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# Factor Demand, Output Supply Elasticities and Supply Projections for Major Crops of India

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**Abstract**

Policy planners face the challenge of formulating suitable agricultural policy by which the required growth in domestic production can be achieved. To attain effective food security policy, one needs reliable empirical knowledge about the degree of responsiveness of factor demand and output supply for commodities. This paper is an attempt in this direction and estimates the factor demand and output supply elasticity for major crops grown in India. These elasticities are used to project the domestic supply of major commodities, viz. rice, wheat, pulse grains, nine major edible oilseeds, and sugarcane under various scenarios with and without acreage expansion and TFP growth. The results of supply projections are compared with the food demand and policy prescription to attain food security is suggested.

## Introduction

Technological change and prices are the important instruments for accelerating growth in the agricultural sector. 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 desired level of resources. At this stage, the policy planners face the challenge of formulating suitable agricultural policy by which the desired growth rate in agricultural output may be achieved. The output supply and factor demand are closely interlinked to each other. Therefore, any change in factor and product prices affects the factor demand and output supply simultaneously. To formulate an effective price policy and food-security policy, one needs reliable empirical knowledge about the degree of responsiveness of input demand and crop output supply to input-output prices and technological changes. This paper is an attempt in this direction and estimates the factor demand and output supply elasticity for major crops grown in India. These elasticities have been used to predict the domestic supply of major commodities, viz. rice, wheat, pulse grains, nine major edible oilseeds, and sugarcane under various scenarios with and without acreage expansion and Total Factor Productivity (TFP) growth. The crops chosen under the study are important for the food security of the nation as rice and wheat are the major sources of foodgrains supply. These two crops share more than 70 per cent of the total foodgrains and are the backbone of India's food and household nutritional security. Pulses, edible oils and sugar are the major commodities in the Indian diet. These are short in domestic supply and significantly depend on imports.

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## Methodology and Data

The econometric application of the new production theory based on the duality relationship between production functions and variable profit/ cost function represents a major step forward towards generating appropriate empirical estimates of agricultural supply and input demand functions which are crucial for application of economic theory for agricultural development policy (Lau and Yotopoloulos, 1972; Sidhu, 1974; Binswanger, 1974; Yotopolous *et al.* 1976). Further, the development of flexible functional forms by Kumar *et al.* (1985), and Chand and Kumar (1986); Bewley *et al.* (1987); Mundlak (1988), Kumar and Mruthyunjaya (1989); Rosegrant and Kasryno (1992), Kumar and Rosegrant (1997); Kumar (1998), and Kumar and Surabhi (2003) permits the application of duality theory for a more disaggregated analysis of the production structure than has been possible by traditional approaches. Each alternative supply response model has its specific merits and limitations.

The approach adopted in a supply response study depends largely on the policy implications which the researchers plan to highlight. The choice of a model could also be directed by certain pragmatic considerations such as data, number of personnel, time as well as computing facilities available for the study. When the aim of the study is comparatively short-run forecasting of the supply of some subset of products, single one-stage econometric procedures, such as the Nerlovian model and series-cross section models, can be employed to directly estimate the functions using the market level time series data. For long-term forecasting of commodities response, a single independent equation may yield misleading projections. However, when the central concern of the study is to derive crop-wise agricultural policy impact, perhaps relatively comprehensive approaches to supply response, such as the profit function or cost function methodology are more suitable since these approaches consider the simultaneity between output supply and factor demand decisions. In the present study, following Binswanger (1974), translog cost function model has been used and the system of factor demand equations has been derived. Using factor demand parameters, the output supply elasticities have been derived.

## Translog Cost Function Model

For minimization 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):

$$C^* = f\,(Q, p_i, \ldots\ldots\ldots, p_n) \qquad \ldots(1)$$

where, $Q$ is the total output and $p_i$s are input prices.

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

$$\ln C = \ln [h\,(Y)] + \ln v_0 + \Sigma\, v_i \ln W_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln W_i \ln W_j + u_t \qquad \ldots(2)$$

where, $C$ is the total cost, $W$ is the factor prices (p/P), $h\,(Y)$ is the scale function of output; $v_0$, $v_i$, $\gamma_{ij}$ are parameters of the cost function, and $u_t$ is the error-term.

## Constraints and Assumptions underlying the Model

(i) **Symmetry constraints hold:** Equality of cross derivatives, i.e.,

$$\gamma_{ij} = \gamma_{ji} \qquad \text{for all } i, j; \qquad i \# j$$

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

$$\sum_i v_i = 1 \qquad \sum_i \gamma_{ij} = 0 \qquad \sum_j \gamma_{ji} = 0$$

for all $i, j$

(iii) **Monotonicity:** The function must be an increasing function of input prices, i.e.,

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

$$i = 1, \ldots\ldots\ldots, n$$

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

## Factor Demand and Output Supply Elasticity

It has been shown, using Shepherd's duality theorem (1953), that the first derivative of Equation (2) with respect to logarithms of the input factor prices are equal to the respective input share in the total cost. The input share equations can be written as Equation (3):

$$S_i = \nu_i + \sum_j \gamma_{ij} \ln W_j + \omega_i \ln t + \varepsilon_t \; ; \quad i = 1, \ldots\ldots\ldots, n \qquad \ldots(3)$$

where,

$S_i$ = Share of the $i^{th}$ input in total cost,

$W_i$ = Price of the $i^{th}$ input ($p_j/P$),

$t$ = Number of years,

$\nu_i$, $\gamma_{ij}$, $\omega_i$ = Parameters of the share equation, and

$\varepsilon_t$ = Error-term.

First, a system of share equations from Equation (3) was constructed by taking the first-order logarithmic derivative of the cost function with respect to input prices. Then, the last component of Equation (3) (with $i=n$) was dropped and its parameter was obtained using homogeneity constraints, as:

$$\gamma_{in} = -\sum_{i=1}^{n-1} \gamma_{ij}$$

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

The estimates of $\gamma_{ij}$ coefficients were converted into point estimates of Allen partial elasticities ($\eta_{ii}$) and cross elasticities of factor demand ($\eta_{ij}$) according to the following equations:

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

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

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

Standard errors were computed as:

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

and $t$ statistics were computed as:

$$t_{ij} = \eta_{ij} / SE(\eta_{ij})$$

### Output Supply Elasticity

From the production function, one can derive the output supply elasticity w.r.t. output and input prices as follows:

$$E_S^P = -\sum \lambda_i \eta_{ii} \qquad \text{for } i = 1, 2, \ldots, n$$

$$E_S^{p_i} = \sum_j^n \lambda_i \eta_{ij} \quad \text{w where, } j = 1, 2 \ldots, n \text{ and } i = 1, 2, \ldots, n$$

where,

$p_i$ = Price of the input,

$P$ = Price of the product,

$S$ = Quantity of the domestic product,

$\lambda_i$ = Share of the $i^{th}$ input cost in the total revenue,

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

$E_S^{p_i}$ = Output supply elasticity with respect to the factor price.

