Ind. Jn. of Agri. Econ.
Vol.65, No.4, Oct.-Dec. 2010

Factor Demand and Output Supply of Wheat in Western India

P.C. Meena,* P. Kumar and G.P. Reddy***

I

INTRODUCTION

Wheat is an important cereal crop in world trade grown on approximately 220 million ha area in the world. In the South Asian region, rice-wheat cropping system occupies 24 million hectares of area and India has 10 million hectares. India is the second largest producer of wheat after China contributing about 12 per cent to the total global wheat (Anonymous, 2005). India produced 75.38 million tonnes of wheat from 28.34 million ha during 2006-07. There had been a rapid increase of about 30 per cent in area under wheat in India from 9.8 million ha in 1950 to 12.8 million ha in 1996, about 92 per cent increase to 24.6 million ha in 1984 and about 15 per cent increase in area to 28.34 million ha in 2006. The yield of wheat increased from 827 kg/ha in 1965 to 2660 kg/ha in 2006-07. There is only a two-fold increase in the area under wheat since 1965, whereas productivity has increased more than three times. However, during the last few years, there is stagnation in wheat productivity and environmental issues are still posing a challenge to researchers and extensions agencies.

The western states of India are, in general, characterised by low productivity, low investment and low crop income for a long time. Technological change and price are the important instruments for accelerating growth in agriculture. Once an appropriate technology becomes available, then it is the positive price policy that plays a significant role in stimulating production through the allocation of the desired level of resources. At this stage, the policy planners face the challenge of formulating a suitable agricultural price policy by which the desired growth rate of agricultural output can be achieved.

The econometric application of the new production theory based on the duality relationship between production functions and variable profit/ cost function represent a major step forward towards generating appropriate empirical estimates of agricultural supply and input demand functions which are crucial for the application of the economic theory for the agricultural development policy (Lau and Yotopoulos, 1971, 1972), Yotopoulos *et al*. (1976); Sidhu (1974) and Sidhu *et al.* (1981). Further,

*National Academy of Agricultural Research Management, Rajendranagar, Hyderabad- 500 407 (Andhra Pradesh) and **Former Professor, Agricultural Economics, Indian Agricultural Research Institute, New Delhi – 110 012.

the development of flexible functional forms by Diewert (1973); Jorgensen, and Lau; and Lau (1974, 1976); Kumar (1975); Jha and Kumar (1976); Chand and Kumar (1986); Kumar and Mruthyunjaya (1989) permits the application of the duality theory for a more disaggregated analysis of the production structure than has been possible by the traditional approaches.

To formulate an effective price policy and food security policy, one needs reliable empirical knowledge about the degree of responsiveness of demand and supply for factors and products, to relative prices and technological changes. The output supply and factor demand are closely interlinked to each other. Therefore, any change in the factor and product prices affect the factor demand and output supply simultaneously.

The agricultural sector needs to be encouraged in every possible manner. Development of innovative technologies and progressive policies are essential to promote agricultural productivity and growth. Once the appropriate price policy and technology are made available, the agricultural sector prospers and stimulates growth of the non-agricultural sector too.

The effectiveness of the price incentive in inducing and sustaining the process of the agricultural growth is crucially dependent upon the sensitivity of crop output response, the relative price movements of inputs and output and marketed surplus of agriculture. The observed impact of changes in the factor and product prices can help in determining the integrated price structure for achieving the desired goals of output and marketed surplus.

II

DATA AND METHODOLOGY

Data on yield, use of input and their prices, collected under the "Comprehensive Scheme for the Study of Cost of Cultivation of Principal Crops" of the Directorate of Economics and Statistics, Government of India were used in the analysis. The maximum period for which data were available was from 1970-1971 to 2002-03. The missing year data on inputs and their prices were estimated using interpolation based on trends in the available data.

