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# Changing Crop Production Cost in India: Input Prices, Substitution and Technological Effects

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**Abstract**

The study has examined economics of crop cultivation at the aggregate level over the past 25 years, identified sources of cost escalation and evaluated the effects of factor prices, substitution and technological effects on the production cost. The results reveal that a disproportionate change in gross return vis-à-vis cost resulted in varying rate of return from crop enterprise during the past 25 years. During 2007-08 to 2014-15, the average cost inflation reached the highest level of 13 per cent, more than half of which was contributed by the rising labour cost alone. Further, at the aggregate level, use of physical inputs increased only marginally and a large share of the increase in the cost of cultivation was attributed to the rising prices of inputs. The estimated negative and inelastic demand of inputs revealed a great scope to reduce the cost by keeping a check on input prices, particularly labour wages. The estimated elasticity of substitution indicated imperfect substitution between labour and machine and the present level of farm mechanization is inadequate to offset the wage-push cost inflation in Indian agriculture. It is therefore necessary to accelerate appropriate farm mechanization through the development of farm machinery suitable and economical at small farms and improvement in its access through the custom hiring. The study has also revealed a slow rate of yield improvement to offset the rising cost.

**Key words:** Production cost, cost inflation, input price effects, factor substitution, technological effects

**JEL Classification:** Q12, Q14, Q16

## Introduction

The agriculture sector, which engages 64 per cent of the rural workforce, assumes a predominant role in improving the overall welfare of rural society. According to the latest available data in Situation Assessment Survey of Agricultural Households conducted by the National Sample Survey Office (NSS-SAS), nearly half of the farmers' income comes from crop cultivation. The economic viability of crop production sector, therefore, becomes an essential condition to sustain interests of the farming community. In this context, accurate information on the cost of cultivation (COC) is indispensable. It not only helps the farmers to decide on the allocation of limited resources among alternate crop choices but also enables an assessment of farm profitability, which in turn influences their decision to invest in agriculture.

During the past five decades, Indian agriculture has witnessed a significant change in input-use away from traditional inputs like human labour, bullock labour, farm-grown seeds, manure and traditional methods of irrigation towards modern inputs like improved seeds, chemical fertilizers, farm machine and large-scale use of tubewells for irrigation. It is pertinent to evaluate the effect of such transitions on crop production cost and profitability of crop enterprise. It is also important to ascertain whether the change in COC, if any, is due to the changes in level of input-use or its prices. The changing relative price of the factors of production prompts farmers to partially substitute

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the related factors (e.g., farm labour with machinery) in order to maximize their profits. The evaluation of effect of factor substitution on crop cultivation cost is useful in devising suitable strategies for controlling the cost inflation in the country.

Most of the studies in the present literature have used cost concepts as a supplementary tool to estimate farm profitability or to assess the economic viability of a technology or to evaluate the impact of policy reforms (e.g., subsidy, MSP) on production cost. But barring few (Sen and Bhatia, 2004; Raghavan, 2008), no study in recent years has focussed exclusively on the changing structure of COC in a comprehensive manner. A properly-designed study on economics of crop production assumes a significant importance, particularly in the recent years when Indian agriculture has witnessed a positive turnaround in its performance since the year 2004-05 (Chand, 2014). With this background, the present study examines the changes in average real COC and relative profitability at the aggregate level during the past 25 years and identifies the sources of cost inflation and contribution of different factors in rising COC. The paper also evaluates the effects of factor prices, factor substitution and technological improvements on production cost by estimating price elasticity of input use, elasticity of factor substitution and yield elasticity of cost in selected crops, respectively.

## Data and Methodology

The study is based on the state-level aggregate and unit-level data on cost of cultivation collected under the *Comprehensive Scheme on Cost of Cultivation of Principal Crops* of Directorate of Economics and Statistics, Ministry of Agriculture & Farmers Welfare, Government of India. Presently, the COC data are collected for 21 principal crops across major producing states in the country. However, consistent time series data over a long time period is available only for a few crops. The present study uses time series data on COC for ten crops across 19 major producing states for the period 1990-91 to 2014-15. The selected crops are paddy, wheat, maize and jowar from cereals group, gram and arhar from pulses group, rapeseed & mustard and groundnut from oilseeds group and sugarcane and cotton among the other cash crops. These crops covered 66.11 per cent of gross cropped area (GCA) in the country in the year 2014-15. The state-wise area covered under the selected crops is given in Appendix 1. For evaluating the effects of factor prices and factor substitution, plot- level data were used for the period 2000-01 to 2012-13 for the selected crops. The technological effects on production cost were evaluated using state-level panel data for the period 2000-01 to 2012-13 in the selected crops.

The trends in average cost and return from crop cultivation were examined by constructing all-India level aggregated time series of selected crops across major producing states using crop area in respective states as weight. The concept of Cost $A_1$+ imputed value of family labour (Cost $A_1$+FL)[1] was used to represent the cost. The cost and return were expressed in real terms using Consumer Price Index for Agricultural Labour (CPI_AL). The relative profitability of a crop enterprise was examined from the ratio of Cost$A_1$+FL and value of gross output during the period 1990-91 to 2014-15. Based on the structural change in cost-output ratio, the crop performance was examined during three distinct sub-periods, viz. 1990-91 to 2002-03, 2002-03 to 2007-08, and 2007-08 to 2014-15.

