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ESTIMATING LABOUR DEMAND FUNCTIONS AND LABOUR ABSORPTION IN AGRICULTURE: A CASE STUDY OF DELHI WHEAT FARMS

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The seed-fertilizer based technology has been shown by many to have a favourable direct effect on farm employment. High opportunity cost of labour and high cost of maintaining bullocks have led to rather rapid tractorisation in some areas of the country. The employment effect of tractorisation, however, continues to be a subject of considerable controversy. This paper provides some evidence on employment elasticities with respect to certain key variables such as factor-product prices, land and capital, and decomposition of total difference in employment between bullock and tractorised farms into constituent causal forces. The specific objectives of this research paper are (1) to estimate employment elasticities for key variables such as wages, fertilizer price, irrigated land and capital inputs, (2) to decompose the total change in employment per acre between tractor and bullock operated farms into (*i*) mechanization component, (*ii*) wage rate component and (*iii*) compensatory inputs component, and (3) to simulate the impact of inflationary cost pressures on the labour market and analyse the required compensatory adjustments in product price and irrigation in order to reach different employment goals.

THE DATA

The data collected under a farm records project in the Division of Agricultural Economics of the Indian Agricultural Research Institute, New Delhi were used. Under this project detailed information on randomly selected farms from two villages of the Union Territory of Delhi was collected by cost accounting method between 1968-69 and 1975-76. In this study, we report the results pertaining to predominantly wheat growing farms. These were classified as bullock and tractor operated farms. Table I gives the details regarding some crucial variables on these two categories of farms.

TABLE I—PER ACRE INPUT USE ON BULLOCK AND TRACTOR OPERATED WHEAT FARMS

Items	Bullock farms	Tractor farms
Number of farms	93	107
Average wheat area (acres)	5·43	11·63
Human labour (hours)	274	128
Bullock labour (hours)	89	1
Tractor (hours)	0·2	8·7
Thresher (hours)	21·7	29·0
Plant nutrients (kg.)	31·8	37·1
Irrigation (No.)	5	5

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The 53 per cent decline in human labour use on tractor operated farms obviously cannot be attributed to tractors alone. Apart from 'farm size effect', this could include a 'mechanization effect' emanating from higher use of machines like threshers, etc.

THEORETICAL FRAMEWORK

The profit function formulation suggested by Lau and Yotopoulos[1] enables us to derive labour demand as a function of the normalized wage rate, variable input prices and the quantities of fixed inputs.

Consider the production function in Cobb-Douglas form with the usual neo-classical properties:

$$Q = A \quad N^{\alpha_1} \; F^{\alpha_2} \; L^{\beta_1} \; K^{\beta_2} \qquad \ldots\ldots(1)$$

where Q is output, N is the variable labour input, F is the variable fertilizer input and L and K are the fixed inputs of land and capital respectively.[2] Following Lau and Yotopoulos, the profit and labour equations are as follows:
Normalized restricted profit equation:

$$\pi^* = A^* \left(\frac{w}{P}\right)^{\alpha_1^*} \left(\frac{r}{P}\right)^{\alpha_2^*} L^{\beta_1^*} \quad K^{\beta_2^*} \qquad \ldots\ldots(2)$$

where $A^* = (1-\alpha)\, A^{\theta}\, \alpha_1^{\alpha_1\theta}\, \alpha_2^{\alpha_2\theta}$, $\alpha = \alpha_1 + \alpha_2$, $\theta = (1-\alpha)^{-1}$,
$\alpha_1^* = -\alpha_1\theta$, $\alpha_2^* = -\alpha_2\theta$, $\beta_1^* = \beta_1\theta$, and $\beta_2^* = \beta_2\theta$.

Labour demand equation:

$$N = A' \left(\frac{w}{P}\right)^{\alpha_1^* - 1} \left(\frac{r}{P}\right)^{\alpha_2^*} L^{\beta_1^*} \quad K^{\beta_2^*} \qquad \ldots\ldots(3)$$

where $A' = -\alpha_1^* . A^*$, $\pi^* = \pi/P$ = normalized profit or unit-output-price (UOP) profit, π = profit, defined as current revenues less current total variable input cost, r = fertilizer price, w = wage rate and P = wheat price.