Methodology

Translog Cost Function Model

For minimisation of total cost, C, subject to a production function, there exists a corresponding minimum cost function, C*, which may be written as per equation (1):

$$C^* = f(Q, P_i \text{-------} P_n) \qquad \ldots(1)$$

where,
Q is total output, P_i are input prices.

The translog version of the cost function is considered to be one of the general functions for the approximation of production and cost relationship in agriculture. The logarithmic Taylor series expansion of this function can be written as Equation (2):

$$\ln C = \ln [h(Y)] + \ln \upsilon_0 + \Sigma\, \upsilon_i \ln W_i + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln W_i \ln W_j + U_t \qquad ....(2)$$

where, C is the total cost, W is the factor prices, h (Y) is the scale function of output; and ν_0, νi, γ_{ij} are parameters of the cost function.

Constraints and Assumptions Underlying the Model

(i) Symmetry constraints hold: Equality of cross derivatives

$\gamma_{ij} = \gamma_{ji}$

for all i, j; i # j

(ii) Linear homogeneity in prices: When all factor prices get doubled, the total cost must double, i.e.,

$$\sum_i \nu_i = 1 \quad \sum_i \gamma_{ij} = 0 \quad \sum_i \gamma_{ji} = 0$$

for all i,j.

(iii) Monotonicity: The function must be an increasing function of input prices

$$\frac{\partial \ln C}{\partial \ln W_j} = \nu_i + \sum_j \gamma_{ij} \ln W_j \geq 0$$

i = 1-----n.

(iv) Concavity in input prices: This implies that the matrix $\frac{\partial^2 C}{\partial W_i W_j}$ must be –ve, semi-definite within range of input prices.

Factor Demand and Output Supply Elasticity

It has been shown, using Shepherd's duality theorem, that the first derivative of equation (2) with respect to the logarithms of the input factor prices are equal to the respective input share in the total cost. The input share equation can written as Equation (3):

$$S_i = \nu_i + \sum_j \gamma_{ij} \ln W_j + \omega_i \ln t + \varepsilon_t \qquad ....(3)$$

where,

Si = the share of i-th input in total cost,

Wi = the price of i-th input,
t = Number of years.
ν_i, γ_{ij}, ω_i = the parameters of the share equation.

First, a system of share equations from Equation (2) was constructed by taking the first-order logarithms derivative of the cost function with respect to input prices. Then, the last equation was dropped and last equation parameter was obtained using homogeneity constraints.

The parameter γ_{ij} was obtained from Equation (3) and information on the input share available, all partial elasticity of substitution and elasticities of factor demand were calculated.

The estimates of γ_{ij} coefficients were converted into elasticities of substitution (σ_{ij}) and elasticity of factor demand (η_{ij}). The elasticities were then evaluated using the following formulae:

$$\sigma_{ij} = \frac{\gamma_{ij}}{S_i S_j} + 1 \qquad (i \# j)$$

$$\sigma_{ii} = \frac{1}{S_i^2}(\gamma_{ii} + S_i^2 - S_i) \qquad (\text{for all i})$$

$$\eta_{ij} = \frac{\gamma_{ij}}{S_i} + S_j \qquad (\text{for i\# j})$$

$$\eta_{ij} = \frac{\gamma_{ij}}{S_i} + S_j - 1 \qquad (\text{for all i})$$

where, S_i and S_j are shares in the total cost of input i and j, respectively.

Output Supply Elasticity

$$E_S^P = -\sum \lambda_i E_{x_i}^{(p_i/P)}$$

where,

λ_i = Share of i-th input cost in the total revenue,

E_S^P = Output supply elasticity with respect to the product price, and

$E_{x_i}^{(p_i/P)}$ = Own elasticity of the factor demand with respect to the real price of the factor.

III

RESULTS AND DISCUSSION

The restricted estimates of the parameters of the translog cost function model obtained from jointly estimating the four factor share equations are presented in Table 1.

