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9. ABSTRACT

In recent contributions to this Review, Lawrence Lau and Pan Yotopoulos (L-Y) applied the profit function concept to the analysis of relative efficiency of Indian agriculture. In this paper, the L-Y model is confronted with new and recent data for wheat farms in the Indian Punjab. The results run counter to their findings in that the author does 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, he also compares 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 LDCs. Section I of the present paper establishes a link between his estimation procedure and the L-Y model and briefly describes the data and the variables. Section II provides empirical estimates, derives the implications of these results, and compares them with those of L-Y. Section III summarizes his conclusions.

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Relative Efficiency in Wheat Production in the Indian Punjab

By SURJIT S. SIDHU*

In recent contributions to this *Review*, Lawrence Lau and Pan Yotopoulos (L-Y) 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 allocative structure of Indian agriculture.

In this paper, the L-Y model is confronted with new and recent data for wheat farms[1] in the Indian Punjab. My results run counter to their findings in that I 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, I 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. Section I of the present paper establishes a link between my estimation procedure and the L-Y model and briefly describes the data and the variables. Section II provides empirical estimates, derives the implications of these results, and compares them with those of L-Y. Section III summarizes my conclusions.

I. Estimating Procedure and the Data

In order to study relative economic efficiency and its components of technical efficiency and price efficiency, the profit function formulation used by Lau and Yotopoulos seems to be an ideal tool. Since this paper is an extension of their work, it is unnecessary to reproduce the model and the related derivations. I provide a brief description of the data and the variables as they relate to the estimating equations.

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

$$Y = F(N; L, K) \tag{1}$$

where Y is output, N is the variable input labor, and L and K are the fixed inputs of land and capital, respectively. Following the L-Y papers, the estimating equations for the Cobb-Douglas case of this production function are presented in Tables 2, 3, and 4.

For statistical specification I assume additive errors with zero expectation and finite variance for each of the two equations. 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

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[1] The Punjab farms are multi-enterprise farms. This investigation deals only with wheat, not all farm enterprises.

TABLE 1—BRIEF SUMMARY OF THE SAMPLES AND DATA

Sample	Geographic Coverage	Villages Included	Farms	Crop Year	Wheat Type	Observations Available
1) Ferozepur	District-Ferozepur	15	150	1967–68	New	105
				1967–68	Old	132
				1968–69	New	144
2) Tractor Cultivation	Punjab	19	304	1969–70	New	287
3) Regionally Stratified	Punjab	7	128	1970–71	New	128

Sources: 1) Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India; 2) The Economic Adviser, Government of Punjab; 3) I was responsible for the design and supervision of data collection work for this sample.

corresponding to different farms are assumed to be zero. With these assumptions an asymptotically efficient method of estimation as proposed by Arnold Zellner is used[2] to estimate jointly the parameters of the two equations. A brief description of the variables and the notation used is as follows:

Y = physical output of wheat measured in quintals per farm including by-products.[3]

N = the labor input per farm used for wheat production measured in hours. It includes both family and hired labor.[4]

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.[5]

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

wN = the total wage bill in rupees for wheat production per farm.[6]

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: total revenue less total variable labor costs.

π = the profit function.

A brief summary of the samples and data used in this study is provided in Table 1. As compared to the group average data used by L-Y and most earlier Indian studies, I have been fortunate to have access to micro level primary data.

II. Empirical Results

A. *Old versus New Varieties of Wheat*

The first test for relative economic efficiency in wheat production in Punjab compares the economic efficiency of new varieties of wheat with the old varieties of wheat. For this purpose 1967–68 data are used from the Ferozepur Sample (see Table 1). The two equations (the profit function and the labor demand function) are estimated jointly using Zellner's method 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.[7] These results are presented in Table 2. They indicate that the new wheats are economically

[2] This will also make our results comparable to those of L-Y.

[3] The by-products are converted into quintals of wheat by dividing the total value of by-products by wheat price.

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

[5] 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 per annum. The actual number of hours of use times the hourly flow of services of each durable input gives its total service flow. Aggregation of these asset-specific service flows plus the seed and fertilizer costs yields a measure of the capital services.

[6] Family labor services are valued as equivalent to those of the annual contract labor for each farm.

[7] This assumption is based on the earlier tests carried out in my dissertation and tests carried out in subsequent sections.