To estimate annual cost inflation and identify sources of change in COC over time, cost index (with base 2004-05=100) was constructed. Relative contribution of different factors in cost inflation was estimated using the following formula;

$$Z_{it} = \frac{(w_{it} \times I_{it})}{\sum_{i=1}^{n}(w_{it} \times I_{it})} \times 100 \quad \ldots (1)$$

where,

$Z_{it}$ = Contribution of $i^{th}$ factor in cost inflation in the $t^{th}$ year

$w_{it}$ = Share of $i^{th}$ factor in cost ($A_1$+FL) in the $t^{th}$ year

$I_i$ = Inflation rate of $i^{th}$ factor cost in the $t^{th}$ year over previous year, and

i = 1, 2,…, n inputs.

[1] Cost $A_1$ comprises of all paid out cost components such as value of hired human labour, hired bullock labour, maintenance and upkeep charges on owned bullock labour, upkeep charges of owned machines, hired machine charges, seed cost, pesticides cost, manure cost, fertilizer cost, canal irrigation charges, depreciation of implements and farm buildings, land revenue cess and other taxes, interest on working capital and miscellaneous expenses on other inputs. Imputed value of family labour was estimated by multiplying working hours of family labour with prevailing wage rate.

The effect of factor prices and factor substitution on COC was evaluated by estimating the price elasticity of factor demand and elasticity of technical substitution between factors (labour and machine) in the selected crops. The price elasticity of factor demand simulates the response of input used to the changes in its prices, while elasticity of technical substitution explains how changes in relative prices of factors affect the share of factors and income distribution. These elasticities were estimated by fitting the transcendental logarithmic (translog) cost function in selected crops for the period 2000-01 to 2012-2013. The translog functional form captures many of the attributes of a cost function that are implied by the economic theory. Because of this flexibility, it has been widely used for studying production relationships. Before logarithms are taken, the function is:

$$\mathrm{C} = \mathrm{a_0} \mathrm{y}^{\mathrm{a_y}} \mathrm{y}^{\frac{1}{2}\mathrm{a_{yy}lny}} \prod_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{w_i}^{\mathrm{a_i}} \prod_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{w_i}^{\mathrm{a_{iy}lny}} \cdot \prod_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{w_i}^{\frac{1}{2}\sum_{\mathrm{j}=1}^{\mathrm{N}} \mathrm{a_{ij}lnw_j}} \qquad \ldots (2)$$

where, w is a vector of prices for the inputs to production and y is a single output. N is the total number of inputs and a's are the parameters of the function.

One disadvantage of the previous form is that it is not linear in parameters. A standard technique when dealing with power functions like the translog cost function, is to take logarithms. The resulting function is linear in parameters and standard statistical techniques can be used for estimation. After taking logarithms, the function is:

$$\ln C = a_0 + \sum_{i=1}^{N} a_i \ln w_i + a_y \ln y + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} a_{ij} \ln w_i \ln w_j \sum_{i=1}^{N} a_{iy} \ln w_i \ln y + \frac{1}{2} a_{yy} \ln y \ln y \qquad \ldots (3)$$

While it is possible to include terms to account for technological progress, the specification used here assumes that cost is independent of time. Using Shepherd's lemma, the derived demand equations are

$$\mathrm{S_i} = \mathrm{a_i} + \mathrm{a_{iy}lny} + \sum_{\mathrm{j}=1}^{\mathrm{N}} \mathrm{a_{ij}} \ln \mathrm{w_j} \qquad \ldots (4)$$

where, $\mathrm{S_i} = \frac{\mathrm{w_i x_i}}{\mathrm{C}}$ is the cost share of the i[th] input. The cost function is assumed to be continuous, so Young's Theorem concerning symmetry of the second derivatives restricts

$a_{ij} = a_{ji}$ for all i ≠ j .

The result of this derivation is a system of N C 1 equations consisting of N derived demand equations and one cost function.

Homogeneity of the first degree implies

$$\sum_{i=1}^{N} a_i = 1, \sum_{j=1}^{N} a_{ij} = 0, \sum_{i=1}^{N} a_{iy} = 0$$

for all i and j .

It is also possible to impose constant returns to scale – equivalent to imposing homogeneity in y – and details of this procedure can be found in Diewert and Wales (1987). The global concavity can also be imposed on this specification by forcing the matrix [$a_{ij}$] to be negative semi definite. A technique for accomplishing this can be found in Jorgenson (1986).

The elasticities of substitution are given by

$$\sigma_{\mathrm{ii}} = \frac{\mathrm{a_{ii}} + \mathrm{S_i}^2 - \mathrm{S_i}}{\mathrm{S_i}^2}$$

$$\sigma_{\mathrm{ij}} = \frac{\mathrm{a_{ij}} + \mathrm{S_i}\ \mathrm{S_j}}{\mathrm{S_i}\ \mathrm{S_j}} \quad \mathrm{i} \neq \mathrm{j} \qquad \ldots (5)$$

The price elasticities (own and cross) are given by

$$\eta_{\mathrm{ij}} = \sigma_{\mathrm{ij}}\ \mathrm{S_j} \qquad \ldots (6)$$

In the empirical analysis, five production factors — labour, machine, seed, fertilizer and irrigation were taken into consideration. The model consisted of four share equations each for the factors, namely labour, machine, seed and fertilizer. The coefficient of 'irrigation' was estimated using homogeneity constraint in the model.