In equation (3), we have a labour demand function in terms of normalized wage rate, normalized fertilizer price, and quantities of land and capital.

Decomposition of total difference in employment between bullock and tractor operated wheat farms is our other main concern. For this purpose, we differentiate (3) totally and convert into per acre terms:

$$\frac{dN}{N} = \frac{d\,\alpha_1^*}{\alpha_1^*} + \frac{dA^*}{A^*} + (\alpha_1^* - 1)\frac{dw'}{w'} + \alpha_2^* \frac{dr'}{r'} + \beta_2^* \frac{dK}{K} + \ln w'\, d\,\alpha_1^* + \ln r'\, d\,\alpha_2^* + \ln K\, d\,\beta_2^*$$

where $w' = w/P$ and $r' = r/P$ $\qquad \ldots\ldots(4)$

The decomposition equation (4) can be expressed in terms of elasticities of production parameters as follows:[3]

1. Lawrence J. Lau and Pan A. Yotopoulos, "Profit, Supply, and Factor demand Functions", *American Journal of Agricultural Economics*, Vol. 54, No. 1, February 1972, pp. 11-18.

2. Fixed capital factors include: expenditure on bullock labour, value of seed, expenditure on irrigation, expenditure on tractor, value of plant protection measures used, expenditure on threshing and transporting, land revenue and interest on crop loan.

3. For a more detailed derivation, see S. Bisaliah, "Decomposition Analysis of Employment Change under New Production Technology in Punjab Agriculture", *Indian Journal of Agricultural Economics*, Vol. XXXIII No. 2, April-June 1978, pp. 70-80. In this paper he developed the decomposition equation taking only labour as a variable input.

$$\frac{dN}{N} = \left[\frac{dA}{A(1-\alpha_1-\alpha_2)}\right] + \left[\frac{d\alpha_1 + d\alpha_2}{(1-\alpha_1-\alpha_2)^2} \ln A + \frac{d\alpha_1 - \alpha_2 d\alpha_1 + \alpha_1 d\alpha_2}{1-\alpha_1-\alpha_2)^2} \ln \alpha_1 + \frac{d\alpha_2 - \alpha_1 d\alpha_2 + \alpha_2 d\alpha_1}{(1-\alpha_1-\alpha_2)^2} \ln \alpha_2 + \frac{d\alpha_1 - \alpha_2 d\alpha_1 + \alpha_1 d\alpha_2}{\alpha_1(1-\alpha_1-\alpha_2)} + \frac{\alpha_2 d\alpha_1 - \alpha_1 d\alpha_2 - d\alpha_1}{(1-\alpha_1-\alpha_2)^2} \ln w + \frac{\alpha_1 d\alpha_2 - \alpha_2 d\alpha_1 - d\alpha_2}{(1-\alpha_1-\alpha_2)^2} \ln r + \frac{d\alpha_1 + d\alpha_2}{(1-\alpha_1-\alpha_2)^2} \ln P + \frac{(1-\alpha_1-\alpha_2) d\beta_2 + \beta_2(d\alpha_1 + d\alpha_2)}{(1-\alpha_1-\alpha_2)^2} \ln K\right] + \left[\left(\frac{-\alpha_1}{1-\alpha_1-\alpha_2} - 1\right)\frac{dw}{w}\right] + \left[\left(\frac{-\alpha_2}{1-\alpha_1-\alpha_2}\right)\frac{dr}{r}\right] + \left[\frac{1}{1-\alpha_1-\alpha_2}\frac{dP}{P}\right] + \left[\frac{\beta_2}{1-\alpha_1-\alpha_2}\frac{dK}{K}\right]. \quad \ldots.(5)$$

This formulation has the advantage of separating the effect of neutral and non-neutral components of technical change on employment. The mechanization effect is captured by adding the value of first (neutral component of technical change) and second (non-neutral component of technical change) bracketed expressions of employment decomposition equation, given w, r and K for bullock operated farms. The third, fourth and fifth bracketed expressions of equation (5) capture the effects of differences in wage rates, fertilizer price and wheat price respectively, given the output elasticities of variable inputs for tractor operated farms. The last bracketed expression measures complementary inputs' effect on employment, given the tractor operated output elasticities.