### Supply Growth

Crop area (AREA), total factor productivity (TFP), supply elasticity and input output price environment are the major sources of supply growth. The supply growth equation for commodity can be expressed as:

$$S_g = E_S^P P_g + \sum E_S^{p_i} p_{ig} + \text{AREA}_g + \text{TFP}_g \qquad \ldots(4)$$

where,

$S_g$ = Supply growth for the commodity,

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

$P_g$ = Output price growth,

$E_S^{p_i}$ = Elasticity of factor demand for the $i^{th}$ input,

$p_{ig}$ = Input price growth of the $i^{th}$ input,

$\text{AREA}_g$ = Acreage growth of the commodity, and

$\text{TFP}_g$ = TFP growth of the commodity.

### Supply Projections

The supply growth equations given above were used to predict the supply of various commodities under the baseline assumptions that the observed growth during 1981-2005 for input-output prices, area and TFP would be maintained in the predicted period. The supply growth has been estimated under the following four scenarios:

S1 = Baseline assumptions as given in Appendix Table 4

S2 = Baseline assumptions without TFP growth

S3 = Baseline assumptions without area growth, and

S4 = Baseline assumptions without TFP and area growths.

The average production during 2003-2005 (TE 2005) has been used as the base year domestic supply. The domestic supplies of major commodities have been explored up to 2025.

$$S_t = S_0 * (1+S_g)^t \quad \ldots(5)$$

where, $S_t$ is the supply for a commodity in time $t$, $S_0$ is the base year production and $S_g$ is the predicted growth under various scenarios. The supply projections were compared with the projected demand based on a recent study conducted by Kumar *et al.* (2010).

## The Data

The 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 (DES), Government of India (GoI), were used for the analysis. Duration of data varied across crops and states. The maximum period for which data were available was from 1970-71 to 2005-06. The missing year data on inputs and their prices were estimated using interpolation based on trends in the available data. All data values used in the estimation are three-year average centred on a particular agricultural year. Details on baseline data on area, yield and production are presented in Appendix Table 1. Among cereals, rice is the major crop, followed by wheat and coarse cereals. The domestic production of pulses and oilseeds was 13.8 million tonnes (Mt) and 25.9 Mt, respectively. These cereals were short in supply in relation to the domestic requirement in the country, the reason for which can be mainly attributed to their low productivity.

The use of inputs and yield achieved at farms seem to be higher for sample farmers than the national average for rice, wheat, coarse cereals and pulses and little lower for oilseeds and sugarcane (Appendix Table 2). The use of inputs varied across crops and the average price of inputs did not vary significantly across crops.

## Results and Discussion

The restricted estimates of the parameters of translog cost function model obtained from estimating the four factor share equations jointly are presented in Appendix Table 3. Most of the restricted estimates were significant for human labour, animal labour, machine labour and fertilizer for all crops. The coefficient of the time variable was negative and significant for animal labour share equation which means that at constant factor prices, the factor share of animal labour would decline which implies non-neutral technical change over time for all the crops. The use of human labour would decline with time for wheat, coarse cereals, edible oils, and sugarcane. The coefficient of time was positive and significant for machinery and fertilizers, hence the technological change was saving of animal labour and use of machinery in all the crops and fertilizer-use for rice, wheat, pulses and sugarcane. Thus, technological change was biased towards machinery and fertilizer-use for all the major crops.

The parameters of the share equation have little economic meaning. They are best evaluated by the values they return for the elasticity of factor demand and elasticity of substitution for major crops in India. The input demand elasticity estimates with respect to own and cross prices were computed for human labour, animal labour, machine labour, and fertilizers. The matrix of input demand elasticity is presented in Tables 1 to 5 respectively for human labour, animal labour, machine labour, fertilizers and other inputs (irrigation, plant protection and others). As expected, all own input price elasticities of demand had statistically significant negative signs. The elasticities of factor demand differed significantly from crop to crop and within a crop, from one input to the other, depending on the technology used. The own-price elasticities of input demand were estimated to be maximum for machine labour (-0.95), followed by irrigation & plant protection (-0.71), fertilizer (-0.64), animal labour (-0.49) and human labour (-0.30). These estimates indicate that demand for modern inputs is sensitive to their price. On the policy front, a reduction in the prices of machinery and fertilizer through subsidy is expected to expand fertilizer-use and mechanization of farming and may lead to enhancement of the crop productivity.

### Human Labour Demand

The human labour demand elasticity with respect to wages was significant for all crops, except sugarcane (Table 1). It was found highest for oilseeds (-0.50), followed by wheat (-0.31) and rice (-0.16). A positive

**Table 1. Estimates of human labour demand elasticities for crops, India**

| Crop | Input price | | | | |
|---|---|---|---|---|---|
| | *w/P* | *b/P* | *m/P* | *r/P* | *i/P* |
| Rice | -0.1680** | -0.0177 | 0.0640** | -0.0086 | 0.1303** |
| | (-4.95) | (-0.89) | (4.02) | (-0.47) | (6.74) |
| Wheat | -0.3060** | 0.1540** | 0.0035 | 0.1693** | -0.0210 |
| | (-8.65) | (8.81) | (0.11) | (6.81) | (-0.65) |
| Pulse grains | -0.2332** | -0.0822** | 0.1246** | 0.0656** | 0.1253** |
| | (-4.21) | (-2.69) | (4.25) | (2.88) | (3.33) |
| Oilseeds | -0.5021** | -0.0071 | 0.0222 | 0.2071 | 0.2799** |
| | (-14.70) | (-0.35) | (0.76) | (10.01) | (7.37) |
| Sugarcane | -0.0768 | 0.0871** | 0.0221 | -0.1073** | 0.0749** |
| | (-1.84) | (4.31) | (0.92) | (-3.92) | (3.10) |
| All crops | -0.3017 | 0.0354 | 0.0372 | 0.0867 | 0.1424 |