While analysing impact of technological improvement on production cost, it was assumed that technological effects get manifested in crop yield. Therefore, the impact of technological improvement on production cost can be evaluated by estimating the association between crop yield and production cost. In the present study, yield elasticity of production cost was estimated for the selected crops by fitting log-linear state-level panel cost functions for the period 2000-01 to 2012-13. The general form of the cost function is given by Equation (7).

Production cost = f(crop yield, seed prices, fertilizer prices, labour wages, machine use prices, irrigation prices, animal use prices, trend) … (7)

The appropriate models among fixed effects, random effects and pooled data regression were selected by following standard panel data modelling process (Gujarati, 2005).

## Results and Discussion

### Trends in Cost and Returns

The trends in average real COC and return from the selected crops during the past 25 years are depicted in Figure 1. The average real COC witnessed a steady rise with annual growth rate of 2.14 per cent over the past 25 years. The rising COC is expected as it implies growth in input use through higher investments in crop cultivation. What matters from producers' point of view is whether increase in cost is accompanied by at least a similar increase in the returns?

The ratio of cost to gross return revealed a disproportionate change in the gross return as compared to the cost during 1990-91 to 2014-15. Based on the trend in the ratio, three distinct phases were delineated. An increase in cost per 100 rupee of output during 1990-91 to 2002-03; a phase of sharp decline in the production cost after 2002-03 till 2007-08, followed by a phase of steep increase in the production cost during 2007-08 to 2014-15.

During 1990-91 to 2002-03, the real COC representing all the selected crops increased by 2.06 per cent per annum, whereas the real gross returns remained stagnant. As a result, cost incurred to produce 100 rupees of crop output increased from ₹ 51 in 1990-91 to ₹ 66 in 2002-03 and the net return declined at the rate of 2.77 per cent per year (Figure 1). The subsequent period till the year 2007-08 witnessed revival in the real output, which witnessed a substantially higher growth rate of 6.56 per cent against a modest increase in real COC. This reduced the cost of producing100 rupees of output to historically lowest level of [1] 48 by the year 2007-08. The crop profitability witnessed a substantial improvement during this period.

However, the impressive growth in the real crop output could not sustain after 2007-08. The value of crop output deflated by CPI_AL during the year 2014-15 dropped to the 2006-07 level. On the other hand, the real COC increased rapidly by 3.22 per cent a year. These changes led to the reversal in the declining cost of production from ₹ 48 /100 rupee output in year 2007-08 to ₹ 64 by the year 2014-15. Based on these results, it can be concluded that during recent years, the growth

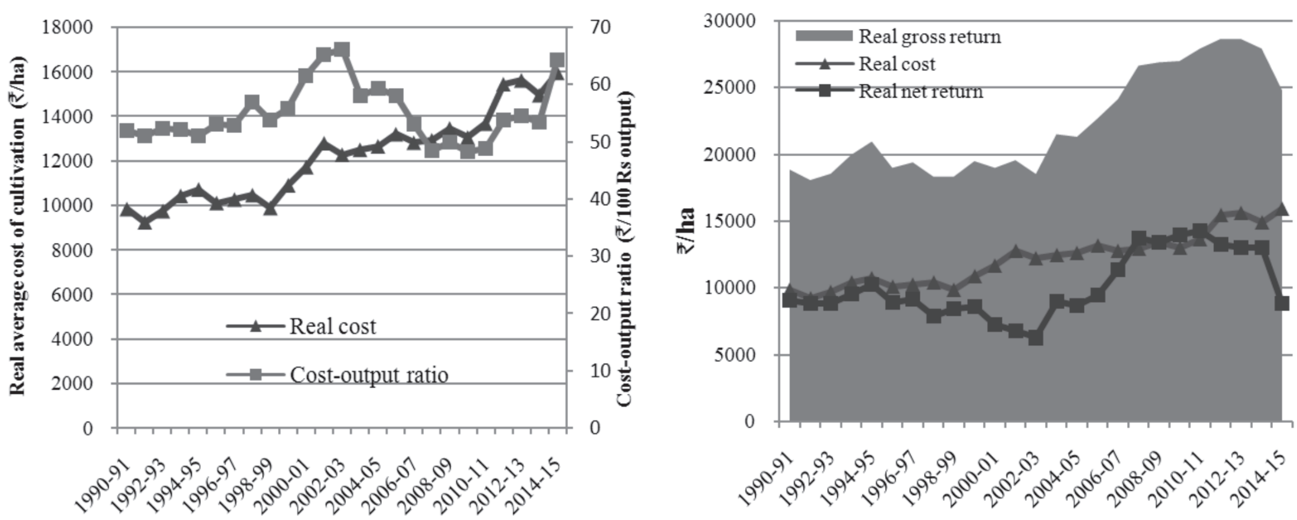


**Figure 1. Trends in average cost and return from the crop cultivation in India**

**Table 1. Cost of production in selected crops across the major producing states in 2014-15**

(₹/quintal)

