Staff Paper Series

Staff Paper P73-11   January 1973

RELATIVE EFFICIENCY IN WHEAT PRODUCTION
IN THE INDIAN PUNJAB

By

Surjit S. Sidhu

Department of Agricultural and Applied Economics

University of Minnesota
Institute of Agriculture
St. Paul, Minnesota 55108

January 1973

Relative Efficiency in Wheat Production
in the Indian Punjab

Surjit S. Sidhu

Relative Efficiency in Wheat Production
in the Indian Punjab

Surjit S. Sidhu*

In recent contributions to the American Economic Review, Lau and Yotopoulos applied the profit function concept to the analysis of relative efficiency of Indian Agriculture. They developed an operational model to measure and compare economic efficiency and its components of technical efficiency and price (or allocative) efficiency for groups of firms. By comparing the actual profit functions of small and large farms, at given output and input prices and fixed quantities of land and capital, they found that smaller farms had higher profits (total revenue minus the total cost of the variable factors of production--in this case labor) than larger farms within the range of output studied and hence were economically more efficient. Further, they were able to show that the relative economic superiority of small farms was due to their technical efficiency since both types of farms were price-efficient. Their results also indicate constant returns to scale in Indian agriculture. Both these findings have far-reaching implications for the optimal agrarian structure of Indian agriculture.

In this paper their model is confronted with new and recent data for wheat farms in Indian Punjab. Our results run counter to the Lau and Yotopoulos findings in that we do not find any differences in the economic efficiency (or its components of technical efficiency and price efficiency) of small and large wheat farms. Using their model, we also compare the economic performance of old Indian wheat varieties with Mexican varieties, and tractor-operated with non-tractor-operated wheat farms. The last mentioned two comparisons have considerable relevance in the context of the 'green revolution' and the absorption of a rapidly growing labor force in

India and other LDC's. In section I of the present paper, we establish a formal link between our estimation procedure and the Lau-Yotopoulos model. In section II, we briefly describe the data and the variables, provide our empirical estimates, derive the implications of these results, and compare them with those of Lau and Yotopoulos. In section III, we summarize our conclusions.

I. The Basic Model

To start with, let the wheat production function be written as:

(1) $$Y = F (N; L, K)$$

where Y is output, N is the variable input labor, and L and K the fixed inputs of land and capital respectively. The production function is assumed to be concave in N, continuous and increasing in N, L, and K, twice differentiable in N and once differentiable in L and K.[1]

The profit P from wheat production is equal to total revenue minus total variable labor costs:

(2) $$P = p F (N; L, K) - w N$$

where p is price of wheat and w the wage rate for labor.

Let $w' \equiv \frac{w}{P}$, the normalized wage rate and write (2) as:

(3) $$P* = \frac{P}{p} = F (N; L,K) - w' N$$

which Lau and Yotopoulous (1972) call the 'Unit-Output-Price' profit or <u>UOP profit.</u>

The profit maximizing conditions imply,

(4) $$\frac{\partial F}{\partial N} = w'.$$

Solving (4) for N*, the optimal quantity of labor, as a function of the normalized wage rate and quantities of L and K gives:

(5) $$N^* = f(w', L, K).$$

Substituting (5) into the profit equation (2) we obtain the (partial) profit function:

(6) $$\pi = p\ [F(N^*; L,K)] - w'\ N^*$$

which gives a maximum profit for each set of values $\{p, w, L, K\}$. Since N^* is a function of w', L and K, we can write (6) as:

(7) $$\pi = p\ g^*(w'; L, K)$$

which gives the UOP profit function:

(8) $$\pi^* = \frac{\pi}{p} = g^*(w'; L, K)$$

which is decreasing and convex in w' and increasing in p and the quantities of L and K. It is continuous in w', L and K; twice differentiable in w' and once differentiable in L and K.

From a set of duality relations connecting the production function and the profit function,[2] the labor demand function N^* and output supply function for wheat Y^* can be written as (9) and (10) respectively:

(9) $$N^* = -\ \frac{\partial \pi^*(w', L, K)}{\partial w'}$$

(10) $$Y^* = \pi^*(w', L, K) - \frac{\partial \pi^*(w', L, K)\ w'}{\partial w'}$$

In order to study relative economic efficiency let us start by rewriting the production function (1) for two farms (1,2) as follows:

(11) $$Y^1 = A^1\ F(N^1; L^1, K^1); \qquad Y^2 = A^2\ F(N^2; L^2, K^2)$$

where management, some intangible inputs or environmental differences could create neutral differences in the technical efficiency parameters A^1 and A^2 of the two farms.

Let us also rewrite the marginal productivity condition (4) for these two farms (1,2) as below:

$$(12) \quad \frac{\partial A^1 \, F \, (N^1; \, L^1, \, K^1)}{\partial N^1} = k^1 \, w'^1; \quad \frac{\partial A^2 \, F \, (N^2; \, L^2, \, K^2)}{\partial N^2} = k^2 \, w'^2$$

$$k^1 \gtreqqless 0 \qquad\qquad\qquad k^2 \gtreqqless 0$$

Equation (12) can be interpreted to mean that the two farms may not be attaining price or allocative efficiency in the sense of maximizing profits by equating the marginal product of labor to the going normalized wage rate w'. Also they may be unequally inefficient. They may in fact be operating upon their own firm-specific (or effective) wage rate,[3] which is simply a firm-specific constant k, times the ruling normalized wage rate. If the two farms are equally price efficient with respect to the input of labor, then $k^1 = k^2$ and they maximize profits if $k^1 = k^2 = 1$. In other words, for two firms, with equal technical efficiency and facing identical input and output prices, differences in k's represent differences in managerial-entrepreueurial ability.

Technical efficiency of the two farms would be equal if the farm specific efficiency parameters A^1 and A^2 in (11) are equal. If and only if $A^1 = A^2$ and $k^1 = k^2$ would the actual UOP profit functions and the labor demand functions of the two farms coincide with each other. Economic efficiency thus has two components: technical efficiency and price efficiency. A more technical efficient firm than another produces larger output from given quantities of inputs. A firm is price efficient if it maximizes profits by equating the marginal value product of variable inputs to their prices. But firms could be price inefficient (and to varying degrees) if they are unable to maximize profits. Thus differences in economic efficiency could originate in differences in their technical efficiency, price efficiency or both. It may be noted that the two farms can have equal economic efficiency with varying degrees of technical and price efficiency. Our purpose now is to develop a method to make these comparisons.

The behavioral UOP profit functions for the two farms corresponding to their production functions (11) can be written as:

(13) $\qquad \pi^{*i} = A^i g^* (k^i w'^i/A^i; L^i, K^i) \qquad\qquad (i = 1,2)$

The actual labor demand and supply functions corresponding to (9) and (10) now are (14) and (15) respectively:

(14) $\qquad N^{*i} = -\dfrac{A^i}{k^i} \dfrac{\partial\, g^* (k^i w'^i/A^i; L^i, K^i)}{\partial\, w^i} \qquad\qquad (i = 1,2)$

(15) $\qquad Y^{*i} = A^i \left[g^* (k^i w'^i/A^i; L^i, K^i) - w'^i \dfrac{\partial\, g^* (k^i w'^i/A^i; L^i, K^i)}{\partial\, w^i} \right]$

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (i = 1,2)$

N^{*i} and Y^{*i} in (14) and (15) are the actual quantities of labor demanded and output supplied by farm i given farm-specific A^i and k^i. From these actual demand and supply functions we can obtain the actual UOP profit functions

(16) $\qquad \pi^{*i} = Y^{*i} - w'^i N^{*i}$

$\qquad\qquad = A^i \left[g^* (k^i w'^i/A^i; L^i, K^i) + \dfrac{(1-k^i) w'^i}{k^i} \dfrac{\partial g^*(k\, w'^i /A^i ; L^i, K^i)}{\partial\, w^i} \right]$

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad (i = 1,2.)$

It should be noted that because of the profit identity, only two of the three functions (14), (15) and (16) need be estimated. We will subsequently work only with (14) and (16).