TABLE 1. RESTRICTED ESTIMATES OF THE COEFFICIENTS OF THE COST FUNCTION OF WHEAT

	Prices of inputs at constant price (1981)							
Factor share (1)	Human labour (2)	Bullock labour (3)	Machinery (4)	Fertiliser (5)	Other[†] (6)	Year (7)	Intercept (8)	R^2 (9)
Human labour	0.1166** (0.013)	-0.0727** (0.008)	-0.0164** (0.006)	-0.0276** (0.009)	0.0001 (0.0003)	-0.0013 (0.001)	2.6445 (1.427)	0.43
Bullock labour	-0.0727** (0.008)	0.0536 ** (0.005)	0.0278** (0.005)	-0.0086 (0.005)	-0.0001 (0.0003)	-0.0041** (0.001)	8.2559** (0.924)	0.82
Machinery	-0.0164** (0.006)	0.0278** (0.005)	0.0047 (0.006)	-0.0160** (0.005)	0.00002 (0.0003)	0.0020** (0.0003)	-3.8857** (0.733)	0.81
Fertiliser	-0.0276** (0.009)	-0.0086 (0.006)	-0.0160** (0.005)	0.0521** (0.009)	0.0001 (0.0003)	0.0030** (0.001)	-5.7801** (1.276)	0.20
Other[a]	0.0001	-0.0001	0.0000	0.0001	0.00001			

Notes: Restrictions imposed were $\gamma_{ij} = \gamma_{ji}$ and $\Sigma\ \gamma_{ij} = 0$ for all i, j.
(a) Estimates derived from homogeneity constraints.
Figures in parentheses are standard error of the parameters.
*Significant at 0.05 level of significance ($t_{0.05} = 1.96$); ** Significant at 0.01 level of significance ($t_{0.01} = 2.58$). Number of observations for each equation = 57.
Other[†] inputs included seed, FYM, irrigation, pesticides, interest, share of own rental value of land.

Most of the restricted estimates were significant at 5 per cent level in all the equations and the values of R^2 were: 0.43, 0.81, 0.81 and 0.20 for human labour, bullock labour, machine labour and fertiliser equations, respectively. The coefficient of the time variable was negative and significant at 5 per cent level in bullock labour share equation which means that at constant factor prices, the factor share would change which implies a non-neutral technical change over time. It means that in recent times the maintenance of bullocks appears to be very costly both in terms of the cost of bullocks and their maintenance, making the use of bullock labour

TABLE 2. DERIVED ESTIMATES OF OWN AND CROSS-PRICE ELASTICITIES OF INPUT DEMAND FOR WHEAT

	Prices of inputs at constant price (1981)				
Factor share (1)	Human labour (2)	Bullock labour (3)	Machinery (4)	Fertiliser (5)	Other[a] (6)
Human labour	-0.2004** (0.066)	-0.2838** (0.040)	-0.0003 (0.032)	-0.0613 (0.047)	0.5458
Bullock labour	-0.5734** (0.081)	-0.3404** (0.079)	0.3779 (0.576)	-0.0081 (0.061)	0.5439
Machinery	-0.0008 (0.073)	0.4202** (0.061)	-0.8592** (0.069)	-0.1055 (0.059)	0.5452
Fertiliser	-0.1427 (0.112)	-0.0094 (0.071)	-0.1094 (0.061)	-0.2849** (0.110)	0.5464
Other[a]	0.1920	0.0947	0.0854	0.0825	-0.4545

(a) These implied estimates were computed using the homogeneity constraints. *Significant at 0.05 level of significance ($t_{0.05} = 1.96$); ** Significant at 0.01 level of significance ($t_{0.01} = 2.58$).

Standard errors, within the parentheses, were computed as follows:

$$SE(\eta_{ij}) = \frac{SE(\gamma_{ij})}{S_i}$$

uneconomical. Even farmers prefer tractors for agricultural operations in the place of bullocks because of several advantages. Timely agricultural operations play an important role in crop production. Hence, wheat production technology in western India was bullock labour saving over time. The coefficients of time in the machinery and fertiliser equation were 0.002 and 0.003, hence the technical change was bullock labour-saving and machinery and fertiliser using in the case of wheat in western India (Sidhu *et al*., 1981). The parameters of the share equation had little economic relevance. They were best evaluated by the value, which implied the elasticity of factor demand and elasticity of substitution.