| State | Paddy | Wheat | Maize | Jowar | Gram | Arhar | Groundnut | Rapeseed & mustard | Cotton | Sugarcane |
|---|---|---|---|---|---|---|---|---|---|---|
| Punjab | 515 | 562 | 934 | - | - | - | - | - | 2473 | - |
| Uttarakhand | 644 | 934 | - | - | - | - | - | - | - | 79 |
| Haryana | 911 | 842 | - | - | 1962 | - | - | 1686 | 4156 | - |
| Jharkhand | 878 | 1505 | 987 | - | 1299 | - | - | - | - | - |
| Rajasthan | - | 1029 | 1567 | 2283 | 2636 | - | 3033 | 1923 | 2948 | - |
| Kerala | 1223 | - | - | - | - | - | - | - | - | - |
| Madhya Pradesh | 1151 | 801 | 1083 | 2917 | 1943 | 2968 | - | 1276 | 4624 | - |
| Bihar | 875 | 1036 | 952 | - | - | - | - | 1356 | - | - |
| Gujarat | - | 993 | - | - | - | 3578 | 3195 | 1423 | 2827 | - |
| Karnataka | 915 | 2085 | 1040 | 1933 | 1947 | - | 3639 | - | 3059 | 91 |
| Chhattisgarh | 938 | - | - | - | 2176 | - | - | - | - | - |
| Andhra Pradesh | 892 | - | 745 | 1431 | - | - | 3424 | - | 3311 | 145 |
| Uttar Pradesh | 1089 | 1220 | 1609 | - | 4166 | 2772 | - | 2512 | - | 100 |
| Tamil Nadu | 1123 | - | - | 2338 | - | - | 2917 | - | 2974 | 134 |
| Himachal Pradesh | - | 1594 | 1713 | - | - | - | - | - | - | - |
| Maharashtra | | 1527 | 1811 | 2376 | - | 4189 | 5014 | - | 3585 | 146 |
| Odisha | 1175 | - | 1061 | - | - | 4336 | - | - | 5228 | - |
| West Bengal | 1234 | 1311 | - | - | - | - | - | - | - | - |
| Assam | 1139 | - | - | - | - | - | - | 3339 | - | - |
| Overall (₹/quintal) | 1016 | 1011 | 1296 | 2279 | 2283 | 3703 | 3379 | 1933 | 3356 | 114 |
| Output-cost ratio | 1.40 | 1.74 | 1.23 | 1.28 | 1.70 | 1.51 | 1.32 | 1.82 | 1.22 | 2.29 |

in output of the major field crops has remained inadequate to offset the rising COC leading to a downward trend in the average net returns from the crop cultivation. In real terms, the net returns received by the farmers in 2014-15 were even less than the returns which they received ten years back in 2005-06. The effects of declining returns from the investment in crop enterprises are reflected in the rising resentment among the farmers across the country during the recent years (Narayanamoorthy, 2013). As rising COC is not translating into the improvement in crop output, strategy to raise farmers' income should include both output acceleration and cost reduction measures.

The results presented in Table 1 show that production cost varies substantially across the crops and the producing states. For instance, the cost of producing a quintal of paddy varied from ₹ 515 in Punjab to ₹ 1234 in west Bengal in 2014-15. Similarly, the cost of producing wheat in Karnataka was 3.7-times the production cost in Punjab. The large variation in the production cost of a crop across the states arises due to difference in production technology (resulting in differential COC), access to irrigation, and the level of productivity. Therefore, in the states with low level of productivity, the production cost can be reduced substantially by improving crop yield.

## Sources of Changes in Cost of Cultivation

The sources of changes in COC have been identified by estimating the contribution of different inputs in the average cost inflation during the three sub-periods of the past 25 years. This in turn depends on respective share of inputs in COC (weight) and extent of rise in the COC during the period under consideration. The composition of the average COC during the three sub-periods is presented in Table 2. The evidences showed that during the past 25 years, Indian agriculture witnessed a steady shift from animal labour towards machine-use. The share of human labour in Cost$A_1$+FL witnessed a fluctuating trend

**Table 2. Changing structure of cost of cultivation: TE 1990-91 to TE 2014-15**

(per cent)

| Year | Share in cost of cultivation | | | | | | | Cost |
|---|---|---|---|---|---|---|---|---|
| | Seed | Fertilizer | Labour | Animal | Machine | Insecticides | Others# | $A_1$+FL* |
| TE 1990-91 | 10 | 12 | 39 | 14 | 7 | 2 | 16 | 3737 |
| TE 2002-03 | 8 | 11 | 42 | 12 | 10 | 2 | 15 | 9768 |
| TE 2007-08 | 9 | 11 | 41 | 9 | 13 | 2 | 15 | 14856 |
| TE 2014-15 | 8 | 11 | 47 | 5 | 14 | 2 | 13 | 34232 |

*₹/ha (at current prices); # Others include manure, depreciation of implements and farm buildings, land revenue cess and other taxes, interest on working capital and miscellaneous expenses on other inputs