LABOUR DEMAND FUNCTIONS

The three equations—the UOP profit function, labour, and fertilizer demand functions—given in Table II were estimated jointly using Zellner's method[4] by imposing appropriate restrictions. The entire area under HYV of wheat was irrigated and, therefore, introduction of a weather index in the profit equation as well as of year dummy variables proved to be insignificant. The explanatory variables in profit function were responsible for explaining more than 72 per cent of variation in profit of wheat.[5]

As expected, the profit function is decreasing in prices of labour and fertilizer and increasing in land and fixed capital inputs. From the estimated parameters of profit function, the elasticities of labour demand and wheat production functions have been derived and presented in Table III.

Employment elasticities with respect to different factors were estimated to be different under bullock and tractor operated farms. This implies that employment response to a given change in these key variables will be different

4. A. Zellner, "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias", *Journal of the American Statistical Association*, Vol. 57, No. 2, June 1962, pp. 348-375.

5. The coefficient of variation (R^2) estimates are based on least-square estimates of the single equation model of unrestricted UOP profit function.

TABLE II—RESULTS OF JOINT ESTIMATION OF COBB-DOUGLAS PROFIT FUNCTION, AND LABOUR AND FERTILIZER DEMAND FUNCTIONS FOR HYV OF WHEAT, DELHI

Parameter	Bullock operated farms	Tractor operated farms	All farms
UOP profit function			
ln A*	0·8955* (0·3627)	0·4143 (0·5231)	0·9439** (0·3182)
α_1^*	—0·2036** (0·0160)	—0·0852** (0·0288)	—0·1456** (0·0183)
α_2^*	—0·0737** (0·0054)	—0·0901** (0·0186)	—0·0852** (0·0112)
β_1^*	0·9722** (0·0639)	0·7772** (0·8540)	0·9361** (0·0527)
β_2^*	0·0277 (0·0638)	0·2227** (0·0854)	0·0639 (0·0527)
Labour demand function			
α_1^*	—0·2036** (0·01567)	—0·0852** (0·0282)	—0·1456** (0·0181)
Fertilizer demand function			
α_2^*	—0·0737** (0·0053)	—0·0901** (0·0182)	—0·0852** (0·0111)

Note:—The estimating equations are:

UOP profit function: $\ln \pi^* = \ln A^* + \alpha_1^* \ln\left(\frac{w}{P}\right) + \alpha_2^* \ln\left(\frac{r}{P}\right) + \beta_1^* \ln L + \beta_2^* \ln K$

Labour demand function: $\frac{\left(\frac{w}{P}\right) N}{\pi^*} = -\alpha_1^*$

Fertilizer demand function: $\frac{\left(\frac{r}{P}\right) X}{\pi^*} = -\alpha_2^*$

Restrictions: $\alpha_1^* = \alpha_1$, $\alpha_2^* = \alpha_2$, and $\beta_1^* + \beta_2^* = 1$

Figures in parentheses are asymptotic standard errors of the estimates.

*, ** indicate the level of significance at 5 per cent and 1 per cent respectively.

TABLE III—ESTIMATES OF ELASTICITIES OF LABOUR DEMAND AND PRODUCTION FUNCTIONS DERIVED FROM THE UOP PROFIT FUNCTION FOR HYV OF WHEAT, DELHI