Elasticity of Substitution

The partial elasticity of substitution (σ ij) between input i and j measured the change in the demand for the i-th input as a result of the change in the price of the j-th input normalised by the price of the i-th input, holding all prices (other than of the j-th input) constant. Positive (negative) value of σ ij indicated that i and j were substitutes (complements). The σ ij was a better measure than ηii (elasticity of substation) of the strength of substitution or complementarity among the input since the magnitude of ηii was influenced by the input cost share whereas the magnitudes of σ ij were not. The matrix of derived estimates of the partial elasticity of substitution (σ ij), is presented in Table 3. It characterises the production technology of wheat in western India in terms of the nature of input substitution (or complementarity relationship). This information is helpful in guiding efforts directed towards the development of new agricultural technology and to compare the nature of input substitution across technology for which similar information is available.

TABLE 3. DERIVED ESTIMATES OF THE PARTIAL ELASTICITY OF INPUT SUBSTITUTION FOR WHEAT

	Prices of inputs at constant price (1981)				
Factor (1)	Human labour (2)	Bullock labour (3)	Machinery (4)	Fertiliser (5)	Other[a] (6)
Human labour	-1.0448**	-2.9885**	-0.0040	-0.7440	1.0007
	(0.348)	(0.424)	(0.380)	(0.581)	
Bullock labour	-2.9885**	-3.5849**	4.4258**	-0.0985	0.9972
	(0.424)	(0.836)	(0.641)	(0.743)	
Machinery	-0.0040	4.4258**	-10.0609**	-1.2815	0.9995
	(0.380)	(0.641)	(0.816)	(0.720)	
Fertiliser	-0.7440	-0.0985	-1.2815	-3.4603**	1.0018
	(0.581)	(0.743)	(0.720)	(1.342)	
Other[a]	1.0007	0.9972	0.9995	1.0018	-0.8333

(a) These implied estimates were computed using the homogeneity constraints.
*Significant at 0.05 level of significance ($t_{0.05}$ = 1.96); ** Significant at 0.01 level of significance ($t_{0.01}$ = 2.58).

Standard errors, within the parentheses, were computed as follows:

$$SE(\eta_{ij}) = \frac{SE(\gamma_{ij})}{S_i S_j}$$

The results indicated some substitution possibilities between bullock labour, machine labour and other inputs. In other words, in wheat production, the technology was such that bullock labour could be easily substituted for machinery and other inputs and vice versa. In addition substitutability was indicated between other inputs and all the remaining inputs, viz., human labour, bullock labour, machinery and fertiliser. On the other hand, Table 3 also indicates that there existed a complementary relationship between human labour and bullock labour, bullock labour and machine labour, human labour and fertiliser, which was significant between human labour and bullock labour. The results have important implications for agricultural research and development policies for developing countries. The availability of labour is a less serious constraint during certain period of crop or crop production activity, wherein labour can be substituted by bullock labour/ machinery indirectly creating a labour abundance situation. However, labour still remains a serious constraint for a major part of crop production. This maybe due to lower skills to take benefit from complex modern technologies combined with the impact of Government of India schemes like Mahatma Gandhi National Rural Employment Guarantee Act. This is especially true in densely populated areas. The in-migration and substitution of bullock labour by human labour were distinct possibilities. The complementarity of labour and bullock labour, thus, was not a serious constraint in the production of wheat.

Output Supply

The output supply elasticities for major wheat in western India were computed from the factor demand elasticities by using the formulae given by Rajkrishna and Raichaudhuri (1980). The factor demand elasticities were computed by estimating the translog cost function model. The output supply elasticities show the response of the output price on the supply. The supply elasticity of wheat for the western states of India was 0.38. It implies that if there is a 10 per cent increase in wheat prices then the supply of wheat will increase by 3.8 per cent.