The Cobb-Douglas Framework

Let the wheat production function (1) be written in Cobb-Douglas form with decreasing returns to the labor input as:

(17) $\qquad\qquad\qquad Y = A\, N^{\alpha_1}, L^{\alpha_2}, K^{\alpha_3}$

where $\qquad\qquad\qquad \alpha_1 < 1.$

For (17) the UOP profit function is given by:[4]

(18) $\pi^* = A^{(1-\alpha_1)^{-1}} (1-\alpha_1)\left(\frac{w'}{\alpha_1}\right)^{-\alpha_1(1-\alpha_1)^{-1}} L^{\alpha_2(1-\alpha_1)^{-1}} K^{\alpha_3(1-\alpha_1)^{-1}}$

which can be written in natural logarithms of the variables as:

(19) $\ln \pi^* = \ln A^* + \beta_1 \ln w' + \beta_2 \ln L + \beta_3 \ln K$

where

$$A^* \equiv A^{(1-\alpha_1)^{-1}} (1-\alpha_1)\, \alpha_1^{\alpha_1(1-\alpha_1)^{-1}}$$

$$\beta_1 \equiv -\alpha_1 (1-\alpha_1)^{-1} < 0$$

$$\beta_2 \equiv \alpha_2 (1-\alpha_1)^{-1} > 0$$

$$\beta_3 \equiv \alpha_3 (1-\alpha_1)^{-1} > 0$$

If we multiply both sides of the labor demand function (9) by $-w'/\pi^*$ we get:

(20) $-\frac{w'N^*}{\pi^*} = \frac{\partial \pi^*}{\partial w'} \cdot \frac{w'}{\pi^*} = \frac{\partial \ln \pi^*}{\partial \ln w'}$

which from (19) becomes:

(21) $-\frac{w'\,N^*}{\pi^*} = \beta_1.$

Equations (19) and (21) are the basic estimating forms. Since β_1 appears in both the UOP profit function and the labor demand function, the two functions are estimated jointly and the β_1's in the two equations are constrained to be equal.

For the purpose of studying relative economic efficiency, (16) can be written as the actual UOP profit function for farm i with efficiency parameter A^i and the farm and labor specific parameter k^i. For the Cobb-Douglas production function (17) it is given by:

(22) $\pi^{*i} = A^{i(1-\alpha_1)^{-1}} (1-\alpha_1/k^i)(k^i)^{-\alpha_1(1-\alpha_1)^{-1}} \alpha_1^{\alpha_1(1-\alpha_1)^{-1}}$

$(w'^i)^{-\alpha_1(1-\alpha_1)^{-1}} (L^i)^{\alpha_2(1-\alpha_1)^{-1}} (K^i)^{\alpha_3(1-\alpha_1)^{-1}}$

$(i = 1,2)$

or

$$(23) \qquad \pi^{*i} = A_*^i \, (w^{,i})^{\beta_1} \, (L^i)^{\beta_2} \, (K^i)^{\beta_3} \qquad\qquad (i = 1,2)$$

where

$$A_*^i \equiv A^{i^{(1-\alpha_1)^{-1}}} (1-\alpha_1/k^i)(k^i)^{-\alpha_1(1-\alpha_1)^{-1}} \alpha_1^{\alpha_1(1-\alpha_1)^{-1}} \qquad (i = 1,2)$$

$$k_*^i \equiv (1-\alpha_1/k^i)(1-\alpha_1)^{-1} \qquad\qquad (i = 1,2)$$

and β_1, β_2 and β_3 are as before in (19).

And the labor demand function for farm i is given by:[5]

$$(24) \qquad N^{*i} = A^{i^{(1-\alpha_1)^{-1}}} (\alpha_1/k^i w^{,i})(k^i)^{-\alpha_1(1-\alpha_1)^{-1}} \alpha_1^{\alpha_1(1-\alpha_1)^{-1}}$$

$$(w^{,i})^{-\alpha_1(1-\alpha_1)^{-1}} (L^i)^{\alpha_2(1-\alpha_1)^{-1}} (K^i)^{\alpha_3(1-\alpha_1)^{-1}} \qquad (i = 1,2)$$

or

$$(25) \qquad N^{*i} = -A_*^i \, \beta_1 \, (k^i)^{-1} \, (w^{,i})^{-1} \, (k_*^i)^{-1} \, (w^{,i})^{\beta_1} \, (L^i)^{\beta_2} \, (K^i)^{\beta_3} \qquad (i = 1,2)$$

or, by substitution from (23)

$$(26) \qquad -\frac{w^{,i} \, N^{*i}}{\pi^{*i}} = (k^i)^{-1} \, (k_*^i)^{-1} \, \beta_1 \equiv \beta_1^i \qquad\qquad (i = 1,2)$$

Equations (23) and (26) indicate that the <u>actual UOP profit functions</u> and the labor demand functions of the two farms differ only by constant factors which are functions of A^i and k^i. Thus in order to compare the relative efficiency of the two farms we have to compare the magnitudes of A^i's and k^i's.

If, for farms 2 and 1 we write A_*^2 and A_*^1 for A_*^i, we can rewrite (23) as (27) and (28):

$$(27) \qquad \pi^{*1} = A_*^1 \, (w^{,1})^{\beta_1} \, (L^1)^{\beta_2} \, (K^1)^{\beta_3}$$

$$(28) \qquad \pi^{*2} = A_*^1 \, (A_*^2/A_*^1) \, (w^{,2})^{\beta_1} \, (L^2)^{\beta_2} \, (K^2)^{\beta_3}$$

And taking natural logarithms of (27) and (28) we have

(29) $\ln \pi^{*1} = \ln A_*^1 + \beta_1 \ln w^{\cdot 1} + \beta_2 \ln L^1 + \beta_3 \ln K^1$

(30) $\ln \pi^{*2} = \ln A_*^1 + \ln (A_*^2/A_*^1) + \beta_1 \ln w^2 + \beta_2 \ln L^2 + \beta_3 \ln K^3$

Maintaining the hypothesis that there are no non-neutral differences in the technologies of the two farms,[6] equations (30) and (26) are rewritten as (31) and (32) respectively for purposes of estimation:

(31) $\ln \pi^* = \ln A_*^S + \delta^L D^L + \beta_1 \ln w + \beta_2 \ln L + \beta_3 \ln K$

(32) $- \dfrac{w' N}{\pi^*} = \beta_1^L D^L + \beta_1^S D^S$

where L and S stand for large and small farms respectively,[7] $\delta^L \equiv \ln (A_*^L/A_*^S)$, and D^L and D^S are dummy variables taking the value of one for large[7] and small farms respectively and zero otherwise. For equal relative economic efficiency $A_*^L = A_*^S$ or $\delta^L = \ln (A_*^L/A_*^S) = 0$. For equal relative price efficiency $\beta_1^L = \beta_1^S$ in (32), and for absolute price efficiency of large farms and small farms respectively $\beta_1 = \beta_1^L$ and $\beta_1 = \beta_1^S$.

Output price p of wheat is government supported at uniform level throughout the state. This helps to simplify equations (31) and (32) further as follows:

(33) $\ln \pi^* = \ln \pi - \ln p = \ln A_*^S + \delta^L D^L + \beta_1 \ln w - \beta_1 \ln p + \beta_2 \ln L + \beta_3 \ln K$

or

$\ln \pi = \ln A_*^S + \delta^L D^L + (1-\beta_1) \ln p + \beta_1 \ln w + \beta_2 \ln L + \beta_3 \ln K$

where π is actual money profit, w the money wage rate per hour and p the output price.