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
$\lambda=$	4.872	0.965
$\delta^N=$	0.485	0.129
$\beta_1=$	0.254	0.013[a]
$\beta_2=$	0.670	0.155
$\beta_3=$	0.330	0.155

Note: The estimating equations are:

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

$$-\frac{wN}{\pi} = \beta_1, \quad \text{where} \quad \lambda = ln\ A_*^0 + (1-\beta_1)\ ln\ p$$

[a] In both equations.

more efficient compared to the old wheats by 48.50 percent. 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, 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 maintaining the *hypothesis of neutral technical shift*,[8] we find that the efficiency parameter for the new wheat production function is larger by 44.70 percent.

B. *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. It is thus important to obtain knowledge of the source of differences (technical or price) in economic efficiency.

For the new varieties of wheat the estimation results using Zellner's method for each of the four years 1967–68 to 1970–71 and for the four-year combined data comparing small and large[9] wheat farms are presented in Table 3. For comparing tractor-operated and non-tractor-operated farms, the results employing data for Tractor Cultivation Sample 1969–70 (as described in Table 1), are presented in Table 4. In order to provide answers to the questions of relative efficiency posed above we carry out the following statistical tests:

1) The hypothesis of equal relative economic efficiency of small and large and tractor and nontractor wheat farms:

(i) H_o: $\delta^L = 0$

(ii) H_o: $\delta^T = 0$

2) The hypothesis of equal relative price efficiency with respect to labor demand of small and large and tractor and nontractor wheat farms:

(i) H_o: $\beta_1^L = \beta_1^S$

(ii) H_o: $\beta_1^T = \beta_1^{NT}$

3) The joint hypotheses of equal relative technical and price efficiency of small and large and tractor and nontractor wheat farms:

(i) H_o: $\delta^L = 0$ and $\beta_1^L = \beta_1^S$

(ii) H_o: $\delta^T = 0$ and $\beta_1^T = \beta_1^{NT}$

[8] In my dissertation I 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.

[9] 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. (See Martin Billings and Arjan Singh, 1971.) Also it facilitates comparisons of our results with those of L-Y (1971, 1973) who also used this criterion for small and large farms.

TABLE 3—RESULTS OF JOINT ESTIMATION OF COBB-DOUGLAS PROFIT FUNCTION AND LABOR DEMAND FUNCTION FOR NEW WHEAT, PUNJAB, INDIA

	UOP Profit Function					Labor Demand Function		
	λ	δ^L	β_1	β_2	β_3	β_1^L	β_1^S	R^2
1967–68								
Single Equation	3.799	−0.141	0.107	0.614	0.487	−0.221	−0.289	0.923
Ordinary Least Squares (*OLS*)	*0.748*	*0.144*	*0.159*	*0.115*	*0.125*	*0.075*	*0.040*	
Unrestricted	3.433	−0.064	0.263	0.506	0.564	−0.221	−0.289	
	0.641	*0.137*	*0.136*	*0.098*	*0.107*	*0.075*	*0.040*	
1 Restriction[a]	3.446	−0.112	0.262	0.506	0.563	−0.274	−0.274	
	0.641	*0.123*	*0.136*	*0.098*	*0.107*	*0.035*	*0.035*	
2 Restrictions[b]	3.019	−0.138	−0.244	0.520	0.599	−0.244	−0.244	
	0.667	*0.131*	*0.034*	*0.104*	*0.113*	*0.034*	*0.034*	
3 Restrictions[c]	3.885	0.093	−0.236	0.537	0.462	−0.236	−0.236	
	0.636	*0.115*	*0.034*	*0.109*	*0.109*	*0.034*	*0.034*	
1968–69								
Single Equation	4.115	−0.041	−0.507	0.713	0.334	−0.406	−0.433	0.771
OLS	*0.994*	*0.160*	*0.207*	*0.179*	*0.170*	*0.065*	*0.059*	
Unrestricted	3.714	0.049	0.024	0.514	0.454	−0.406	−0.433	
	0.692	*0.133*	*0.144*	*0.124*	*0.118*	*0.065*	*0.059*	
1 Restrictions[a]	3.725	0.026	0.024	0.514	0.454	−0.421	−0.421	
	0.691	*0.111*	*0.144*	*0.124*	*0.118*	*0.043*	*0.043*	
2 Restrictions[b]	3.391	0.061	−0.381	0.477	0.495	−0.381	−0.381	
	0.673	*0.109*	*0.041*	*0.122*	*0.116*	*0.041*	*0.041*	
3 Restrictions[c]	3.309	0.015	−0.381	0.498	0.503	−0.381	−0.381	
	0.655	*0.070*	*0.041*	*0.114*	*0.114*	*0.041*	*0.041*	

Note: Zellner's method of estimation was used to obtain joint estimates of the *UOP* Profit Function and the Labor Demand Function.