*Note:* The figures within the parentheses are the corresponding student *t*-statistics
Here, *w* = Wage (Rs/hour), *b* = Cost on animal labour (Rs/hour), *m* = Cost on machine labour (Rs/hour) *P* = Price of crop (Rs/100 kg), *r* = Cost of fertilizer (NPK) (Rs/kg), *i* = Cost of irrigation (Rs/ha)

**Table 2. Estimates of animal labour demand elasticities for crops, India**

| Crop | Input price | | | | |
|---|---|---|---|---|---|
| | *w/P* | *b/P* | *m/P* | *r/P* | *i/P* |
| Rice | -0.0582 | -0.2802** | 0.2439** | 0.0196 | 0.0749 |
| | (-0.89) | (-3.97) | (6.29) | (0.39) | (1.63) |
| Wheat | 0.3727** | -0.6213** | 0.1856** | -0.2018** | 0.2648** |
| | (8.81) | (-13.26) | (3.96) | (-4.41) | (5.40) |
| Pulse grains | -0.1897** | -0.1543 | 0.2704** | -0.0118 | 0.0854 |
| | (-2.69) | (-1.88) | (4.84) | (-0.33) | (1.26) |
| Oilseeds | -0.0176 | -0.4878** | -0.0043 | -0.0291 | 0.5388** |
| | (-0.35) | (-8.51) | (-0.07) | (-0.76) | (7.25) |
| Sugarcane | 0.7560** | -0.7777** | -0.2332 | 0.2571 | -0.0022 |
| | (4.31) | (-5.50) | (-1.98) | (1.75) | (-0.02) |
| All crops | 0.2111 | -0.4895 | 0.1309 | 0.0188 | 0.1287 |

*Note:* The figures within the parentheses are the corresponding student *t*-statistics
Here, *w* = Wage (Rs/hour), *b* = Cost on animal labour (Rs/hour), *m* = Cost on machine labour (Rs/hour) *P* = Price of crop (Rs/100 kg), *r* = Cost of fertilizer (NPK) (Rs/kg), *i* = Cost of irrigation (Rs/ha)

**Table 3. Estimates of machine labour demand elasticities for crops, India**

| Crop | Input price | | | | |
|---|---|---|---|---|---|
| | *w/P* | *b/P* | *m/P* | *r/P* | *i/P* |
| Rice | 0.3920** | 0.4536** | -1.2564** | 0.0635 | 0.3473** |
| | (4.02) | (6.29) | (-15.31) | (0.95) | (5.01) |
| Wheat | 0.0070 | 0.1515** | -0.3236** | 0.2307** | -0.0656 |
| | (0.11) | (3.96) | (-3.20) | (4.20) | (-0.61) |
| Pulse grains | 0.4123** | 0.3879** | -0.7598** | 0.0426 | -0.0830 |
| | (4.25) | (4.84) | (-6.20) | (0.76) | (-0.80) |
| Oilseeds | 0.0841 | -0.0065 | -1.3750** | -0.1327 | 1.4301** |
| | (0.76) | (-0.07) | (-7.56) | (-1.34) | (7.40) |
| Sugarcane | 0.2275 | -0.2770* | -1.4102 | 1.4267** | 0.0330 |
| | (0.92) | (-1.98) | (-5.14) | (6.92) | (0.23) |
| All crops | 0.0372 | 0.1309 | -0.9506 | 0.0882 | 0.2153 |

*Note:* The figures within the parentheses are the corresponding student *t*-statistics
Here, *w* = Wage (Rs/hour), *b* = Cost on animal labour (Rs/hour), *m* = Cost on machine labour (Rs/hour) *P* = Price of crop (Rs/100 kg), *r* = Cost of fertilizer (NPK) (Rs/kg), *i* = Cost of irrigation (Rs/ha)

**Table 4. Estimates of fertilizer demand elasticities for crops, India**

| Crop | Input price | | | | |
|---|---|---|---|---|---|
| | *w/P* | *b/P* | *m/P* | *r/P* | *i/P* |
| Rice | -0.0345 | 0.0238 | 0.0415 | -0.2452** | 0.2144** |
| | (-0.47) | (0.39) | (0.95) | (-3.57) | (4.30) |
| Wheat | 0.3111** | -0.1532** | 0.2147** | -0.3504** | -0.0222 |
| | (6.81) | (-4.41) | (4.20) | (-5.63) | (-0.34) |
| Pulse grains | 0.6424** | -0.0500 | 0.1259 | -0.8094** | 0.0911 |
| | (2.88) | (-0.33) | (0.76) | (-5.12) | (0.51) |
| Oilseeds | 0.9695** | -0.0550 | -0.1639 | -1.1183** | 0.3677** |
| | (10.01) | (-0.76) | (-1.34) | (-9.21) | (2.66) |
| Sugarcane | -0.3256** | 0.0899 | 0.4201** | -0.4278** | 0.2434** |
| | (-3.92) | (1.75) | (6.92) | (-4.32) | (3.84) |
| All crops | 0.4051 | -0.0456 | 0.0882 | -0.6458 | 0.1982 |

*Note:* The figures within the parentheses are the corresponding student *t*-statistics
Here, *w* = Wage (Rs/hour), *b* = Cost on animal labour (Rs/hour), *m* = Cost on machine labour (Rs/hour) *P* = Price of crop (Rs/100 kg), *r* = Cost of fertilizer (NPK) (Rs/kg), *i* = Cost of irrigation (Rs/ha)

**Table 5. Estimates of irrigation demand elasticities for crops, India**

| Crop | Input price | | | | |
|---|---|---|---|---|---|
| | *w/P* | *b/P* | *m/P* | *r/P* | *i/P* |
| Rice | 0.3375 | 0.0589 | 0.1469 | 0.1389 | -0.6823 |
| Wheat | -0.0269 | 0.1403 | -0.0426 | -0.0155 | -0.0553 |
| Pulse grains | 0.2324 | 0.0687 | -0.0465 | 0.0173 | -0.2718 |
| Oilseeds | 0.4288 | 0.3330 | 0.5780 | 0.1203 | -1.4601 |
| Sugarcane | 0.1169 | -0.0004 | 0.0050 | 0.1252 | -0.2467 |
| All crops | 0.2489 | 0.1636 | 0.2153 | 0.0895 | -0.7172 |

*Note:* The estimates were derived using homogeneity condition, as explained in the methodology section.
Here, *w* = Wage (Rs/hour), *b* = Cost on animal labour (Rs/hour), *m* = Cost on machine labour (Rs/hour) *P* = Price of crop (Rs/100 kg), *r* = Cost of fertilizer (NPK) (Rs/kg), *i* = Cost of irrigation (Rs/ha)

sign for cross price elasticity with respect to the price of other variable inputs shows that the pair is substitutive and a negative sign is the indicator of complementary relationship. Human labour and bullock labour had a substitutive relationship for wheat and sugarcane, and complementary relationship for pulse crops. Human and machine labour had a substitutive relationship for rice and pulses. Human labour had a substitutive relationship with fertilizers for wheat, pulse grains, and oilseeds, and a complementary relationship for sugarcane. Human labour had a substitutive relationship with irrigation for all crops, except wheat. However, for the crop sector as a whole, human labour had a substitutive relation with all the inputs. With inflation in wages, human labour will be substituted by machine labour, fertilizer and irrigation. It is likely to induce efficiency in crop production and may improve productivity and yield.