For the case when four years (1967/68 to 1970/71) data are pooled, year dummies are introduced to capture the effects due to $(1-\beta_1)\ln p$ and weather, etc. and equation (33) rewritten as:

(34) $\ln \pi = \ln A_*^S + \delta^L D^L + \sum_{i=1}^{3} \delta^i D^i + \beta_1 \ln w + \beta_2 \ln L + \beta_3 \ln K$

where

D_1, D_2, D_3 are the year dummies with the value of 1 for 1968/69, 1969/70, 1970/71 respectively and zero otherwise.

But for the individual years we have to write (33) as:

(35) $$\ln \pi = \lambda + \delta^L D^L + \beta_1 \ln w + \beta_2 \ln L + \beta_3 \ln K$$

where

$$\lambda = \ln A_*^S + (1-\beta_1) \ln p,$$

from which $\ln A_*^S$ can be evaluated at the sample mean value for $(\ln p)$.

The labor demand equation (32), however, holds independently of the price of output and can be written as:

(36) $$- \frac{w' \, N}{\pi^*} = - \frac{w \, N}{\pi} = \beta_1^L D^L + \beta_1^S D^S$$

When we analyze and compare tractor operated (T) versus non-tractor operated (NT) farms D^L and D^S in equations (31) and (32) will be replaced by D^T and D^{NT} respectively with no other change involved. D^T and D^{NT} will take the value of 1 for tractor and non-tractor farms and zero otherwise.

In order to compare the relative economic efficiency of the Mexican wheat varieties with the old wheat varieties we can write (33) as:

(37) $$\ln \pi = \lambda + \delta^N D^N + \beta_1 \ln w + \beta_2 \ln L + \beta_3 \ln K$$

where

$$\lambda = \ln A_*^0 + (1-\beta_1) \ln p$$

D^N is a dummy variable with value of one for new wheat and zero for the old wheat. δ^N if significantly different from zero and positive indicates the percent upward shift in the profit function.

A_{*}^{0} is defined by the first identity in (23) and the remaining variables and parameters are as defined earlier. Superscript 0 stands for old wheat. In this case the labor demand function (21) can be written without output price simply as:

$$(38) \qquad\qquad - \frac{wN}{\pi} = \beta_1$$

In recapitulation we have three systems of two equations each as our three models:

Model I: Equations (37) and (38) for comparing relative economic efficiency of old and new wheats;

Model II: Equations (35) and (36) for comparing relative economic efficiency of small and large farms and tractor operated and non-tractor operated farms;

Model III: Equations (34) and (36) for comparing relative economic efficiency of small and large farms and to obtain various elasticity estimates from the pooled data for four years.

For statistical specification of these models, following Lau and Yotopoulous (1972 and Memorandum 104) we assume additive errors with zero expectation and finite variance for each of the two equations in all three models. The covariance of the errors of the two equations for the same farm may not be zero but the covariances of the errors of either equation corresponding to different farms are assumed to be zero. With these assumptions an asymptotically efficient method of estimation as proposed by Zellner (1962) is used[8] to estimate jointly the parameters of the two equations for each of the three models and since β_1 appears in both equations of the models, we impose the restriction that it be equal in each pair of equations. Additionally we also impose the restriction of constant returns to scale in all factors of production by restricting the sum of the coefficients of the fixed factors [see Lau and Yotopoulos 1972] in the logarithmic profit function to be equal to one, that is: $\beta_2 + \beta_3 = 1$.

II. The Data and Empirical Results

Farm size efficiency of Indian agriculture has been extensively studied and debated. Data used in certain studies came mostly from the mid-fifties when Indian agriculture was relatively static or closer to Schultz's (1964) traditional agriculture.[9] Researches by Lau and Yotopoulos indicate that smaller farms were relatively more economic efficient due to technical efficiency--both types of farms being price-efficient. In this section their model is confronted with new and recent data for comparing economic efficiency of old and new wheats, to verify their conclusions for wheat farms of Punjab and to compare the efficiency of tractor versus non-tractor wheat farms. This is important since most analyses of Indian agriculture have expressed reservations about the quality of earlier data.

A. The Data and the Variables

Our data come from three different samples with slightly different geographic coverages and also different in size and purposes of stratification. A brief summary of these samples and their coverage is provided in Table 1. As compared to the group average data used by Lau and Yotopoulos and most earlier Indian studies, we have been fortunate to have access to micro level primary data.

The variables used in this study are defined as follows:

Y = physical output of wheat measured in quintals per farm including by-products.[10]

TABLE 1. BRIEF SUMMARY OF THE SAMPLES AND DATA

Sample	Geographic Coverage	No. of Villages Included	No. of Farms	Crop Year	Wheat Type	Observations Available
Ferozepur[a]	District-Ferozepur	15	150	1967-68	New	105
				1967-68	Old	132
				1968-69	New	144
Tractor Cultivation[b]	Punjab	19	304	1969-70	New	287
Regionally Stratified[c]	Punjab	7	128	1970-71	New	128

Sources: (a) Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India.
          (b) From the Economic Adviser, Government of Punjab.
          (c) The author was himself responsible for the design and supervision of data collection work for this sample.

N = the labor input per farm used for wheat production measured in hours. It includes both family and hired labor.[11]

L = the land input measured as acres of wheat grown per farm.

K = a measure of flow of capital services going into wheat production per farm.[12]

p = the price of wheat per quintal as reported for each farm.

wN = the total wage bill in rupees for wheat production per farm, including payments to labor hired on daily wage bases, labor hired on annual contract basis and the imputed value of services of family labor.[13]

w = the hourly wage rate of labor. It is obtained simply by dividing the total wage bill wN by total labor input N.

P = the profit from wheat production is defined as total revenue less total variable labor costs.

B. Old <u>versus</u> <u>New</u> Varieties of Wheat

The first test for relative economic efficiency in wheat production in Punjab compared the economic efficiency of new varieties of wheat with the old varieties of wheat. For this purpose Model I is used employing 1967/68 data from the Ferozepur Sample. Equations (37) and (38) are estimated jointly using Zellner's method (1962) of estimation by imposing the restrictions that $\beta_1 = \beta_1$ in the two equations and requiring that $\beta_2 + \beta_3 = 1$, that is, assuming constant returns to scale. These results are presented below in Table 2. The results indicate that the new wheats are economically more efficient compared to the old wheats by 48.50 percent.

TABLE 2: RESULTS OF JOINT ESTIMATION OF COBB-DOUGLAS PROFIT FUNCTION AND LABOR DEMAND FUNCTION FOR WHEAT, 1967/68, PUNJAB, INDIA

Parameter		Estimated Coefficient	Standard Error
λ	=	4.872	(0.965)
δN	=	0.485	(0.129)
β_1	=	0.254	(0.013) in both equations
β_2	=	0.670	(0.155)
β_3	=	0.330	(0.155)

From $\lambda = \ln A_*^0 + (1-\beta_1) \ln p$ we evaluate A_*^0 by substituting the sample mean value of $\ln p$ for old wheat. Then we get A^0 the efficiency parameter in the Cobb-Douglas production function for old wheat from the identity in (23), the computed value of which is 5.641. In the same way, from $\lambda = \ln A_*^0 + \delta^N + (1-\beta_1) \ln p$, we get A^N the efficiency parameter for new wheat = 8.166. Thus <u>maintaining the hypothesis of neutral technical shift,</u>[14] we find that the efficiency parameter for the new wheat production function is larger by 44.70 percent.

C. Relative Efficiency

There are different policy implications associated with each component of differences (technical efficiency or price efficiency) in economic efficiency of small and large farms. For example, the finding that small farms are more technical efficient and that both small and large farms are absolute price efficient could lead to the conclusion that small farms serve the national interest better (leaving aside the equity considerations). If we find that smaller farms are less price-efficient, policies which improve market information for them may improve their allocative efficiency. Similar implications would follow if tractor-operated farms were more price efficient than non-tractor-operated farms. And if we find no differences in either the technical or price efficiency parameters of the two kinds of farms, then agrarian policies can be based on social and political considerations. It is thus important to obtain knowledge of the source of differences (technical or price) in economic efficiency. Models II and III are designed to provide this knowledge.