**Table 3. Contribution of factors in average cost inflation in India**

(per cent)

| Period | Contribution in cost inflation | | | | | | | Cost |
|---|---|---|---|---|---|---|---|---|
| | Seed | Fertilizer | Labour | Animal | Machine | Insecticides | Others* | inflation |
| 1990-02 | 7 | 11 | 46 | 10 | 11 | 3 | 11 | 10 |
| 2002-07 | 12 | 8 | 34 | 8 | 21 | 3 | 20 | 6 |
| 2007-14 | 7 | 9 | 53 | 2 | 16 | 2 | 5 | 13 |
| Overall | 9 | 10 | 46 | 5 | 15 | 3 | 12 | 10 |

*Others include manure, depreciation of implements and farm buildings, land revenue cess and other taxes, interest on working capital and miscellaneous expenses on other inputs

during the successive periods and attained the highest level of 47 per cent by TE 2014-15. The labour was followed by machine, fertilizer, seed, animal labour and insecticide with their respective shares of 14 per cent, 11 per cent, 8 per cent, 5 per cent and 2 per cent.

During the past 25 years, the average annual inflation in Cost$A_1$+FL (2004-05=100) was about 10 per cent per annum (Table 3).The rise in COC was not uniform during the period under consideration. The average annual cost inflation declined from 10 per cent during 1990-91 to 2002-03 to 6 per cent during 2002-03 to 2007-08. But, the post 2007-08 period witnessed a sharp increase in COC at the annual rate of 13 per cent. The decomposition of cost inflation among various factors revealed that labour alone contributed 53 per cent to the increase in COC during 2007-08 to 2014-15. The labour cost was followed by cost on machine, fertilizer, seed, insecticides, and animal labour with their respective contribution of 16 per cent, 9 per cent, 7 per cent, 2 per cent and 2 per cent. Thus, the evidences revealed that labour cost is the predominant source of cost inflation, particularly in the recent years and managing this factor of production alone can substantially reduce the COC.

## Effect of Input Prices on Cost of Cultivation

The effects of input prices and input-use on increase in COC were seen from the trend in cost expressed at current and at 2004-05 prices[2]. The trend in Cost$A_1$+FL at the base year prices represents changes in the physical use of inputs. Figure 2 shows that at the aggregate level, physical use of inputs has changed only marginally[3], whereas COC at current prices witnessed a sharp increase which turned exponential

[2] The Cost$A_1$+FL at 2004-05 prices was arrived at by deflating cost of individual inputs with its implicit price deflator and summing over all input costs.

[3] The trend in Cost$A_1$+FL at 2004-05 prices does not capture change in the use of individual inputs which might have witnessed differential (increase/decrease) trend in its use

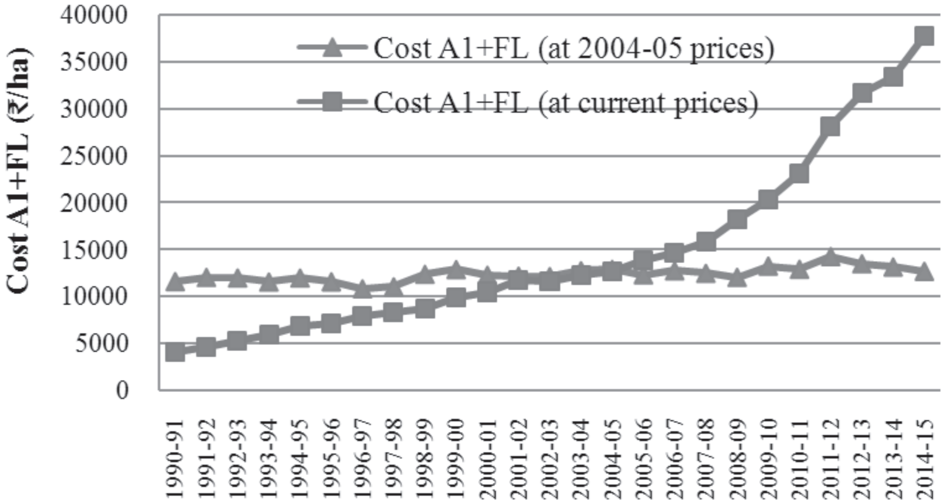


**Figure 2. Trend in cost$A_1$+FL at current and 2004-05 prices**

after mid-2000. These changes imply that a large share of the increase in cost is attributed to the rising prices of the inputs.

Further, the input prices also exert an indirect effect on the cost by influencing the actual use of the input. Such effects can be predicted from the price elasticity of inputs used in the crop cultivation (Chand, 1986). In the present study, the price elasticities of inputs used in the cultivation of selected crops were estimated by fitting translog cost functions using the SURE estimation technique. The estimated price elasticities for labour, irrigation, seed, fertilizer and machine are given in Table 4. The average estimated price elasticities varied across the inputs used and the crops taken into consideration. The elasticity values were negative and less than one, which imply that the increase in prices of the inputs would lead to less than proportionate decline in their use. Therefore, in a situation of rising input prices, COC will increase. Thus, inelastic demand of inputs explains a rapid increase in COC, especially during the recent years. At the same time, inelastic demand for inputs reveals a great scope to reduce the COC by controlling input prices because reduction in input prices would lead to a less than proportionate increase in input use which in turn will result in the cost saving for the farmers.