## Animal Labour Demand

The animal labour demand elasticity with respect to animal labour wages was negative and statistically significant for all crops, except pulse grains (Table 2). It ranged from -0.15 for pulses to -0.78 for sugarcane. A 10 per cent rise in animal labour wage, would lead to a reduction in its use at an average rate of 4.9 per cent. The use of animal labour had substitutive relationship with machine for rice, wheat and pulses. This suggests that an increase in the animal labour wage would induce mechanization in the rice-wheat system. However, it had a complementary relationship with fertilizers for wheat and substitutive relationship with irrigation for wheat and oilseeds. Looking at all the crops together, a rise in the cost of animal labour would induce use of modern inputs and machine labour to enhance the productivity of farm.

**Machine Labour Demand**

The machine labour demand elasticities (Table 3) ranged from -0.32 for wheat to -1.41 for sugarcane, with average elasticity to the tune of -0.95. The machine labour demand was more sensitive to its price as compared to the demand of other inputs. A 10 per cent increase in the price of machine labour to farmers would lead to a decline in its use by 12.6 per cent for rice, 3.2 per cent for wheat, 7.6 per cent for pulses, 13.8 per cent for oilseeds and 14.1 per cent for sugarcane. Substitutive relationships exist between machine labour and animal labour for rice, wheat and pulse crops and of machine labour and human labour for rice and pulses.

**Fertilizer Demand**

The own price elasticity of demand for fertilizer (Table 4) was -0.24 for rice, -0.35 for wheat, -0.81 for pulses, -1.12 for oilseeds, and -0.43 for sugarcane. Taking all the crops together, with 10 per cent rise in its price, the demand for fertilizer would get reduced by 6.5 per cent on an average. However, the reduction in the use of fertilizer will be substantial for oilseeds and pulses. Fertilizer was found to be a weak complement and substitute of inputs for rice. But, it had a strong complementary relationship with bullock labour and was a strong substitute for human labour and machine labour for wheat. In the case of sugarcane, fertilizer and machine labour were strong substitutes.

**Irrigation Demand**

The own price elasticity of irrigation demand (Table 5) was estimated to be -0.72. It varied substantially across crops, from -0.055 for wheat to -1.46 for oilseeds. With 10 per cent increase in irrigation price, the demand for irrigation would decline maximum for oilseeds (14.6%), followed by rice (6.8%), pulses (2.7%), sugarcane (2.5%) and minimum for wheat (0.6%). Cross price elasticities of irrigation demand with respect to wages, animal labour wage, machine charges and fertilizer price were positive for the crop sector, indicating substitutive relationships.

To sum up, the wage rate has depicted a negative effect on the use of human labour and a positive effect on the use of machine labour, fertilizer and irrigation. This implies that with an increase in the wages, human labour becomes more costly. Once human labour becomes costly, the process of substitution from human labour to machine labour takes place. Mechanisation induces fertilizer-use and irrigation and the trade-offs between these inputs improve production efficiency and yield. Higher animal labour charges will induce higher use of machine labour, as it results into the substitution of bullock use to machine use. Own price elasticity of demand for machine labour and fertilizer has been found highly negative and significant. The subsidy on tractor and fertilizer would induce higher use of modern inputs and improve farming efficiency and productivity. Fertilizer price policy has a differential effect on crops. A gradual increase in fertilizer price has not declined the use of fertilizer in rice and wheat as compared to other crops. These crops are the technologically advanced crops and the relative profitability of these crops is high (Kumar, 1998).

**Growth of Input Demand**

Using factor demand elasticities and input-output price structure for the period 1981-82 to 2005-06, the growth rates of various inputs under different crops were estimated assuming no change in fixed factors or technology (Table 6). The input-output price structure had resulted in a decrease in the use of human labour by 3.1 per cent for oilseeds, 1.7 per cent for pulses, 0.8 per cent for rice, and 0.6 per cent for wheat. It also had a negative effect on the demand for animal labour. However, the demand for modern inputs, viz. machine labour, fertilizers and irrigation would increase substantially for most of the crops. The focus of modern inputs is likely to shift from rice and wheat to pulses and oilseeds to induce higher yields, as these crops are in short supply in the domestic market. The predicted growth in input demand as compared to the observed growth in the past would be slowed down if the past structure of input-output prices is maintained in the future too, without any technological change. Thus, it is expected that the demand for inputs would grow at a slower rate than that achieved in the past. It may slow down the yield growth for these crops.

**Supply Response Elasticities**

The output supply elasticities for major crops were computed from the factor demand elasticities and are presented in Table 7. The output supply elasticities have shown the response of output price and input prices on the supply of major crops of India. Among crops, highest supply elasticity with respect to its price was for

**Table 6. Observed and predicted growths of input demand by crop in India: 1981-2005**

| Inputs | Rice | Wheat | Pulse grains | Oilseeds | Sugarcane |
|---|---|---|---|---|---|
| | | **Observed growth in input-use** | | | |
| Human labour | -0.1996 | -1.5126 | -0.1384 | -0.5733 | 0.3872 |
| Animal labour | -3.8379 | -8.9311 | -4.9164 | -4.5588 | -4.9548 |
| Machine labour | 5.8011 | 4.8545 | 7.3174 | 7.7651 | 7.9007 |
| Fertilizer | 3.5455 | 2.5468 | 8.6492 | 4.9247 | 2.8128 |
| Irrigation | 4.5274 | 4.6017 | 5.5978 | 4.2050 | 1.8118 |
| | | **Predicted growth in input-use** | | | |
| Human labour | -0.7772 | -0.5544 | -1.7214 | -3.0519 | 0.0850 |
| Animal labour | -1.6321 | -2.7335 | -1.9394 | -2.8089 | 0.1190 |
| Machine labour | 3.5679 | 1.0363 | 4.5252 | 0.1064 | -1.5580 |
| Fertilizer | 0.2615 | 0.7447 | 3.1003 | 5.5466 | -0.9649 |
| Irrigation | 1.6187 | 0.9662 | 1.6296 | 4.5532 | 0.5779 |