The estimation results (Model II) using Zellner's method (1962) for each of the four years 1967/68 to 1970/71 and similar results for the four-year combined data (Model III) are presented in Table 3. And for comparing tractor-operated and non-tractor-operated farms, the results employing data for Tractor Cultivation Sample 1969/70, are presented in Table 4. In order to provide answers to the questions of relative efficiency posed above we carry out the following statistical test:[15]

TABLE 3

RESULTS OF JOINT ESTIMATION OF COBB-DOUGLAS PROFIT FUNCTION AND LABOR DEMAND FUNCTION FOR NEW WHEAT, PUNJAB, INDIA

Function	Parameter	Single-Equation Ordinary Least Squares	Estimated Coefficients Zellner's Method with Restrictions (Model II)			
			Unrestricted	1 Restriction $\beta_1^L = \beta_1^S$	2 Restrictions $\beta_1^L = \beta_1$ $\beta_1^S = \beta_1$	3 Restrictions $\beta_1^L = \beta_1$ $\beta_2 + \beta_3 = 1$ $\beta_1^S = \beta_1$
1967/68						
UOP Profit Function	λ	3.799 (0.748)	3.433 (0.641)	3.446 (0.641)	3.019 (0.667)	3.885 (0.636)
	δ^L	-0.141 (0.144)	-0.064 (0.137)	-0.112 (0.123)	-0.138 (0.131)	0.093 (0.115)
	β_1	0.107 (0.159)	0.263 (0.136)	0.262 (0.136)	-0.244 (0.034)	-0.236 (0.034)
	β_2	0.614 (0.115)	0.506 (0.098)	0.506 (0.098)	0.520 (0.104)	0.537 (0.109)
	β_3	0.487 (0.125)	0.564 (0.107)	0.563 (0.107)	0.599 (0.113)	0.462 (0.109)
Labor Demand Function	β_1^L	-0.221 (0.075)	-0.221 (0.075)	-0.274 (0.035)	-0.244 (0.034)	-0.236 (0.034)
	β_1^S	-0.289 (0.040)	-0.289 (0.040)	-0.274 (0.035)	-0.244 (0.034)	-0.236 (0.034)
	R^2	0.923				
1968/69						
UOP Profit Function	λ	4.115 (0.994)	3.714 (0.692)	3.725 (0.691)	3.391 (0.673)	3.309 (0.655)
	δ^L	-0.041 (0.160)	0.049 (0.133)	0.026 (0.111)	0.061 (0.109)	0.015 (0.070)
	β_1	-0.507 (0.207)	0.024 (0.144)	0.024 (0.144)	-0.381 (0.041)	-0.381 (0.041)
	β_2	0.713 (0.179)	0.514 (0.124)	0.514 (0.124)	0.477 (0.122)	0.498 (0.114)
	β_3	0.334 (0.170)	0.454 (0.118)	0.454 (0.118)	0.495 (0.116)	0.503 (0.114)
Labor Demand Function	β_1^L	-0.406 (0.065)	-0.406 (0.065)	-0.421 (0.043)	-0.381 (0.041)	-0.381 (0.041)
	β_1^S	-0.433 (0.059)	-0.433 (0.059)	-0.421 (0.043)	-0.381 (0.041)	-0.381 (0.041)
	R^2	0.771				
1969/70						
UOP Profit Function	λ	4.651 (0.477)	4.748 (0.411)	4.744 (0.410)	4.744 (0.413)	4.694 (0.408)
	δ^L	0.093 (0.108)	0.136 (0.098)	0.142 (0.093)	0.142 (0.094)	0.099 (0.055)
	β_1	-0.278 (0.124)	-0.058 (0.106)	-0.058 (0.106)	-0.248 (0.081)	-0.247 (0.081)
	β_2	0.740 (0.038)	0.714 (0.085)	0.714 (0.085)	0.716 (0.086)	0.742 (0.072)
	β_3	0.259 (0.082)	0.260 (0.070)	0.260 (0.070)	0.256 (0.072)	0.257 (0.072)
Labor Demand Function	β_1^L	-0.501 (0.153)	-0.501 (0.153)	-0.482 (0.122)	-0.248 (0.081)	-0.247 (0.081)
	β_1^S	-0.449 (0.204)	-0.440 (0.204)	-0.482 (0.122)	-0.248 (0.081)	-0.247 (0.081)
	R^2	0.776				

TABLE 3 (continuted   16

		1970/71				
UOP Profit Function	λ	2.859 (0.641)	3.287 (0.595)	3.291 (0.594)	3.386 (0.581)	3.438 (0.576)
	δ^L	0.056 (0.110)	-0.048 (0.104)	-0.051 (0.102)	-0.057 (0.101)	-0.010 (0.059)
	β_1	-0.481 (0.189)	-0.184 (0.176)	-0.184 (0.175)	-0.255 (0.025)	-0.254 (0.025)
	β_2	0.477 (0.131)	0.496 (0.121)	0.496 (0.121)	0.512 (0.117)	0.477 (0.110)
	β_3	0.581 (0.112)	0.539 (0.103)	0.539 (0.103)	0.523 (0.100)	0.523 (0.100)
Labor Demand Function	β_1^L	-0.234 (0.051)	-0.254 (0.051)	-0.259 (0.025)	-0.255 (0.025)	-0.254 (0.025)
	β_1^S	-0.304 (0.048)	-0.265 (0.046)	-0.259 (0.025)	-0.255 (0.025)	-0.254 (0.025)
	R^2	0.870				

		1967/68-1970/71				
UOP Profit Function	$\ln A_*^S$	4.405 (0.334)	4.479 (0.301)	4.475 (0.301)	4.410 (0.303)	4.568 (0.297)
	δ^L	-0.025 (0.059)	-0.021 (0.056)	-0.012 (0.053)	-0.015 (0.054)	0.075 (0.038)
	δ_1	-0.411 (0.068)	-0.384 (0.061)	-0.384 (0.061)	-0.377 (0.062)	-0.336 (0.060)
	δ_2	-0.393 (0.063)	-0.353 (0.057)	-0.353 (0.057)	-0.347 (0.057)	-0.305 (0.054)
	δ_3	-0.242 (0.071)	-0.241 (0.064)	-0.240 (0.064)	-0.200 (0.063)	-0.163 (0.061)
	β_1	-0.243 (0.073)	-0.085 (0.072)	-0.085 (0.072)	-0.279 (0.042)	-0.271 (0.042)
	β_2	0.709 (0.058)	0.690 (0.053)	0.690 (0.052)	0.700 (0.053)	0.663 (0.050)
	β_3	0.359 (0.056)	0.358 (0.051)	0.358 (0.051)	0.358 (0.051)	0.337 (0.050)
Labor Demand Function	β_1^L	-0.411 (0.078)	-0.412 (0.078)	-0.379 (0.052)	-0.279 (0.042)	-0.271 (0.042)
	β_1^S	-0.351 (0.078)	-0.346 (0.077)	-0.379 (0.052)	-0.279 (0.042)	-0.271 (0.042)

Notes: The estimating equations for the four individual years are:

$$\ln \pi = \lambda + \delta^L D^L + \beta_1 \ln w + \beta_2 \ln L + \beta_3 \ln K$$
$$\frac{-wN}{\pi} + \beta_1^L D^L + \beta_1^S D^S$$

The estimating equations for the four years' pooled data are:

$$\ln \pi = \ln A_*^S + \delta^L D^L + \sum_{i=1}^{3} \delta_i D_i + \beta_1 \ln w + \beta_2 \ln L + \beta_3 \ln K$$
$$-\frac{wN}{\pi} = \beta_1^L D^L + \beta_1^S D^S \qquad \text{where}$$

π is profit (total receipts less wage bill)

w   is money eage rate

D^L is a dummy variable taking the value of one if wheat area is greater than ten acres and zero otherwise

D^S is a dummy variable taking the value of one if wheat area is less than ten acres and zero otherwise.