[a] 1 Restriction: $\beta_1^L = \beta_1^S$.

[b] 2 Restrictions: $\beta_1^L = \beta_1$; $\beta_1^S = \beta_1$.

[c] 3 Restrictions: $\beta_1^L = \beta_1$; $\beta_2 + \beta_3 = 1$; $\beta_1^S = \beta_1$.

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:

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

$$-\frac{wN}{\pi} = \beta_1^L D^L + \beta_1^S D^S$$

where

π = profit (total receipts less wage bill)

w = money wage rate

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

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

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

N = labor in hours per farm used in wheat production

L = land in acres used for producing wheat

K = total costs of capital services for wheat per farm

Asymptotic standard errors are in italics.

TABLE 3 (*Continued*)

	UOP Profit Function					Labor Demand Function		
	λ	δ^L	β_1	β_2	β_3	β_1^L	β_1^S	R^2
1969–70								
Single Equation	4.651	0.093	−0.278	0.740	0.259	−0.501	−0.449	0.776
OLS	*0.477*	*0.108*	*0.124*	*0.098*	*0.082*	*0.153*	*0.204*	
Unrestricted	4.748	0.136	−0.058	0.714	0.260	−0.501	−0.440	
	0.411	*0.098*	*0.106*	*0.085*	*0.070*	*0.153*	*0.204*	
1 Restriction[a]	4.744	0.142	−0.058	0.714	0.260	−0.482	−0.482	
	0.410	*0.093*	*0.016*	*0.085*	*0.070*	*0.122*	*0.122*	
2 Restrictions[b]	4.744	0.142	−0.248	0.716	0.256	−0.248	−0.248	
	0.418	*0.094*	*0.081*	*0.086*	*0.072*	*0.081*	*0.081*	
3 Restrictions[c]	4.694	0.099	−0.247	0.742	0.257	−0.247	−0.247	
	0.408	*0.055*	*0.081*	*0.072*	*0.072*	*0.081*	*0.081*	
1970–71								
Single Equation	2.859	0.056	−0.481	0.477	0.581	−0.234	−0.304	
OLS	*0.641*	*0.110*	*0.189*	*0.131*	*0.112*	*0.051*	*0.048*	
Unrestricted	3.287	−0.048	−0.184	0.496	0.539	−0.254	−0.265	
	0.595	*0.104*	*0.176*	*0.121*	*0.103*	*0.051*	*0.046*	
1 Restriction[a]	3.291	−0.051	−0.184	0.496	0.539	−0.259	−0.259	
	0.594	*0.102*	*0.175*	*0.121*	*0.103*	*0.025*	*0.025*	
2 Restrictions[b]	3.386	−0.057	−0.255	0.512	0.523	−0.255	−0.255	
	0.581	*0.101*	*0.025*	*0.117*	*0.100*	*0.025*	*0.025*	
3 Restrictions[c]	3.438	−0.010	−0.254	0.477	0.523	−0.254	−0.254	
	0.576	*0.059*	*0.025*	*0.110*	*0.100*	*0.025*	*0.025*	

	UOP Profit Function								Labor Demand Function	
	$\ln A_*^s$	δ^L	δ_1	δ_2	δ_3	β_1	β_2	β_3	β_1^L	β_1^S
1967–68 to 1970–71										
Single Equation	4.405	−0.025	−0.411	−0.393	−0.242	−0.243	0.709	0.359	−0.411	−0.351
OLS	*0.334*	*0.059*	*0.068*	*0.063*	*0.071*	*0.079*	0.058	0.056	0.078	0.078
Unrestricted	4.479	−0.021	−0.384	−0.353	−0.241	−0.085	0.690	0.358	−0.412	−0.346
	0.301	*0.056*	*0.061*	*0.057*	*0.064*	*0.072*	*0.053*	*0.051*	*0.078*	*0.077*
1 Restriction[a]	4.475	−0.012	−0.384	−0.353	−0.240	−0.085	0.690	0.358	−0.379	−0.379
	0.301	*0.053*	*0.061*	*0.057*	*0.064*	*0.072*	*0.052*	*0.051*	*0.052*	*0.052*
2 Restrictions[b]	4.410	−0.015	−0.377	−0.347	−0.200	−0.279	0.700	0.358	−0.279	−0.279
	0.303	*0.054*	*0.062*	*0.057*	*0.063*	*0.042*	*0.053*	*0.051*	*0.042*	*0.042*
3 Restrictions[c]	4.568	0.075	−0.336	−0.305	−0.163	−0.271	0.663	0.337	−0.271	−0.271
	0.297	*0.038*	*0.060*	*0.054*	*0.061*	*0.042*	*0.050*	*0.050*	*0.042*	*0.042*