**Table 7. Supply response elasticity for different crops in India**

| Variable | Rice | Wheat | Pulse grains | Oilseeds | Sugarcane |
|---|---|---|---|---|---|
| Own crop price (P) | 0.2357 | 0.2164 | 0.1695 | 0.5079 | 0.1216 |
| | | **Input price** | | | |
| Human labour (w) | -0.0017 | 0.0163 | -0.0007 | -0.0011 | 0.0021 |
| Animal labour (b) | -0.0004 | -0.0288 | -0.0012 | 0.0021 | -0.0002 |
| Machinery (m) | 0.0004 | 0.0095 | 0.0020 | 0.0168 | -0.0020 |
| Fertilizer (r) | 0.0001 | -0.0095 | -0.0013 | 0.0062 | 0.0045 |
| Irrigation (i) | 0.0017 | 0.0125 | 0.0012 | -0.0240 | -0.0044 |

oilseeds (0.51), followed by rice (0.24), wheat (0.22), pulses (0.17) and sugarcane (0.12). The input response elasticties were highly inelastic, nearly zero. The crop price had a dominating response on supply of commodities and therefore a positive price policy will enhance domestic supply of food commodities.

## Supply Projections

The supply growth was predicted using the supply response elasticities and is given in Table 7. The base-line assumption for factor and product price, acreage and TFP growth are given in Appendix Table 4 for major crops and the results are presented in Table 8 under four different scenarios. The growth for various commodities was estimated using Equation (4) and was found to be higher than that achieved in the past, during 1981-2005. The estimated growth under various scenarios was assumed to prevail in future also. Based on the estimated supply growth, as given in Table 8, the supply for various commodities has been projected using TE 2005 as the base year production and is presented in Tables 9 to 13. The estimated production for the years 2006-07 to 2009-10 were observed to be closer to the production achieved during this period (GoI, 2009). The domestic supply and demand projections for each commodity under study are presented in the subsequent section. A comparison of scenarios 1 and 2 assesses the effect of TFP growth. A comparison between scenarios 1 and 3 assesses the effect of area response on supply, while the comparison between scenarios 1 and 4 demonstrates the effects of TFP and area response on the supply of commodities.

### Rice

The annual growth in rice supply is predicted to be 2.64 per cent corresponding to the baseline scenario. As the possibility of area expansion is limited, under the assumption of no area expansion as shown in scenario S3, the supply of rice would grow annually by 2.26 per cent. Under scenario S2 without TFP growth, the supply is estimated to grow at the rate of 1.92 per cent annually. However, under the scenario S4 (without

**Table 8. Projected growth of domestic supply of food commodities in India**

| Scenario | Rice | Wheat | Pulse grains | Oilseeds | Sugarcane |
|---|---|---|---|---|---|
| S1 | 2.64 | 2.82 | 1.06 | 5.07 | 3.07 |
| S2 | 1.92 | 2.26 | 1.18 | 4.66 | 2.56 |
| S3 | 2.26 | 2.11 | 1.35 | 3.84 | 1.53 |
| S4 | 1.54 | 1.55 | 1.47 | 3.43 | 1.02 |

S1 = Baseline assumptions as given in Appendix Table 4
S2 = Baseline assumptions without TFP growth
S3 = Baseline assumptions without area growth
S4 = Baseline assumptions without TFP and area growths

growth in TFP and rice area), the rice supply would grow at a smaller rate of about 1.54 per cent.

The domestic supply of rice under the baseline scenario (S1) is projected to be 102.7 Mt in the year 2010 and will grow to 117 Mt by the year 2015, 133 Mt by the year 2020 and to 152 Mt by the year 2025 (Table 9). Looking at the supply and demand balances for rice, it appears that the demand for rice will be met in the future with a surplus of 2 Mt in the year 2010 and a substantial surplus in the subsequent years. However, under scenario S4 (without TFP and rice area growths), India may not be a net exporter of rice. Thus, there is a need to strengthen the efforts on maintaining the TFP and increasing the yield per unit area through public investment in irrigation, infrastructural development, research, efficient use of water and a balanced use of plant nutrients.

## Wheat

The projected annual growth in wheat supply is estimated to be 2.82 per cent under the baseline scenario. In the absence of TFP growth, wheat production would grow at the rate of 2.26 per cent per annum. Under the assumption with no growth in acreage, the wheat production would grow by 2.11 per cent. Under the scenario 4 (without growth in TFP and wheat area), the supply would grow at a smaller rate of about 1.55 per cent. The domestic supply of wheat under the baseline scenario will be 82.8 Mt in the year 2010 and will grow to 95.1 Mt in 2015 and 125.7 Mt by 2025 (Table 10). Considering the baseline scenario without TFP growth, the domestic supply of wheat will be about 90 Mt by the year 2015 and 112 Mt by the year 2025. If TFP growth is not maintained, the loss in wheat production will be substantial, about 6 Mt in the year 2015 and 13 Mt in 2025. A look at the scenario S3 revealed that the area response remained one of the important sources of domestic supply. However, the possibility of area expansion was limited. In the absence of area expansion, the loss in wheat supply will be 7 Mt in 2015 and 17 Mt by the year 2025. This loss needs to be compensated for by increasing yield levels per unit of land. The domestic wheat supply in scenario 4 (without TFP and wheat area growths) is projected to be 77 Mt in the year 2010 and will grow to 83 Mt by 2015, 90 Mt by 2020 and 97 Mt by 2025. This scenario

**Table 9. Projected domestic supply and demand of rice, India**

(Mt)

| Year | Supply scenario | | | | Demand |
|---|---|---|---|---|---|
| | S 1 | S 2 | S 3 | S 4 | |
| TE 2005 | 87.78 | 87.78 | 87.78 | 87.78 | 93.16 |
| 2005 | 90.11 | 89.47 | 89.77 | 89.14 | 94.46 |
| 2010 | 102.67 | 98.42 | 100.41 | 96.24 | 100.67 |
| 2015 | 116.98 | 108.27 | 112.31 | 103.91 | 106.82 |
| 2020 | 133.29 | 119.10 | 125.61 | 112.19 | 112.79 |
| 2025 | 151.88 | 131.01 | 140.50 | 121.53 | 117.34 |