D_i are the three year dummy variables taking the value of one for 1968/69, 1969/70 and 1970/71 respectively and zero otherwise.

N   is labor in hours per farm used in wheat production.

L   is land in acres used for producing wheat.

K   is total costs of capital services for wheat per farm.

Asymptotic standard errors are in parentheses.

TABLE 4

RESULTS OF JOINT ESTIMATION OF COBB-DOUGLAS PROFIT FUNCTION AND LABOR DEMAND FUNCTION FOR NEW WHEAT, 1969/70, PUNJAB, INDIA

Function	Parameter	Single-Equation Ordinary Least Squares	Estimated Coefficients Zellner's Method with Restrictions (Model II)			
			Unrestricted	1 Restriction $\beta_1^L = \beta_1^S$	2 Restrictions $\beta_1^L = \beta_1$ $\beta_1^S = \beta_1$	3 Restrictions $\beta_1^L = \beta_1$ $\beta_2 + \beta_3 = 1$ $\beta_1^S = \beta_1$
UOP Profit Function	λ	4.330 (0.501)	4.778 (0.433)	4.794 (0.433)	4.811 (0.441)	4.934 (0.398)
	δ^T	0.089 (0.073)	0.075 (0.070)	0.032 (0.063)	0.041 (0.064)	0.062 (0.054)
	β_1	-0.286 (0.124)	-0.062 (0.107)	-0.064 (0.107)	-0.253 (0.081)	-0.256 (0.081)
	β_2	0.730 (0.083)	0.785 (0.071)	0.785 (0.071)	0.788 (0.073)	0.779 (0.072)
	β_3	0.224 (0.065)	0.241 (0.073)	0.241 (0.073)	0.235 (0.075)	0.221 (0.072)
Labor Demand Function	β_1^T	-0.259 (0.203)	-0.259 (0.202)	-0.481 (0.122)	-0.252 (0.081)	-0.256 (0.081)
	β_1^{NT}	-0.610 (0.153)	-0.610 (0.153)	-0.481 (0.122)	-0.252 (0.081)	-0.256 (0.081)
	R^2	0.777				

Notes: The estimating equations are:

$$\ln \pi = \lambda + \delta^T D^T + \beta_1 \ln w + \beta_2 \ln L + \beta_3 \ln K$$

$$-\frac{wN}{\pi} = \beta_1^T D^T + \beta_1^{NT} D^{NT}$$

where

D^T is a dummy variable taking the value of one for farms owning a tractor and zero otherwise.

D^{NT} is a dummy variable taking the value of one for farms not owning a tractor (animal operated) and zero otherwise.

Asymptotic standard errors are in parentheses.

(1) (a) The hypothesis of equal relative economic efficiency of small and large wheat farms:

$$Ho: \quad \delta^L = 0,$$

that is, $\ln (A_*^L/A_*^S) = 0$ or $A_*^L = A_*^S$. From the Appendix we see that we cannot reject this hypothesis at the 90 percent level of significance for any of the four years separately as well as for the four years combined. Thus the hypothesis that small and large farms have equal over-all economic efficiency is supported by these results.

(b) The hypothesis of equal relative economic efficiency of tractor and non-tractor farms:

$$Ho: \quad \delta^T = 0,$$

that is, $\ln (A_*^T/A_*^{NT}) = 0$, or $A_*^T = A_*^{NT}$.

From the Appendix we see that the null hypothesis is not rejected. The results support the hypothesis that tractor and non-tractor farms have equal economic efficiency.

(2) (a) The hypothesis of equal relative price efficiency:

$$Ho: \quad \beta_1^L = \beta_1^S.$$

The meaning of this test is whether in their labor demand function large and small farms have the same price efficiency parameters. This hypothesis also cannot be rejected at the 90 percent level of significance for any of the four years separately or for the four year pooled data. Thus the conclusion is that with respect to labor, small and large farms have been equally successful (or unsuccessful) in maximizing profits, that is, they have had the same price-efficiency parameters during each of the four years studied.

(b) The hypothesis of equal relative price efficiency of tractor and non-tractor farms:

$$Ho: \quad \beta_1^T = \beta_1^{NT}.$$

By this test we attempt to determine whether tractor and non-tractor farms have the same price efficiency parameters β_1^T and β_1^{NT} in their labor demand functions. The null

hypothesis cannot be rejected. Hence we conclude that both tractor and non-tractor
farms are equally price efficient, i.e., they have the same price efficiency para-
meters (k^i's).

(3) (a) The joint hypotheses of equal relative technical and price efficiency:

$$\text{Ho:} \quad \delta^L = 0 \quad \text{and} \quad \beta_1^L = \beta_1^S.$$

The meaning of these tests is whether large and small farms have equal over-all
economic efficiency and at the same time have the same price efficiency para-
meters β_1^L and β_1^S in labor demand functions. These hypotheses also cannot be rejected
at the 90 percent level of significance for any of the four years individually or
for the combined data. These results are consistent with the results of tests
(1) and (2) above, i.e., that small and large farms were equally efficient eco-
nomically and had equal price efficiency during each of the four years and on an
average for the four years. This implies that they also had equal technical efficiency.

(b) The joint hypotheses of equal relative technical and price efficiency of
tractor and non-tractor farms:

$$\text{Ho:} \quad \delta^T = 0 \quad \text{and} \quad \beta_1^T = \beta_L^{NT}.$$

Here we test whether tractor and non-tractor farms have equal economic effi-
ciency and whether at the same time they have the same price efficiency para-
meter in their labor demand functions. Again we cannot reject the null hypothesis.
This also is consistent with the results of tests (1) and (2) above that tractor and
non-tractor farms have equal economic efficiency and equal price efficiency, and
in turn implies that they have equal technical efficiency.

(4) (a) Next maintaining the hypothesis of equal price efficiency in (2), we turn
to the hypotheses of:

(i)   Absolute price-efficiency of large farms,   Ho: $\beta_1^L = \beta_1$ and

(ii)   Absolute price-efficiency of small farms,   Ho: $\beta_1^S = \beta_1$.

For the first two years 1967/68 and 1968/69 and for the four years pooled data we reject these hypotheses at 99 percent level of significance and for the year 1969/70 at 95 percent level of significance. But, for the latest year 1970/71 we cannot reject these hypotheses at 90 percent level of significance. This means that during the years 1967/68 and 1968/69, both small and large farms were not in a state of equilibrium in the sense of equating the value of marginal product of labor to its wage rate. During the year 1969/70, they were still not in a state of equilibrium, but we reject the hypothesis of profit maximization less strongly than for the years 1967/68 and 1968/69. For the year 1970/71, however, we find that both small and large farms were in equilibrium, i.e., maximizing profits. We discuss these results later.

(b) Maintaining the hypothesis of equal price efficiency in (2), we also test the hypotheses of:

(i)   Absolute price efficiency of tractor farms, Ho: $\beta_1^T = \beta_1$ and

(ii) Absolute price efficiency of non-tractor farms, Ho: $\beta_1^{NT} = \beta_1$.

The meaning of these tests is whether tractor and non-tractor farms maximize profits by equating the value of marginal product of labor to its opportunity price. The null hypothesis is rejected. The conclusion is that both tractor and non-tractor farms were not able to maximize profits during the year 1969/70. In light of the results of test for the hypothesis of equal relative price efficiency in (2), we conclude that, with respect to labor, tractor and non-tractor farms were equally unsuccessful in their efforts to maximize profits by using the optimum amount of labor.