Interestingly, labour, a predominant source of cost inflation, exhibited the lowest price elasticity among all the inputs in most of the crops. This implies that in a situation of falling wage rates, COC will reduce substantially. This fact also strengthens the argument to manage the labour use in agriculture and devise a strong strategy to offset the cost-push effects of wages, which have risen sharply during the recent years (Chand and Srivastava, 2014). On the other hand, cost-reducing effect for the machine, which exhibited the highest price elasticity among all the inputs used in all crops, would be the lowest. Nevertheless, these results

**Table 4. Prices elasticity of inputs used in crop production**

| Inputs | Paddy | Wheat | Maize | Jowar | Gram | Arhar | Groundnut | Rapeseed & mustard | Cotton | Sugarcane |
|---|---|---|---|---|---|---|---|---|---|---|
| Labour | -0.21 | -0.27 | -0.21 | -0.17 | -0.14 | -0.21 | -0.16 | -0.25 | -0.20 | -0.23 |
| Irrigation | -0.25 | -0.47 | -0.10 | -0.40 | -0.30 | -0.29 | -0.04 | -0.49 | -0.38 | -0.46 |
| Seed | -0.29 | -0.26 | -0.34 | -0.36 | -0.21 | -0.28 | -0.28 | -0.18 | -0.60 | -0.44 |
| Fertilizer | -0.46 | -0.38 | -0.38 | -0.39 | -0.38 | -0.34 | -0.46 | -0.44 | -0.42 | -0.29 |
| Machine | -0.62 | -0.53 | -0.58 | -0.55 | -0.55 | -0.59 | -0.64 | -0.54 | -0.65 | -0.69 |

*Note:* The estimated parameters of the models are not given due to paucity of space and can be obtained from the authors

**Table 5. Elasticity of substitution between labour and machine use in different crops**

| EoS | Paddy | Wheat | Maize | Jowar | Gram | Arhar | Groundnut | Rapeseed & mustard | Cotton | Sugarcane |
|---|---|---|---|---|---|---|---|---|---|---|
| Value | 0.73 | 0.60 | 0.72 | 0.68 | 0.54 | 0.78 | 0.47 | 0.61 | 0.68 | 0.62 |

reveal an ample scope to reduce COC by controlling the input prices.

### Effect of Factor Substitution on Cost of Cultivation

Apart from controlling input prices, crop budget can also be managed to some extent by substituting the dearer inputs with technically feasible relatively cheaper inputs. For instance, farmers can substitute human labour with machine for several farm operations if relative labour wages (to machine-use prices) rises. It was observed that average labour-use in crop cultivation witnessed a 13 per cent reduction during 2000-01 to 2014-15. Farm mechanization has played a major role in reducing labour use in agriculture (Reddy *et al.*, 2014). However, inspite of declining labour-use, its share in CostA$_1$+FL has increased during the recent years (Table 2). Therefore, it is pertinent to evaluate the effect of substitution between labour and machine use on crop budget. This was examined by estimating elasticity of technical substitution between labour and machine (EoS) in cultivation of selected crops.

The EoS between human labour and machine hour varied from 0.47 for groundnut to 0.78 for arhar (Table 5). The positive but less than one value of elasticity implies that labour and machine are inelastic substitutes to each other. A 10 per cent increase in the ratio of wages-machine use price would result in 6.4 per cent (smaller) increase in ratio of machine use –labour use in crop production. Therefore, in the situation of increase in labour wages relative to machine-use prices, labour is not completely substituted by the machine and the share of labour in cost increases. The empirical evidences showed increase in labour wages-machine use prices ratio from 0.82 in 2001-02 to 1.03 in 2012-13 and this was accompanied by the increase in ratio of the share of labour and machine in crop outlay from 2.6 to 3.5 during the same period. Thus, inelastic substitution between labour and machine along with inelastic demand for labour appropriately explains why the share of labour in COC is increasing in the recent years despite reduction in the use of human labour in farm operations.

The imperfect substitution between human labour and machine use in agriculture also signifies the fact that it is technically not feasible to replace all manual farm operations with machine. Other reasons for the smaller (inelastic) value of EoS might be the slow progress in the development of efficient labour-saving farm machinery as well as its suitability and accessibility to the predominantly small and marginal farmers in the country. Based on these results it can be concluded that at present level of farm mechanization, substitution between labour and machine is not sufficient to offset the rising labour cost in Indian agriculture. Greater efforts, therefore, are warranted to accelerate the development of suitable farm machinery and to improve its economic access to the farmers through the institutional innovations like custom hiring centres.

### Effect of Technological Improvement on Production Cost

While evaluating impact of technological improvement on production cost, it was assumed that technological improvement is manifested in the yield of the crops. In a log-linear cost function, estimated coefficient of crop yield represents cost elasticity of yield which explains per cent change in production cost due to one per cent change in crop yield. The estimates of state –level panel cost functions for different crops are given in Table 6. It is to be noted that cross-section (state) effects were fixed to account for state-specific differences in production environment and climatic conditions. Further, inclusion of ‘time’ variable in the regression captured the temporal changes in production cost due to the factors other than those included in the model.