**Table 10. Projected domestic supply and demand of wheat in India**

(Mt)

| Year | Supply scenario | | | | Demand |
|---|---|---|---|---|---|
| | S 1 | S 2 | S 3 | S 4 | |
| TE 2005 | 70.04 | 70.04 | 70.04 | 70.04 | 70.84 |
| 2005 | 72.02 | 71.62 | 71.52 | 71.13 | 72.31 |
| 2010 | 82.77 | 80.10 | 79.40 | 76.83 | 79.54 |
| 2015 | 95.14 | 89.59 | 88.15 | 82.98 | 87.24 |
| 2020 | 109.35 | 100.20 | 97.87 | 89.63 | 95.31 |
| 2025 | 125.68 | 112.06 | 108.66 | 96.81 | 104.01 |

is likely to occur and the nation would face the shortage of indigenous wheat to match the domestic wheat demand. However, under scenarios with TFP response or area response, wheat demand in future will be met with a marginal surplus. This emphasizes the need of strengthening the efforts at increasing wheat production through technological change and raising resource productivity in the less developed areas.

## Pulse Grains

The production of pulses is almost stagnating at the level of 14 Mt due to negative growth in area and TFP. The projected annual growth of pulse grains under the baseline scenario is 1.06 per cent. The negative area and TFP growths lower down the production of pulse grains by 0.41 per cent per annum. The pulse grains production is projected to be 15.6 Mt in the year 2015 and will grow to 17.3 Mt by the year 2025 (Table 11). The supply will fall short of the demand for pulses under all the scenarios. The policies that may increase TFP growth and area expansion in the long-run can help in keeping a balance between domestic production and demand for pulses.

## Oilseeds

The annual growth in domestic production of nine major oilseeds is estimated to be 5.1 per cent under the baseline scenario, which is much higher than envisaged in the past, during 1981-2005 ( 3.1%) with area growth of 1.8 per cent, and TFP growth of 0.41 per cent. The domestic supply of oilseeds under baseline scenario will be about 34.9 Mt in 2010, 44.7 Mt in 2015, 57.2 Mt in 2020, and 73.3 Mt in the year 2025 (Table 12). Considering the baseline scenario without TFP growth, the domestic supply of oilseeds will be about 42.8 Mt in 2015 and 67.5 Mt in 2025. The contribution of TFP growth is projected to be 1.9 Mt in the year 2015 and 5.8 Mt in the year 2025. The scenario of oilseeds production without area expansion is estimated to be 39.3 Mt in the year 2015 and 57.2 Mt in the year 2025. Under the scenario S4, the supply is projected to be 37.6 Mt in 2015 and 52.7 Mt in 2025. Thus, without TFP growth and area expansion under oilseeds, the domestic production will fall short of the domestic demand for edible oils. There is a need for strengthening efforts to enhance production of oilseeds by increasing their productivity through raising resources for

**Table 11. Projected domestic supply and demand of pulse grains in India**

(Mt)

| Year | Supply scenario | | | | Demand | |
|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | Pulse grains | Pulses |
| TE 2005 | 13.88 | 13.88 | 13.88 | 13.88 | 13.96 | 12.56 |
| 2005 | 14.03 | 14.05 | 14.07 | 14.09 | 14.30 | 12.87 |
| 2010 | 14.79 | 14.90 | 15.05 | 15.16 | 15.97 | 14.37 |
| 2015 | 15.60 | 15.80 | 16.10 | 16.31 | 18.05 | 16.24 |
| 2020 | 16.45 | 16.76 | 17.22 | 17.55 | 20.62 | 18.55 |
| 2025 | 17.34 | 17.78 | 18.42 | 18.88 | 23.87 | 21.48 |

**Table 12. Projected domestic supply and demand of oilseeds in India**

(Mt)

| Year | Supply scenario | | | | Demand | |
|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | Oilseeds | Edible oils |
| TE 2005 | 25.94 | 25.94 | 25.94 | 25.94 | 30.97 | 9.29 |
| 2005 | 27.26 | 27.15 | 26.94 | 26.83 | 31.81 | 9.54 |
| 2010 | 34.90 | 34.09 | 32.52 | 31.76 | 35.94 | 10.78 |
| 2015 | 44.69 | 42.81 | 39.26 | 37.59 | 41.34 | 12.40 |
| 2020 | 57.22 | 53.75 | 47.40 | 44.49 | 48.35 | 14.50 |
| 2025 | 73.27 | 67.49 | 57.22 | 52.66 | 57.62 | 17.29 |

**Table 13. Projected domestic supply and demand of sugarcane in India**

(Mt)

| Year | Supply scenario | | | | Demand | |
|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | Sugarcane | Sugar |
| TE 2005 | 252.78 | 252.78 | 252.78 | 252.78 | 255.67 | 20.45 |
| 2005 | 260.54 | 259.25 | 256.65 | 255.36 | 260.82 | 20.87 |
| 2010 | 303.05 | 294.16 | 276.88 | 268.64 | 286.14 | 22.89 |
| 2015 | 352.50 | 333.78 | 298.70 | 282.61 | 313.82 | 25.11 |
| 2020 | 410.01 | 378.73 | 322.25 | 297.30 | 343.84 | 27.51 |
| 2025 | 476.91 | 429.73 | 347.65 | 312.76 | 382.66 | 30.61 |

investment in less-developed areas and introducing new technologies.

## Sugarcane

Under the baseline scenario, the annual growth in sugarcane production is estimated to be 3.07 per cent, which is higher than that observed during 1981-2005 (2.23%). Under scenario without TFP growth, supply will grow at a growth rate of 2.56 per cent. Sugarcane supply would be augmented significantly as a result of area response. Thus, under the assumption without acreage response, sugarcane production would grow at the annual growth rate of 1.53 per cent. Under the scenario S4 (without growth in TFP and sugarcane area), the domestic sugarcane production would grow at a smaller rate of about 1.02 per cent. The area response remains one of the important sources of domestic supply of sugarcane.