(5) Lastly, we test the hypothesis of constant returns to scale in all factors
of production:

$$Ho: \quad \beta_2 + \beta_3 = 1.$$

This hypothesis is rejected at the 99 percent level of significance in all cases.
The sum $\beta_2 + \beta_3 > 1$ for the years 1967/68, 1970/71 and for the four-year pooled
data. But $\beta_2 + \beta_3 < 1$ for the years 1968/69 and 1969/70. These differences from
unity are quite small in either case. Also, perhaps slightly increasing returns
for the years 1967/68 and 1970/71 resulted because a larger number of observations
for these years were below the respective sample averages. Thus even though on
statistical grounds we do reject the hypothesis of constant returns to scale, we
do not find convincing evidence favoring the hypothesis of increasing returns in
wheat farming in Punjab.

The results of the first three statistical hypotheses--(1), (2) and (3)--
present rather convincing evidence that small and large wheat farms, and tractor-
operated and non-tractor-operated ones have no differences in their over-all eco-
nomic efficiency, technical efficiency, a price (or allocative) efficiency. The
view that small and large farmers have the same degree of economic motivation seems
to hold. Because wheat is a dominant enterprise on these farms, one can argue
that these conclusions would perhaps be equally applicable to all enterprises
on these farms.

Important policy implications follow from these findings. Most substantive
one is that policies with respect to land redistribution and ceilings on ownership
of land can be based primarily on social and political considerations. Secondly
governmental policies with respect to pricing, supply of agricultural inputs, market-
ing facilities, provision of credit and extension services, etc. need not favor

either large or small farms (or farms having tractors or without tractors) on
the basis of their economic efficiency or its components of technical efficiency
or price efficiency. This view is reinforced by the absence of any strong evidence
against constant returns to scale.

The results of statistical test (4) have interesting implications with respect
to the profit-maximizing behavior (or rationality) of the wheat producers. They
have a bearing on earlier price or allocative studies.[16] The results appear to
indicate the -xistence of a short-period disequilibrium between the profit-
maximizing attempts and the actual results achieved by wheat producers; this dis-
equilibrium was created by a shift to the right in the labor demand function result-
ing from the introduction of high-yielding wheats.[17] During the first two years
1967/68, 1968/69 the producers were not in equilibrium in the sense of equating
the marginal value product of labor to its opportunity cost. For the third year
1969/70 we reject the hypotheses of absolute price-efficiency at 95 percent level
of significance (but not at 99 percent as for the years 1967/68 and 1968/69), that
is, not as strongly as during the first two years. And finally during the last
year 1970/71, we cannot reject the hypotheses of absolute price efficiency at all,
that is, we find that producers on the average (both small and large) were able
to equate the marginal value product of labor to its going opportunity cost. This
seems to be a good demonstration of short-run disequilibrium being overcome by the
rational producer behavior. Producers do indeed seem to react energetically to
the existence of disequilibrium.

D. Comparison with Findings by Lau and Yotopoulos

We provide two brief comparisons of our results with the researches of Lau
and Yotopoulos (March 1971 and Memo 104) regarding relative efficiency in Indian
agriculture.

Estimates for the Cobb-Douglas production function elasticities for various inputs were derived indirectly from the profit function estimates for Model III (Table 3) using four-year data and are presented in Table 5. These estimates are obtained from identities in Equation 19 which are the connecting links between the coefficients of the profit function and those of the production function. The main advantage of these indirect input elasticities over the ones obtained from direct estimates of the production function is their statistical consistency. Since β_1 appears in both the profit and labor demand equations, imposing the restriction that it be equal in both equations improves the efficiency of these estimates. Furthermore, since these estimates are derived from four-year data they should be quite reliable for predictive purposes.

We note that all our estimates of output elasticities with respect to various inputs (including capital) have the expected signs and reasonable magnitudes. We seem to have been fortunate in having data which yielded reasonable elasticity estimates for capital. Lau and Yotopoulos obtained (because of the problem of measuring the capital input) negative elasticity for capital and, under constrained estimation with constant returns to scale, relatively large elasticity values for labor and land.

Secondly, whereas our findings agree with theirs regarding equal relative price efficiency and equal absolute price-efficiency of small and large farms, our findings regarding equal technical and thus equal over-all economic efficiency differ. They find small farms relatively more efficient technically and thus more efficient economically, whereas our results indicate no differences in technical or economic efficiency of small and large farms. A possible explanation for this discrepancy might be as follows:

TABLE 5:   ESTIMATES OF THE INPUT ELASTICITIES OF THE COBB-DOUGLAS PRODUCTION
FUNCTION DERIVED FROM THE PROFIT FUNCTION DERIVED FROM THE PROFIT
FUNCTION FOR NEW WHEAT 1967/68-1970/71,* PUNJAB, INDIA

		Model III		
		1 Restriction $\beta_1^L = \beta_1^S$	2 Restrictions $\beta_1^L = \beta_1$ $\beta_1^S = \beta_1$	3 Restrictions $\beta_1^L = \beta_1$ $\beta_2 + \beta_3 = 1$ $\beta^S = \beta_1$
Labor	α_1	0.078	0.218	0.213
Land	α_2	0.636	0.547	0.522
Capital (K)	α_3	0.349	0.280	0.265
$(\alpha_1 + \alpha_2 + \alpha_3)$		1.063	1.045	1.000

*Table 3

Their findings pertain to the mid-fifties. Indian agriculture at that time
could be characterized as traditional and in a state of equilibrium with available
technology (Schultz, 1964). Modern inputs like chemical fertilizers were conspicuous
by their absence. Smaller farms which had more labor available per unit of land[18]
perhaps used it for more intensive land improvement programs which resulted in
superior technical efficiency compared to the larger farms. Also as emphasized
by Lau and Yotopoulos, under these circumstances, the technical-managerial input
becomes more intensive on smaller farms. Their finding of superior technical
efficiency of smaller farms thus seems to be consistent with these observations.

Since the mid-fifties, however, Indian agriculture underwent a great transformation especially in Punjab. The level of land fertility which formerly depended on the level of labor input and could be higher on small labor-surplus farms no longer depends upon intensive labor input alone. The availability of fertilizers, other chemical inputs and increased irrigation input reduces the fertility (productivity) differences of land on small and large farms. Thus a major source of greater technical efficiency of smaller farms during the mid-fifties seems to be less important during the late sixties.

Another explanation can be advanced in the form of an hypothesis. There are two elements to this hypothesis. First, we may agree (in a somewhat qualified manner) with the findings of Lau and Yotopoulos (March 1971 and Memo. 104) that, in traditional agriculture or in an agriculture in a state of equilibrium, smaller labor-surplus farms have greater technical efficiency and thereby are more efficient economically. Second, we postulate that large farms have better access to research information because of relatively easier (often free) access to extension services. The period covered by the present study immediately followed the introduction of high-yielding varieties of wheat. Thus, it may well be that larger farms, because of their comparative advantage in research information, assimilated the new wheat technology more rapidly than smaller farms and this offset the technical superiority of smaller farms. This hypothesis can be verified only in the future.