From Table 5 we see that none of these three hypotheses can be rejected at the 90 percent level of significance. Thus the hypotheses 1) that small and large wheat producing farms have equal relative *economic efficiency* and equal relative *price efficiency* and 2) that tractor-operated and non-tractor-operated wheat producing farms have equal relative *economic efficiency* and equal relative *price efficiency* are supported by these results. This implies that these farms also have equal *technical 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.

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

(i) Absolute price efficiency of large farms,

$$H_o: \quad \beta_1^L = \beta_1$$

TABLE 4—RESULTS OF JOINT ESTIMATION OF COBB-DOUGLAS PROFIT FUNCTION AND LABOR DEMAND FUNCTION FOR NEW WHEAT, 1969–70, PUNJAB, INDIA

		Estimated Coefficients				
			Zellner's Method with Restrictions			
Function	Parameter	Single Equation *OLS*	Un-restricted	1 Restriction[a]	2 Restrictions[b]	3 Restrictions[c]
UOP Profit Function	λ	4.830	4.778	4.794	4.811	4.934
		(0.501)	(0.433)	(0.433)	(0.441)	(0.398)
	δ^T	0.089	0.075	0.032	0.041	0.062
		(0.073)	(0.070)	(0.063)	(0.064)	(0.054)
	β_1	−0.286	−0.062	−0.064	−0.253	−0.256
		(0.124)	(0.107)	(0.107)	(0.081)	(0.081)
	β_2	0.790	0.785	0.785	0.788	0.779
		(0.083)	(0.071)	(0.071)	(0.073)	(0.072)
	β_3	0.224	0.241	0.241	0.235	0.221
		(0.085)	(0.073)	(0.073)	(0.075)	(0.072)
Labor Demand Function	β_1^T	−0.259	−0.259	−0.481	−0.252	−0.256
		(0.203)	(0.202)	(0.122)	(0.081)	(0.081)
	β_1^{NT}	−0.610	−0.610	−0.481	−0.252	−0.256
		(0.153)	(0.153)	(0.122)	(0.081)	(0.081)
	R^2	0.777				

Note: 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; and 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.

[a] See fn. a, Table 3.

[b] See fn. b, Table 3.

[c] See fn. c, Table 3.

TABLE 5—TESTING OF STATISTICAL HYPOTHESES

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

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

(ii) Absolute price efficiency of small farms,

$$H_o: \ \beta_1^S = \beta_1$$

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, 1968–69, and 1969–70, 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. For the year 1970–71, however, we find that both small and large farms were in equilibrium, i.e., maximizing profits.

4b) Maintaining the hypothesis of equal price efficiency in 2), we also test the hypotheses of:

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

(ii) Absolute price efficiency of nontractor farms, $Ho: \beta_1^{NT} = \beta_1$

The meaning of these tests is whether tractor and nontractor farms maximize profits by equating the value of marginal product of labor to its opportunity price. The null hypothesis is rejected in both cases. The conclusion is that both tractor and nontractor farms were not able to maximize profits during the year 1969–70. In light of the results for the hypothesis of equal relative price efficiency in statistical test 2), we conclude that, with respect to labor, tractor and nontractor 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:

$$H_o: \ \beta_2 + \beta_3 = 1$$

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.

Important policy implications follow from these findings. The 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, marketing 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.

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 and allocative studies.[10] The results appear to indicate the existence of a disequilibrium between the profit-maximizing attempts and the actual results achieved by wheat producers. It is most likely created by a shift to the right in the labor demand function, resulting from the introduction of high-yielding wheats.[11] During the first three years, 1967–68, 1968–69, and 1969–70, producers were not in equilibrium in the sense of equating the marginal value product of labor to its opportunity cost. And during the last year 1970–71, we cannot reject the hypotheses of absolute price efficiency. 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. These results seem to suggest that in a changing agriculture one should

[10] See for example David Hopper, A. M. Khusro, Theodore Schultz, G. S. Sahota and L-Y (1971, 1973).