The domestic supply of sugarcane under baseline scenario will be about 303 Mt in 2010, 352 Mt in 2015, 410 Mt in 2020, and 477 Mt in 2025 (Table 13). Considering the baseline scenario without TFP growth, the domestic supply of sugarcane would be 334 Mt in 2015 and 430 Mt in 2025. The contribution of TFP growth is projected to be 19 Mt in the year 2015 and is assessed to be 47 Mt in 2025. The scenario of sugarcane production without area expansion is estimated to be 299 Mt in the year 2015 and 348 Mt in 2025. Under the scenario S4, the supply is projected to be 283 Mt in 2015 and 313 Mt in the year 2025. The domestic production of sugarcane would fall short of the demand of sugar in India under the scenarios S3 and S4, but the supply would be surplus if the scenarios S1 and S2 would prevail in all the years.

## Conclusions

Empirical studies on the dynamics of supply and demand of food crops are valuable for a country like India from the point of view of food security, and often serve the purpose of providing important insights to policy planners regarding the existing state of affairs and future directions on food self-sufficiency. This study has estimated the factor demand and output supply elasticties for major food crops in India. The elasticities provide insights on the responsiveness of output supply and factor demand to changes in product and factor prices. The estimates have been used to arrive at the short- and medium-term supply projections of these crops. The projections have been carried out under four different scenarios of growth in crop area, total factor productivity and input-output prices and essentially compare the changes in supply of important food commodities under these potential scenarios. An assessment of crop demand-supply balance for these alternative scenarios provides valuable insights on the possible levels of self-sufficiency for each of the selected crops in future.

The results have suggested that the demand for rice and wheat will be met in future with a marginal surplus/deficit under the scenarios of with or without TFP growth and acreage response. However, it is highly likely that pulse grains, edible oilseeds and sugarcane would be short in supply of demand in the coming years under study. The policies that can help in maintaining the TFP growth in the long-run will be able to keep the balance between domestic production and demand for cereals, pulses, edible oils and sugar. This emphasizes the need for strengthening the efforts at increasing production potential through public investment in irrigation, infrastructural development, agri-research and efficient use of water and plant nutrients (Fan *et al*., 1999; Kumar *et al*., 2008).

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**Appendix Table 1**

**Base year area, yield and production of different crops: TE 2005 and TFP growth: 1975-2005**

| Crop | Yield (t/ha) | Area (Mha) | Production (Mt) | TFP growth (%) |
|---|---|---|---|---|
| Rice | 2.05 | 42.72 | 87.78 | 0.67 |
| Wheat | 2.64 | 26.48 | 70.04 | 1.92 |
| Pulse grains | 0.63 | 22.04 | 13.88 | -0.12 |
| Oilseeds | 0.98 | 26.35 | 25.94 | 0.76 |
| Sugarcane | 62.57 | 4.04 | 252.78 | -0.41 |

GoI (2009)

**Appendix Table 2**

**Input use, prices and yield for crops in India: TE 2005**

| Particulars | | Rice | Wheat | Pulse grains | Oilseeds | Sugarcane |
|---|---|---|---|---|---|---|
| | | **Average use of inputs (TE 2005)** | | | | |
| Human labour | (hours / ha) | 889.3 | 392.8 | 360.5 | 507.5 | 1535.9 |
| Bullock labour | (Pair hours / ha) | 90.0 | 21.8 | 44.0 | 43.8 | 32.5 |
| Fertilizer | (NPK in kg / ha) | 114.6 | 149.0 | 25.5 | 66.0 | 269.7 |
| Machine | (Rs/ha) | 1510 | 2876 | 1066 | 1507 | 944 |
| Irrigation | (Rs/ha) | 895 | 1770 | 269 | 843 | 1444 |
| | | **Average input price (TE 2005)** | | | | |
| Wage | (Rs / hour) | 7.45 | 8.16 | 6.66 | 7.33 | 5.30 |
| Animal labour | (Rs /hour) | 16.15 | 22.27 | 25.62 | 29.88 | 12.74 |
| Fertilizer price | (Rs / kg NPK) | 12.52 | 12.59 | 14.13 | 13.55 | 9.51 |
| Crop price | (Rs /100 kg) | 536.7 | 630.4 | 1525.4 | 1634.4 | 63.3 |
| Yield | (q/ha) | 34.00 | 30.76 | 7.00 | 11.48 | 568.7 |

**Appendix Table 3**

**Restricted estimates of the coefficients of translog cost function and t-ratios for major crops in India**

| Input | Input price | | | | | Year | Irrigation | Intercept |
|---|---|---|---|---|---|---|---|---|
| | *w/P* | *b/P* | *m/P* | *r/P* | *i/P* | | | |
| | | | | **Rice** | | | | |
| Human labour | 0.1695 | -0.0771 | -0.0065 | -0.0606 | -0.0253 | -0.0008 | -0.0148 | 2.1800 |
| | (10.52) | (-8.17) | (-0.86) | (-6.97) | (-2.76) | (-1.11) | (-5.94) | (1.49) |
| Animal labour | -0.0771 | 0.0831 | 0.0240 | -0.0143 | -0.0157 | -0.0037 | -0.0272 | 7.6246 |
| | (-8.17) | (8.16) | (4.29) | (-1.99) | (-2.37) | (-5.83) | (-11.18) | (6.03) |
| Machine labour | -0.0065 | 0.0240 | -0.0259 | -0.0043 | 0.0127 | 0.0018 | 0.0040 | -3.5962 |
| | (-0.86) | (4.29) | (-4.07) | (-0.83) | (2.36) | (4.55) | (2.75) | (-4.44) |
| Fertilizer | -0.0606 | -0.0143 | -0.0043 | 0.0756 | 0.0037 | 0.0031 | 0.0191 | -6.2488 |
| | (-6.97) | (-1.99) | (-0.83) | (9.26) | (0.62) | (5.50) | (9.96) | (-5.48) |
| Others[a] | -0.0253 | -0.0157 | 0.0127 | 0.0037 | 0.0246 | | | |
| | | | | **Wheat** | | | | |
| Human labour | 0.1189 | 0.0082 | -0.0470 | 0.0005 | -0.0806 | -0.0022 | -0.0190 | 4.8403 |
| | (10.91) | (1.53) | (-4.89) | (0.06) | (-8.10) | (-4.76) | (-5.90) | (5.18) |
| Animal labour | 0.0082 | 0.0320 | 0.0038 | -0.0471 | 0.0031 | -0.0087 | -0.0346 | 17.6621 |
| | (1.53) | (5.36) | (0.63) | (-8.09) | (0.50) | (-23.45) | (-10.69) | (23.75) |
| Machine labour | -0.0470 | 0.0038 | 0.0812 | 0.0098 | -0.0478 | 0.0061 | 0.0218 | -12.1274 |
| | (-4.89) | (0.63) | (5.15) | (1.15) | (-2.84) | (12.05) | (6.16) | -11.9000 |