Parameter	Bullock operated farms	Tractor operated farms	All farms
Labour demand function (Cobb-Douglas)			
Intercept term	0·4985	0·1289	0·3742
Wage (Rs./hour)	—1·2036	—1·0852	—1·1456
Fertilizer price (Rs./kg.)	—0·0737	—0·0901	—0·0852
Wheat price (Rs./quintal)	1·2773	1·1753	1·2308
Irrigated land (acres)	0·9722	0·7773	0·9361
Capital	0·0278	0·2227	0·0639
Production function (Cobb-Douglas)			
Intercept term (A)	3·8575	2·4037	3·9471
Labour (α_1)	0·1594	0·0725	0·1183
Fertilizer (α_2)	0·0577	0·0767	0·0692
Land (β_1)	0·7612	0·6613	0·7606
Capital (β_2)	0·0217	0·1895	0·0519

on these two types of farms. Tractorised farms were less sensitive to changes in wages, wheat price and irrigated land as compared to bullock operated farms. Elastic responses to wages and output price underscore the crucial importance of these variables, irrespective of the type of farms. Thus, the estimated labour demand functions identify wages, product price and irrigation as the dominant determinants.

DECOMPOSITION OF EMPLOYMENT CHANGE

Using the parameters of the production function given in Table III, the total difference in per acre employment between bullock and tractorised wheat farms can be decomposed as shown in Table IV.

TABLE IV—DECOMPOSITION OF DIFFERENCE IN PER ACRE EMPLOYMENT OF HUMAN LABOUR BETWEEN BULLOCK AND TRACTOR OPERATED FARMS, DELHI

Item	Percentage attributable
Total percentage change in employment	—53·18
Sources of change	
1. Tractorisation effect	
(*a*) Neutral technical change	—48·14
(*b*) Non-neutral technical change	+ 6·71
2. Difference in wage rate	—14·87
3. Difference in fertilizer price	— 1·41
4. Difference in wheat price	+ 8·52
5. Difference in capital inputs	+ 1·07
Total change due to all sources	—48·12

The decomposition analysis, assuming Hicks-non-neutral technical change between bullock and tractorised farms, yielded quite satisfactory results. The effect of non-neutral component of technical change on employment was positive whereas the neutral component was overwhelmingly negative. The pure tractorisation effect, which is the total of neutral and non-neutral components of technical change, on employment was found to be large (41 per cent) and negative. Wage rate and fertilizer price differentials[6] between bullock and tractor operated farms affected employment negatively. The negative employment effects of tractorisation, wages and fertilizer price were not offset by positive employment effect of wheat price and of complementary capital inputs.

POLICY ANALYSIS AND CONCLUSIONS

Elasticities presented in Table III suggest that wages, product price and irrigation are the major variables relevant in the present context. The estimat-

6. The tractor operated farms employed more skilled labour and used more chemical fertilizers in the place of farmyard manure as compared to bullock operated farms. Therefore, the difference in wages and price per unit of plant nutrients exists between the tractorised and bullock operated farms.

ed model of labour demand based on all farms (Table II) can be used to derive the wheat price adjustments and expansion of irrigated land needed to reach specific employment goals. The relative change in labour demand can be measured as follows:

$$\frac{dN}{N} = \frac{dA'}{A'} + E_N^w \frac{dw}{w} + E_N^r \frac{dr}{r} + E_N^P \frac{dP}{P} + E_N^L \frac{dL}{L} + E_N^K \frac{dK}{K} \quad \ldots\ldots(6)$$

where E_N^w, E_N^r, E_N^P, E_N^L and E_N^K are the employment elasticities with respect to wage (w), fertilizer price (r), wheat price (P), irrigated land (L) and fixed level of capital use (K). The fixed level of capital use K can be written as $K = f.\ F$ where f is the price of fixed factors and F is the level of fixed factors.

$$\frac{dK}{K} = \frac{df}{f} + \frac{dF}{F} \quad \ldots\ldots(7)$$

The equation (6) can be written as:

$$\frac{dN}{N} = \frac{dA'}{A'} + E_N^w \frac{dw}{w} + E_N^r \frac{dr}{r} + E_N^P \frac{dP}{P} + E_N^L \frac{dL}{L} + E_N^K \frac{df}{f} + E_N^K \frac{dF}{F} \quad \ldots\ldots(8)$$