E. Elasticity Estimates

Next we derive a number of important elasticity estimates using parameter estimates from the last column of Table 5. Let the labor demand function (21) be written as:

$$N = - \frac{\beta_1 \pi^*}{w'} = - \frac{\beta_1 \pi}{w} \qquad \text{or}$$

(39) $\qquad \ln N = \ln (-\beta_1) + \ln \pi - \ln w$ [19] $\qquad$ or

$\qquad \ln N = \ln (-\beta_1) + \ln \pi^* - \ln w'$

From Equation (39) and by using profit function estimates of last column in Table 4, the labor demand elasticities with respect to wage rate, land L, capital K and price of output p are obtained as follows:

(40) $\qquad \dfrac{\partial \ln N}{\partial \ln w} = \dfrac{\partial \ln \pi}{\partial \ln w} - 1$

$\qquad\qquad\qquad = \beta_1 - 1 = -1.271$

(41) $\qquad \dfrac{\partial \ln N}{\partial \ln L} = \dfrac{\partial \ln \pi}{\partial \ln L} = \beta_2 = 0.663$

(42) $\qquad \dfrac{\partial \ln N}{\partial \ln K} = \dfrac{\partial \ln \pi}{\partial \ln K} = \beta_3 = 0.337$

(43) $\qquad \dfrac{\partial \ln N}{\partial \ln p} = \dfrac{\partial \ln N}{\partial \ln w'} \dfrac{\partial \ln w'}{\partial \ln p} = 1.271$

All these elasticity estimates have the expected signs. From (40) we see that price elasticity of demand for labor is negative and indicates that demand is quite responsive to wage levels. Positive responses for labor demand to increases of land and capital and output price have important implications for labor absorption in wheat farming.

In order to calculate the output responses of the firm Equation 16 can be written as output supply function:

(44) $\qquad Y = \pi^* + w' N^*$

$\qquad\qquad = \pi^* (1-\beta_1) -- $ by a substitution of N^* from (21), or

(45) $\qquad \ln Y = \ln \pi^* + \ln (1-\beta_1).$

The elasticity of output supply with respect to the normalized wage rate (using parameter estimates from last column of Table 4) is given by:

(46) $\qquad \dfrac{\partial \ln Y}{\partial \ln w'} = \dfrac{\partial \ln \pi^*}{\partial \ln w'} = \beta_1 = -0.271,$

which shows a relatively inelastic response. This finding along with an elastic response of demand for labor with respect to wage rate is important, because it

implies that exogenously enforced wage rates for agricultural labor above the market determined wage rates could result in substantial increase in unemployment of the agricultural labor force.

From (45) output supply response with respect to output price is given by

(47) $$\frac{\partial \ln Y}{\partial \ln p} = \frac{\partial \ln Y}{\partial \ln w'} \frac{\partial \ln w'}{\partial \ln p} = 0.271$$

This finding is also important. Not only does it show a positive supply response to wheat price, but the magnitude is important for any effort to use the output price variable as a policy instrument for inducing increased supply of wheat.

From (45) we can also obtain the reduced form elasticities with respect to land and capital using parameter estimates presented in the last column of Table 4.

(48) $$\frac{\partial \ln Y}{\partial \ln L} = \frac{\partial \ln \pi^*}{\partial \ln L} = \beta_2 = 0.663$$

(49) $$\frac{\partial \ln Y}{\partial \ln K} = \frac{\partial \ln \pi^*}{\partial \ln K} = \beta_3 = 0.337$$

These elasticities indicate the output response of the average farm with respect to exogenous increases in land and capital respectively, holding the normalized wage rate and not the quantities of labor as constant. A given increase in the quantity of land (capital) shifts upward the marginal productivity curves of labor and other factors of production. As a result more of these inputs are employed than before. Thus, holding wage rate constant (but not the quantities of labor) a one percent expansion in wheat land will result in 0.663 percent increase in wheat output and one percent increase in capital will result in 0.337 percent increase in wheat output.

III. Summary and Conclusions

In summary there are two substantive conclusions that follow from the analysis of our data. First, there seem to be limited possibilities for growth by improving allocative efficiency in moving toward production frontiers. This is the inference from tests indicating rational producer response to disturbances in the labor market generated by shifts in the labor demand function. On the other hand

technical changes such as the shift in the wheat production function on the order of about 45 percent, popularly known as 'green revolution' constitute the more important source for potential increases of output. Second, we find that tractor-operated wheat farms are no better in terms of their economic performance than non-tractor-operated ones and that large farms are no better than small farms--there are no differences in the technical and price efficiency parameters of these classes of farms. Policy for curtailing farm size may be based only on social and political considerations. This policy implication is reinforced since we do not find any strong evidence against the hypothesis of constant returns to scale. A qualification about this implication, however, is necessary because we have studied only the wheat crop out of the complete set of enterprises on Punjab farms. There could be a question that the picture may be different if we study the production relationship between aggregate output of all enterprises and the inputs used.

Finally, the analyses of our data have yielded a number of elasticity estimates which are important for applications of economic theory for developmental policy. These estimates are the coefficients of the wheat production function and the elasticities of labor demand and output supply with respect to wage rate of labor, price of wheat and the quantities of land and capital.

Appendix

TESTING OF STATISTICAL HYPOTHESES, MODEL II AND MODEL III

Maintained Hypothesis	Tested Hypothesis	Computed F-Ratio				
		1967/68	1968/69	1969/70	1970/71	1967/68 to 1970/71
	(1) $\delta^L = 0$	F(1,203)=0.22	F(1,265)=0.14	F(1,567)=1.93	F(1,249)=0.23	F(1,1302)=0.15
	(2) $\beta_1^L = \beta^S$	F(1,203)=0.64	F(1,265)=0.10	F(1,567)=0.04	F(1,249)=0.02	F(1,1302)=0.34
	(3) $\delta^L = 0$, $\beta_1^L = \beta^S$	F(2,203)=0.73	F(2,265)=0.08	F(2,567)=1.20	F(2,249)=0.14	F(2,1302)=0.20
$\beta_1^L = \beta_1^S$	(4) $\beta_1^L = \beta_1$	F(2,203)=7.72	F(2,265)=4.71	F(2,567)=3.44	F(2,249)=0.10	F(2,1302)=5.58
$\beta_1^L = \beta_1^S$	(5) $\beta_1^S = \beta_1$	F(2,203)=7.72	F(2,265)=4.71	F(2,567)=3.44	F(2,249)=0.10	F(2,1302)=5.58
	(6) $\beta_2+\beta_3=1$	F(1,203)=839.81	F(1,265)=373.61	F(1,567)=384.94	F(1,249)=306.41	F(1,1302)=1812.13
	(1) $\delta^T = 0$			F(1,567) = 1.13		
	(2) $\beta_1^I = \beta_1^{NT}$			F(1,567) = 1.92		
	(3) $\delta^I = 0$, $\beta_1^I = \beta_1^{NT}$			F(2,567) = 1.09		
$\beta_1^I = \beta_1^{NT}$	(4) $\beta_1^I = \beta_1$			F(4,567) = 4.31		
$\beta_1^I = \beta_1^{NT}$	(5) $\beta_1^{NT} = \beta_1$			F(4,567) = 4.31		
	(6) $\beta_2 + \beta_3 = 1$			F(1,567) = 914.14		

Note.—Critical F-ratios are: $F_{0.10}(1, \infty) = 2.70$; $F_{0.05}(1, \infty) = 3.84$; $F_{0.01}(1, \infty) = 6.63$;
$F_{0.10}(2, \infty) = 2.30$; $F_{0.05}(2, \infty) = 3.00$; $F_{0.01}(2, \infty) = 4.61$

Footnotes

[1] These assumptions are necessary to insure the existence of a unique, optimal solution to the profit-maximizing problem and consequently the existence of single-valued supply and derived demand functions as continuously differentiable functions of normalized wage rate, L and K.

[2] See Shephard (1953). For these derivations we follow Lau and Yotopoulos (1972).

[3] Lau and Yotopoulous (March, 1971, p. 99) provide several reasons for this. Also see Bhagwati and Chakravarty (1969) for a summary of the viewpoints of Sen, Khusro, Mazumdar and Rao as to why small family farms evaluate their family labor at less than the going wage rates. For more recent attempts to explain this point see Srinivasan (1971) and Bardhan (1972).

[4] Production function (17) and the profit maximizing equations for labor can be solved for the optimal quantity of labor N^*. The UOP profit function (18) is obtained by substituting N^* in the UOP profit equation (3): $P^* = Y - w'N$.

[5] The labor demand function (24) is obtained by direct computations from the production function (17) and the marginal productivity condition for labor.