The estimated coefficient of yield was negative for all the selected crops indicating an inverse relationship between yield and cost of production. These results

**Table 6. Estimated coefficients of log-linear cost function for different crops**

| Variable | Paddy | Wheat | Maize | Jowar | Gram | Arhar | Groundnut | Rapeseed & mustard | Cotton | Sugarcane |
|---|---|---|---|---|---|---|---|---|---|---|
| Dependent variable: Cost of production (₹/qtl) in logarithmic form | | | | | | | | | | |
| Explanatory variables : | | | | | | | | | | |
| Intercept | 7.402*** | 6.593*** | 7.440*** | 5.327*** | 4.578*** | 7.552*** | 4.832*** | 6.099*** | 6.722*** | 4.971*** |
| | (0.323) | (0.395) | (0.455) | (0.810) | (0.495) | (0.891) | (0.476) | (0.528) | (0.510) | (0.958) |
| ln(Yield) | -0.758*** | -0.933*** | -0.812*** | -0.251*** | -0.251*** | -0.638*** | -0.651*** | -0.962*** | -0.621*** | -0.428*** |
| | (0.061) | (0.049) | (0.054) | (0.065) | (0.053) | (0.131) | (0.060) | (0.088) | (0.053) | (0.122) |
| ln(Seed prices) | - | 0.146* | 0.094** | 0.005 | 0.287** | -0.040 | 0.413*** | -0.064 | 0.042* | 0.059 |
| | - | (0.083) | (0.041) | (0.075) | (0.134) | (0.137) | (0.150) | (0.073) | (0.024) | (0.095) |
| ln(Fertiliser prices) | 0.065 | 0.310*** | -0.179 | 0.159 | 0.025 | -0.321 | 0.037 | 0.304* | 0.304** | -0.202 |
| | (0.086) | (0.102) | (0.165) | (0.303) | (0.146) | (0.216) | (0.069) | (0.164) | (0.143) | (0.221) |
| ln(Labour wages) | 0.238*** | 0.332*** | 0.453*** | 0.326** | 0.392*** | 0.585** | 0.386*** | 0.529*** | 0.412*** | -0.247 |
| | (0.055) | (0.074) | (0.080) | (0.139) | (0.073) | (0.238) | (0.080) | (0.123) | (0.089) | (0.249) |
| ln(Machin-use prices) | 0.082** | 0.067* | 0.023 | -0.052 | 0.133** | 0.005 | 0.179*** | 0.125* | -0.055*** | 0.521*** |
| | (0.033) | (0.037) | (0.035) | (0.094) | (0.055) | (0.100) | (0.063) | (0.073) | (0.028) | (0.129) |
| ln(Irrigation machine- use prices) | 0.052*** | 0.121*** | -0.014*** | 0.012 | 0.021 | 0.035 | -0.004 | 0.078 | 0.036 | -0.124 |
| | (0.017) | (0.024) | (0.021) | (0.046) | (0.037) | (0.067) | (0.028) | (0.057) | (0.029) | (0.192) |
| ln(Animal-use prices) | -0.001 | 0.004 | 0.120 | 0.255** | 0.066 | 0.046 | 0.209*** | 0.122** | 0.125** | -0.002 |
| | (0.032) | (0.026) | (0.039) | (0.099) | (0.052) | (0.114) | (0.058) | (0.054) | (0.055) | (0.066) |
| Trend | 0.002 | -0.011*** | -0.006 | -0.014* | -0.012* | 0.030** | 0.004 | -0.012 | -0.019** | 0.027*** |
| | (0.003) | (0.003) | (0.005) | (0.008) | (0.007) | (0.012) | (0.006) | (0.008) | (0.007) | (0.006) |
| Model (Fixed/Random/Pooled) | F | F | F | F | P | F | P | F | R | P |
| Cross-section effect | Y | Y | Y | Y | N | Y | N | Y | Y | N |
| Period effect | N | N | N | N | N | N | N | N | N | N |
| $R^2$ | 0.87 | 0.92 | 0.93 | 0.71 | 0.69 | 0.73 | 0.72 | 0.91 | 0.727 | 0.681 |
| Hausman test | 14.53** | 15.550** | - | - | - | - | - | - | 11.390 | - |
| | (7) | (8) | | | | | | | (8) | |
| LR test: Cross section F | - | 16.880*** | 10.506*** | 2.912** | - | 8.556*** | - | 17.069*** | - | - |
| | | (10,124) | (6,76) | (4,52) | | (4, 52) | | (5,64) | | |
| LR test: Cross section: Chai square | - | 122.870***(10) | 54.966***(6) | 13.140**(4) | - | 32.871***(4) | - | 66.097***(5) | - | |
| Observations | (13*11)143 | (13*11)143 | (13*7)91 | (13*5)65 | (13*6)78 | (13*5)65 | (13*5)65 | (13*6)78 | (13*9)117 | (13*6) 78 |

***, **, * denote significance at 1, 5 and 10 per cent levels, respectively show that yield improvement through technological interventions offers an opportunity to absorb the rising cost of production of crops. It is worth mentioning that yield elasticities of production cost were less than one for all the crops which implies that increase in yield resulted in less than the proportionate increase in cost of production during the past decade in the country. This draws attention to the nature of technological change in Indian agriculture. A one per cent increase in yield resulted in 0.25 to 0.96 per cent reduction in COC of different crops. The yield effect on reducing cost was quite strong in the case of wheat and rapeseed & mustard but quite weak in the case of gram and jowar.