Substituting the employment elasticity from Table III into equation (8), the employment growth can be written as:

$$\frac{dN}{N} = -1.1456 \frac{dw}{w} - 0.0852 \frac{dr}{r} + 1.2308 \frac{dP}{P} + 0.9361 \frac{dL}{L} + 0.0639 \frac{df}{f} + 0.0639 \frac{dF}{F} \quad \ldots\ldots(9)$$

The employment growth equation (9) can be solved corresponding to different combinations of factor-product price configurations and the consequent employment effects can be ascertained. We discuss a few interesting situations:

(1) Assuming an expansion in irrigated land and use of fixed inputs ($dL = dK = 0$) and no change in employment ($dN = 0$), the elasticity of product price with respect to the rate of inflation in factor price $\left(\frac{dr}{r} = \frac{dw}{w} = \frac{df}{f}\right)$ can be worked out. Equation (9) yields an estimate of 0.95 implying that for a 10 per cent inflation in factor prices, wheat prices would need to be adjusted by 9.5 per cent to hold employment constant. Higher output induced by high product prices just offsets the negative employment effect of rising factor prices.

(2) In the situation of pure price inflation $\left(\frac{dw}{w} = \frac{dr}{r} = \frac{dP}{P} = \frac{df}{f} = 1\right)$

the growth in employment will be 6.4 per cent of the rate of inflation. The actual rate of factor price inflation in 1979-80 was 16 per cent. In case of pure inflation of 16 per cent, employment would have increased at the rate of 1.02 per cent per annum. The observed annual changes in prices during the period 1968-69 to 1975-76 were 4 per cent in wheat price, 17 per cent in fertilizer price, 19 per cent in wages and 18 per cent in fixed factor prices. The wheat price was adjusted to an extent of only 25 per cent of the factor price inflation whereas equation (9) suggests a 95 per cent adjustment to maintain the employment on farms unaltered. As it is, the observed structure of factor product price changes would result in the displacement of labour to the extent of 17.14 per cent per annum as a result of negative employment response to factor price inflation.

(3) Compensatory price policies on product side to ensure constant employment on farms require a massive increase (76 per cent)[7] in the monetary income of the consumer. Clearly, it would be more appropriate if the adjustment is effected via a programme to enhance technological change and horizontal expansion of irrigation rather than compensatory price policies on product side. The expansion of irrigated land by 18.3 per cent per annum will be required to absorb the surplus farm labour generated through factor price inflation faced by wheat growers. This will be an equally formidable task. Therefore, a combination of product price hike and expansion of irrigated land will be the appropriate policy for maintaining the farm labour employment. The optimal policies of wheat price and irrigation can be worked out from equation (9) to attain the specific goals of farm labour employment for a given level of factor price inflation. For the year 1979-80, factor price inflation being 16 per cent, if the gross irrigated area growth continues at the rate of 2.6 per cent per annum, the complementary countervailing rate of inflation in product price needs to be 14.8 per cent in order to maintain labour employment growth at 2 per cent per annum.

Wages, product price and irrigation are the dominant determinants of employment. The negative employment effect of tractorisation, wages and fertilizer price was not offset by the positive employment effect of wheat price and of complementary inputs. The wheat price must be sufficiently high to induce output response to cancel the negative employment effect which occurs as a result of wage and other factor price inflation. The present structure of input-output prices will displace the labour on farms. Programmes for enhancing technological change and horizontal expansion of irrigation will absorb the surplus farm labour generated through tractorisation and factor price inflation.

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7. In the wheat market, supply will balance demand if the monetary income of non-farm consumers increases to maintain demand and hence real income remains constant. This required increase in monetary income is obtained from $\frac{dD}{D} = E_D^P \frac{dP}{P} + E_D^I \frac{dI}{I} = 0$ where E_D^P and E_D^I are the price (P) and income (I) elasticities of demand respectively.

If $E_D^P = -0{\cdot}4$ and $E_D^I = 0{\cdot}5$, $\left(\frac{dI}{I}\right) dD = 0 = -E_D^P \frac{dP}{P} \Big/ E_D^I = 0{\cdot}76$.