[6] See Sidhu (1972), where we compared production functions for old and new varieties of wheat, small and large wheat farms, and tractor-operated and non-tractor-operated wheat farms and found that the differences in these production functions are only of the neutral type.

[7]In this study farms with more than 10 acres of wheat are defined as large farms and farms with 10 acres or less as small farms. This seems to be a realistic dividing line between large and small wheat farms for Punjab where the average farm size is 12.5 acres (Singh and Billings, 1971). Also it facilitates comparisons of our results with those of Lau and Yotopoulos (March 1971 and Memorandum 104) who also used this crieteria for small and large farms.

[8]This will also make our results comparable to those of Lau and Yotopoulos as reported in the above references.

[9]There appeared to be a consensus about the existence of constant returns to scale in Indian agriculture. There does not seem to have been a similar consensus on whether relatively smaller or larger farms are economically more efficient.

[10]The by-products are converted into quintals of wheat by dividing the total value of by-products by wheat price. The major by-product is wheat straw, which in chaffed form is fed to cattle. Sometimes, sarson (an oilseeds crop) is also grown mixed with wheat.

[11]Child and female labor is converted into man equivalents by treating 2 children (or women) equal to one man.

[12]An hourly flow of services is derived for each durable input including capital in the form of livestock that the farm uses in wheat production. It includes depreciation charges, interest charges and operating expenses. Depreciation schedules are based on the specific life of each input, but interest costs are estimated at a uniform interest rate of 10 percent for annum. (A. S. Kahlon, S. S. Miglani and S. K. Mehta (1968/69, p. 70) report that 68 percent of the amount borrowed in case of Ferozepur Sample for the year 1968.69 was at an interest rate of 9-10 percent per annum. The range of interest charges varied from 6.5 to 20 percent.) The actual number of hours of use times the hourly flow of services of each durable input gives

its total service flow. (For the Regionally Stratified Sample (1970/71), this procedure was carried out by the author himself. For Ferozepur Sample and Tractor Cultivation Sample, essentially the same procedure was employed.) Aggregation of these asset-specific service flows plus the seed and fertilizer costs yields a measure of the capital services.

[13]Family labor services are valued as equivalent to those of the annual contract labor for each farm. For farms which do not employ labor on annual contracts, the average rate of those farms in the sample which do employ contract labor was applied for evaluating the services of family labor.

[14]As reported in (Sidhu, 1972), we tested the hypothesis of neutral technical shift in the wheat production function and could not reject it.

[15]The results of all these tests are presented in the Appendix.

[16]See Hopper (1965), Khusro (1964), Schultz (1964), Sahota (1968) and Lau and Yotopoulos (March 1971 and Memo 104).

[17]Results reported elsewhere (Sidhu 1972) indicate that the per acre factor demand functions shifted to the right by 25 percent resulting from the introduction of Mexican wheat varieties in Punjab.

[18]At this point a reference is made again to the studies cited earlier, particularly by Sen (1966), the survey article by Bhagwati and Chakravarty (1969) and by Bardhan (1972).

[19]Note that ln π is the estimating equation (logarithmic profit function) shown in notes to Table 3.

References

Pranab K. Bardnan, "Size Productivity and Returns to Scale: An Analysis of
Farm-Level Data in Indian Agriculture," an unpublished paper, 1972.

J. S. Bhagwati and S. Chakravarty, "Contributions to Indian Economic Analysis:
A Survey," Am. Econ. Rev., 59:1-73, September 1969 (Supplement).

Martin H. Billings and Arjan Singh, "The Effect of Technology on Farm Employment
in India," Development Digest 9:98-107, January 1971.

_____, "Conventional Energy as a Constraint to the Green Revolution 1964-84:
The Punjab Case," mimeo for USAID, New Delhi, April 1969.

Directorate of Economics and Statistics, "Studies in Economics of Farm Management,
Ferozepur District (Punjab)--Part II Tables," Ministry of Food and Agriculture,
Government of India, 1967-68, 1968-69.

David W. Hopper, "Allocation Efficiency in a Traditional Agriculture," J. Farm Econ.,
47:611-624, August 1965.

Bruce F. Johnston and John Cownie, "The Seed Fertilizer Revolution and Labor Force
Absorption," American Economic Review, LIX:569-582, Sept. 1969.

A. S. Kahlon, S. S. Miglani and S. K. Mahta, "Studies in Economics of Farm Manage-
ment, Ferozepur District, Punjab - Report for 1968-69," Department of Economics
and Sociology, Punjab Agricultural University Ludhiana, Punjab, India.

Hiromitsu Kaneda, "Economic Implications of the 'Green Revolution' and the Strategy
of Agricultural Development in West Pakistan," Pakistan Development Review,
9:111-143, Summer 1969.

A. M. Khusro, "Returns to Scale in Indian Agriculture," Indian J. Agr. Econ., 19:51-80,
October 1964.

Raj Krishna, "New Technology, Food Production and Equity," A paper presented at the
Symposium on Food Production and Income Distribution in South Asia--The Double
Dilemma, Kansas State University, Manhattan, Kansas, September 1969.

L. J. Lau, "Some Applications of Profit Functions," Memorandum No.s 86A and 86B, Research Center in Economic Growth, Stanford University, November 1969.

_____ and P. A. Yotopoulos, "A Test for Relative Economic Efficiency and Application to Indian Agriculture," Am. Econ. Rev., 61:94-109, March 1971.

_____, "Profit, Supply and Factor Demand Functions," Am. J. Agr. Econ., 54:11-18, Feb. 1972.

_____, "A Test for Relative Economic Efficiency: Some Further Results," Memorandum No. 104, Research Center in Economic Growth, Stanford University, Aug. 1970.

Roger Lawrence, "Some Economic Aspects of Farm Mechanization in Pakistan," Aug. 1970, unpublished.

Dipak Mazumdar, "On the Economics of Relative Efficiency of Small Farmers," Econ. Weekly, 5:1212-24, Special No., July 1963.

C. H. Hanumantha Rao, "Alternative Explanations of the Inverse Relationship Between Farm Size and Output per Acre in India," Indian Econ. Rev., Oct. 1966.

_____, "Farm Mechanization in a Labor-Abundant Economy," Econ. and Pol. Weekly, Annual Number, Feb. 1972.

G. S. Sahota, "Efficiency of Resource Allocation in Indian Agriculture," Am. J. Agr. Econ., 50:584-605, August 1968.

G. R. Saini, "Farm Size, Productivity and Returns to Scale," Econ. and Pol. Weekly IV, No. 26:A119-A122, June 1969.

_____, "Holding Size, Productivity, and Some Related Aspects of Indian Agriculture," Econ. and Pol. Weekly, Rev. of Agr.: A79-A85, June 1971.

Theodore W. Schultz, Transforming Traditional Agriculture. (New Haven: Yale University Press, 1964).

Amartya K. Sen, "Peasant and Dualism with or without Surplus Labor," J. Pol. Econ., 74:425-450, October 1966.

_____, "Size of Holdings and Productivity," Econ. Weekly, 6:57-61, Annual No., February 1964.

R. W. Shephard, Cost and Production Functions, (Princeton: Princeton University Press, 1953).

Surjit Singh Sidhu, "Economics of Technical Change in Wheat Production in Punjab, India," Ph.D. Thesis, University of Minnesota, 1972.

T. N. Srinivasan, "Farm Size and Productivity: Implications for Choice Under Uncertainty," Discussion Paper No. 53, Planning Unit, Indian Statistical Institute, January 1971.

P. A. Yotopoulos, "On the Efficiency of Resource Utilization in Subsistence Agriculture," Food Research Institute Studies in Agricultural Economics, Trade and Development, Vol. VIII, No. 2, 1968, Stanford University, Stanford, California.

Arnold Zellner, "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," J. Am. Stat. Assoc. 57:348-375, June 1962.