*Contd.*

**Appendix Table 3 *Contd.***

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Fertilizer | 0.0005 | -0.0471 | 0.0098 | 0.0808 | -0.0441 | 0.0029 | 0.0341 | -5.6827 |
| | (0.06) | (-8.09) | (1.15) | (7.75) | (-4.06) | (5.40) | (9.40) | -5.3800 |
| Others[a] | -0.0806 | 0.0031 | -0.0478 | -0.0441 | 0.1694 | | | |
| | | | | **Pulses** | | | | |
| Human labour | 0.1456 | -0.1113 | -0.0011 | 0.0095 | -0.0427 | 0.0019 | 0.0027 | -3.3759 |
| | (6.24) | (-8.66) | (-0.09) | (0.99) | (-2.70) | (1.89) | (1.03) | (-1.69) |
| Animal labour | -0.1113 | 0.1210 | 0.0261 | -0.0100 | -0.0258 | -0.0049 | -0.0137 | 10.0216 |
| | (-8.66) | (8.07) | (2.57) | (-1.55) | (-2.09) | (-6.51) | (-5.27) | (6.66) |
| Machine labour | -0.0011 | 0.0261 | 0.0144 | -0.0001 | -0.0394 | 0.0028 | 0.0077 | -5.5098 |
| | (-0.09) | (2.57) | (0.92) | (-0.01) | (-2.97) | (4.08) | (4.09) | (-3.98) |
| Fertilizer | 0.0095 | -0.0100 | -0.0001 | 0.0063 | -0.0058 | 0.0020 | -0.0047 | -3.9437 |
| | (0.99) | (-1.55) | (-0.01) | (0.93) | (-0.76) | (4.23) | (-3.90) | (-4.15) |
| Others[a] | -0.0427 | -0.0258 | -0.0394 | -0.0058 | 0.1137 | | | |
| | | | | **Edible oilseeds** | | | | |
| Human labour | 0.0407 | -0.0656 | -0.0323 | 0.0485 | 0.0088 | 0.0061 | -0.0242 | -11.6580 |
| | (3.02) | (-8.25) | (-2.80) | (5.94) | (0.59) | (9.06) | (-8.18) | (-8.73) |
| Animal labour | -0.0656 | 0.0562 | -0.0173 | -0.0181 | 0.0448 | -0.0034 | -0.0201 | 7.0369 |
| | (-8.25) | (6.16) | (-1.86) | (-2.98) | (3.78) | (-6.50) | (-7.60) | (6.73) |
| Machine labour | -0.0323 | -0.0173 | -0.0499 | -0.0226 | 0.1221 | 0.0048 | 0.0052 | -9.5340 |
| | (-2.80) | (-1.86) | (-2.63) | (-2.19) | (6.07) | (6.62) | (1.57) | (-6.56) |
| Fertilizer | 0.0485 | -0.0181 | -0.0226 | -0.0171 | 0.0093 | -0.0004 | 0.0110 | 0.8243 |
| | (5.94) | (-2.98) | (-2.19) | (-1.67) | (0.80) | (-0.74) | (5.59) | (0.80) |
| Others[a] | 0.0088 | 0.0448 | 0.1221 | 0.0093 | -0.1849 | | | |
| | | | | **Sugarcane** | | | | |
| Human labour | 0.2131 | 0.0157 | -0.0103 | -0.1184 | -0.1002 | -0.0023 | -0.0446 | 5.1105 |
| | (11.13) | (1.70) | (-0.93) | (-9.44) | (-9.04) | (-2.71) | (-4.63) | (3.04) |
| Animal labour | 0.0157 | 0.0091 | -0.0147 | 0.0056 | -0.0116 | -0.0041 | 0.020 | 8.0001 |
| | (1.70) | (1.20) | (-2.36) | (0.72) | (-2.62) | (-8.65) | (3.27) | (8.66) |
| Machine labour | -0.0103 | -0.0147 | -0.0202 | 0.0567 | -0.0116 | 0.0033 | 0.0083 | -6.5197 |
| | (-0.93) | (-2.36) | (-1.66) | (6.19) | (-1.79) | (6.20) | (1.74) | (-6.19) |
| Fertilizer | -0.1184 | 0.0056 | 0.0567 | 0.0636 | -0.0076 | 0.0050 | -0.0226 | -9.5711 |
| | (-9.44) | (0.72) | (6.19) | (4.26) | (-0.79) | (6.23) | (-2.99) | (-6.06) |
| Others[a] | -0.1002 | -0.0156 | -0.0116 | -0.0076 | 0.1349 | | | |

*Notes:* Restrictions imposed were $\gamma_{ij} = \gamma_{ji}$ and $\Sigma\ \gamma_{ij} = 0$ for all *i*, *j*.
[a]Estimates derived from homogeneity constraints
If $t_{0.05} = 1.96$, coefficient is significant at 0.05 level; If $t_{0.01} = 2.58$, coefficient is significant at 0.01 level
The figures within the parentheses are the corresponding student *t*-statistics
Here, *w* = Wage (Rs/hour), *b* = Cost on animal labour (Rs/hour), *m* = Cost on machine labour (Rs/hour) *P* = Price of crop (Rs/100 kg), *r* = Cost of fertilizer (NPK) (Rs/kg), *i* = Cost of irrigation (Rs/ha)

**Appendix Table 4**

**Annual growth of input-output prices, area and TFP for crops in India: 1981-2005**

(Per cent)

| Price | Rice | Wheat | Pulse grains | Oilseeds | Sugarcane |
|---|---|---|---|---|---|
| Human labour | 10.10 | 11.39 | 10.91 | 11.83 | 11.68 |
| Bullock labour | 10.95 | 13.82 | 12.69 | 11.40 | 11.04 |
| Machine labour | 6.12 | 6.12 | 6.12 | 6.12 | 6.32 |
| Fertilizer | 4.73 | 5.32 | 5.66 | 5.76 | 5.30 |
| Irrigation | 5.85 | 5.85 | 5.85 | 5.85 | 5.99 |
| Crop price | 6.59 | 7.79 | 8.76 | 6.73 | 8.32 |
| Area growth | 0.38 | 0.71 | -0.29 | 1.23 | 1.54 |
| TFP growth* | 0.72 | 0.56 | -0.12 | 0.41 | 0.51 |

*Source: computed by authors