IV

SUMMARY AND CONCLUSIONS

To formulate an effective price policy and food security policy, one needs reliable empirical knowledge about the degree of responsiveness of demand and supply for factors and products to relative prices and technological changes. The output supply and factor demand are closely interlinked to each other. Therefore, any change in the factor and product prices affect the factor demand and output supply simultaneously. The results of the study shows that all own-elasticities of factor demand had the correct signs, which was negative. It should be noted that the demand for machinery was influenced significantly by a change in the price of bullock labour.

A change in the wage rate of labour did not appear to influence machine labour demand significantly. It should be pointed out that the demand for labour was influenced much more by a change in the bullock labour prices than by a change in the wage rate and fertiliser prices since they are close substitutes for certain crop production activities. The reduction in fertiliser prices through subsidies may expand the fertiliser use stimulating the use of other inputs. The supply elasticity of wheat for the western states of India was 0.38. It implies that with a 10 per cent increase in wheat prices, the supply of wheat will increase by 3.8 per cent.

Received February 2010. Revision accepted December 2010.

REFERENCES

Christensen, L.R. (1975),"Concepts and Measurement of Agricultural Productivity", *American Journal of Agricultural Economics*, Vol.57, pp. 910-15.

Diewert, W.E (1973) "Functional Form for Profit and Transformation Function" *Journal of Economic Theory*, Vol 6, No.3, pp.284-316.

Jha, D. and P. Kumar (1976), "Effect of Price Changes on Cost Structure and Factor Demand: A Case Study on Selected Farms in Delhi Territory," *Indian Journal of Agricultural Economics*, Vol. 31, No.3, July-September, pp. 63-71.

Kumar, P. (1975), "An Application of Generalised Least Square Estimation of Linear Regression Model with Random Coefficient to Paddy Production Function for Sambalpur District (Orissa)," *Indian Journal of Agricultural Economics*, Vol. 30, No.4, October-December, pp. 88-102.

Kumar, P. and Mruthyunjaya (1989), *Methodology for Simultaneous Determination of Factor Product Prices of Crops*, Research Report, Division of Agricultural Economics, Indian Agricultural Research Institute, Delhi.

Lau, L.J. and P.A. Yotopoulos (1971), "A Test for Relative Efficiency and Application to Indian Agriculture," *The American Economics Review*, Vol. 61, No.1, pp. 94-109.

Lau, L.J. and P.A. Yotopoulos (1972), "Profit, Supply and Factor Demand Functions," *American Journal of Agricultural Economics*, Vol. 54, No.1, pp. 11-18.

Ramesh Chand and Praduman Kumar (1986), "Supply Response Functions for Major Crops of Punjab in Green Revolution Period – A Profit Function Approach," *Indian Journal of Economics,* Vol. LXVII Part 1, July, pp. 91-109.

Raj Krishna and G.S. Raichaudhuri, (1980), *Some Aspects of Wheat and Rice Price Policy in India,* World Bank Staff Working Paper No. 281, The World Bank, Washington, D.C., U.S.A.

Sidhu, S.S. (1974), "Relative Efficiency in Wheat Production in Indian Punjab," *American Economic Review*, Vol. 64, No.4, pp. 742-751.

Sidhu, S.S. and Carlos A. Bannante (1981), "Estimating Farm level Input Demand and Wheat Supply in the Indian Punjab Using a Translog Profit Function," *American Journal of Agricultural Economics*, Vol. 63, No.2, pp. 237-246.

Yotopolous, P.A., Lawrence J. Lau and Wau Long Lin (1976), "Micro-Economics, Output Supply and Factor Demand Function in the Agriculture of the Province of Taiwan," *American Journal of Agricultural Economics*, Vol.58, pp. 333-340.