[11] Results reported in my dissertation indicate that the per acre factor demand functions shifted to the right by 25 percent as a result of the introduction of Mexican wheat varieties in Punjab.

expect the existence of a fair amount of inefficiency in the labor market but that producers do seem to react to overcome the existence of a disequilibrium.

C. *Comparison with Findings by Lau and Yotopoulos*

We provide two brief comparisons of our results with the research of L-Y (1971, 1973) 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 (Table 3) using four-year (1967–68 to 1970–71) data, and are presented in Table 6. These estimates are obtained from identities which link 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.

All the estimates of output elasticities with respect to various inputs (including capital) have the expected signs and reasonable magnitudes. I seem to be fortunate in having data which yielded reasonable elasticity estimates for capital. L-Y 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 my findings agree with L-Y regarding equal relative price efficiency and equal absolute price efficiency of small and large farms, the findings regarding equal technical and thus equal overall economic efficiency differ. They find small farms relatively more efficient technically and thus more efficient economically, whereas my results indicate no differences in technical or economic efficiency of small and large farms.

TABLE 6—ESTIMATES OF THE INPUT ELASTICITIES OF THE COBB-DOUGLAS PRODUCTION FUNCTION DERIVED FROM THE PROFIT FUNCTION FOR NEW WHEAT 1967–68 to 1970–71,[a] PUNJAB, INDIA

		1 Restriction[b]	2 Restrictions[c]	3 Restrictions[d]
Labor	α_1	0.078	0.218	0.213
Land	α_2	0.636	0.547	0.522
Capital	α_3	0.349	0.280	0.265
$(\alpha_1+\alpha_2+\alpha_3)$		1.063	1.045	1.000

[a] Table 3, last column.
[b] See fn. a, Table 3.
[c] See fn. b, Table 3.
[d] See fn. c, Table 3.

A possible explanation for this discrepancy might be as follows:

Their findings pertain to the mid-1950's. Indian agriculture at that time could be characterized as traditional and in a state of equilibrium with available technology (see Schultz). Modern inputs like chemical fertilizers were conspicuous by their absence. Smaller farms which had more labor available per unit of land[12] perhaps used it for more intensive land improvement programs which resulted in superior technical efficiency compared to the larger farms. Also as emphasized by L-Y, 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-1950's, however, Indian agriculture has undergone 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

[12] At this point a reference is made to the studies by Amartya Sen, the survey article by Jagdish Bhagwati and Sukhamay Chakravarty, and T. N. Srinivasan.

smaller farms during the mid-1950's seems to be less important during the late 1960's.

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 L-Y (1971, 1973) 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.

D. *Elasticity Estimates*

Next I present a number of important elasticity estimates derived from the profit function estimates for four-year data (1967–68 to 1970–71), shown in the last column of Table 3. The labor demand elasticities with respect to wage rate w, land L, capital K, and price of output, respectively, are -1.271, 0.663, 0.337, and 1.271.

All these elasticity estimates have the expected signs. The price elasticity of demand for labor indicates that demand is quite responsive to wage levels. Positive responses for labor demand to increases of land, capital and output price have important implications for labor absorption in wheat farming.

The elasticities of output supply with respect to the normalized wage rate and output price are -0.271 and 0.271, respectively. The relatively inelastic output response with respect to wage rate along with an elastic response of demand for labor with respect to wage rate imply 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.[13] The magnitude of output response with respect to wheat price is important for any effort to use the output price variable as a policy instrument for inducing increased supply of wheat.

We also obtain the reduced form output elasticities with respect to land and capital, 0.663 and 0.337, respectively. 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 1 percent expansion in wheat land will result in 0.663 percent increase in wheat output and a 1 percent increase in capital will result in 0.337 percent increase in wheat output.

III. Summary and Conclusions

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 the "green revolution," constitute the more important source for potential increases of output. Second, we find that tractor-operated wheat farms are no better off in terms of their economic performance than non-tractor-operated farms and that large farms are no better off than small farms. There are no differences in the technical and price efficiency parameters of these classes of farms. Policy for cur-

[13] For excellent discussions of the impending problem of labor force absorption in the context of the "green revolution" and farm mechanization, see Bruce Johnston and John Cownie, Billings and Singh, and C. H. Hanumantha Rao.

tailing farm size may be based only on social and political considerations. 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. The picture may be different if we study the production relationship between aggregate output of all enterprises and the inputs used.

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