics of the agricultural sector in Nepal was presented. It would seem that population has grown much more rapidly relative to the supply of arable land. Within the context of a stagnant technology, the farmers have been forced to apply more and more of their traditional inputs to production on the land. Given that there are few alternative economic

opportunities available, it was argued that the marginal products of these traditional inputs may be zero or, in the case of labour, even negative.

In order to test this proposition, a modified form of a VES production function was used. This function allowed for the possibility of input congestion. In other words, it was possible for the marginal products of the inputs to become zero or negative.

The results of the estimation showed that it was possible for congestion to occur only with respect to bullocks. In other words, it was possible that too many bullocks had been applied to the land and that the marginal product of bullocks had become negative. However, when the marginal products for all of the inputs for each farm were actully calculated, it was found that the marginal product of bullocks was positive and higher than the marginal products of labour and fertilizer. The latter were very close to zero for almost all the farms in the survey. This tends to support the proposition that within the Nuwakot District of Nepal the application of labour and the use of traditional forms of fertilizer have reached their limit. In order to increase output, a new technology is essential. Such a technology would involve the development of new seeds and the application of chemical fertilizers.

These results are supported by other work concerning Nepalese agriculture. For example, Som Pudasaini [7] has shown that investment in education yields a much higher return in technologically dynamic agricultural regions in Nepal than in regions where new technologies have not yet been developed or applied. Thus, again, it seems that the development of new technology is the key to rapid agricultural development.

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