## Conclusions and Policy Implications

The aggregate cost of production and output of ten major crops grown in India showed three distinct patterns during 1990-91 to 2014-15. The period 1990-91 to 2002-03 witnessed a steady rise in the real cost of cultivation (COC) accompanied by a relatively slower increase in the crop output. This mismatch resulted into a decline in profitability and net returns in real terms from crop production during this sub-period. The subsequent period till the year 2007-08 witnessed a significant acceleration in growth of output of the selected crops and the real cost of production reached a historically low level. The crop profitability registered a high growth during this period. However, this could not sustain and growth in the crop output remained inadequate to absorb the rising COC after 2007-08 till 2014-15. Over the 25 year period since 1990-91, the aggregate cost of cultivation of the selected crops increased at a faster rate than the increase in output during 1990-91 to 2014-15.

The average annual inflation in COC reached the highest level of 13 per cent during 2007-08 to 2014-15. More than half of the cost inflation during this period was contributed by the rising labour cost. Therefore, managing human labour alone would bring a substantial reduction in the crop budget of the farmers. Further, the results revealed that at the aggregate level physical use of inputs increased at a smaller rate and a large share of the increase in the COC was attributed to the rising prices of inputs. The negative and inelastic demand for farm inputs explains the sharp increase in the COC due to rising prices of inputs in the recent years. At the same time, keeping a check on input prices offers a great scope to reduce cost as it would lead to a less than proportionate increase in its use and the net effect will be lower COC.

Apart from input price effect, elasticity of substitution (EoS) between labour and machine is quite important in influencing COC. The EoS between labour and machine use was positive and less than one in all the crops under study indicating imperfect substitution between labour and machine. One consequence of this has been increase in the share of labour in COC in the recent years, despite declining labour-use for farm operations. The evidences revealed that the present level of farm mechanization is inadequate to offset the wage-push cost inflation in Indian agriculture. It is therefore necessary to promote efficient and appropriate farm mechanization suitable for small farm situation. Institutional innovations like custom hiring centres and online taxi type model for machinery services to the farmers seems to hold scope to reduce COC. Nevertheless, the possibility of a perfect substitution between labour and machine in Indian agriculture is remote and therefore efforts should be made to improve crop productivity to absorb rising COC.

The cost elasticity of yield has indicated an inverse association between yield and cost of production in all the crops. However, the elasticity coefficient in most crops barring wheat and rapeseed & mustard was low which revealed that the pace of improvement in the crop yield was less than the increase in COC during the past decade in the country. Such evidences indicate the slow pace of technological improvement in Indian agriculture and underline the need to accelerate efforts to raise yield at a faster rate to offset the effects of rising COC and maintain a fair profit margin in crop cultivation.

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## Appendix

**Appendix 1. Area under selected crops across major producing states in 2014-15**

(000, ha)

| State | Paddy | Wheat | Maize | Jowar | Gram | Arhar | Groundnut | Rapeseed & mustard | Cotton | Sugarcane | Selected crops(a) | GCA (b) | Per cent (a/b)*100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Andhra Pradesh | 2394 | | 303 | 141 | | | 874 | | 821 | 253 | 4787 | 7690 | 62.24 |
| Assam | 2495 | | | | | | | 281 | | | 2776 | 4083 | 68.00 |
| Bihar | 3263 | 2154 | 707 | | 60 | | | | | | 6184 | 7673 | 80.60 |
| Chhattisgarh | 4036 | 103 | 125 | | 293 | | | | | | 4557 | 5728 | 79.57 |
| Gujarat | | 1253 | | | | 214 | 1846 | 185 | 2773 | 258 | 6529 | 12773 | 51.12 |
| Haryana | 1278 | 2628 | | | 65 | | | 482 | 647 | | 5100 | 6536 | 78.04 |
| Himachal Pradesh | | 330 | 293 | | | | | | | | 623 | 918 | 67.84 |
| Jharkhand | 993 | 64 | | | | | | | | | 1056 | 1554 | 67.99 |
| Karnataka | 1327 | | 1311 | 1045 | | | 650 | | 875 | 691 | 5899 | 12247 | 48.17 |
| Kerala | 198 | | | | | | | | | | 198 | 2625 | 7.55 |
| Madhya Pradesh | 2058 | 6351 | 885 | 231 | 2446 | 375 | | 620 | 551 | | 13517 | 23810 | 56.77 |
| Maharashtra | | | | 3288 | | 1210 | 327 | | 4190 | 1030 | 10045 | 23474 | 42.79 |
| Odisha | 4166 | | | | | 141 | | | | | 4307 | 5173 | 83.26 |
| Punjab | 2895 | 3505 | | | | | | | 421 | | 6821 | 7857 | 86.80 |
| Rajasthan | | 3318 | 904 | | 1256 | | 505 | 2434 | 487 | | 8904 | 24235 | 36.74 |
| Tamil Nadu | 1795 | | | 415 | | | | | 187 | 263 | 2660 | 5995 | 44.37 |
| Uttar Pradesh | 6136 | 10047 | 691 | | 534 | 274 | | 584 | | 2216 | 20483 | 26147 | 78.34 |
| Uttarakhand | 260 | 344 | | | | | | | | 101 | 705 | 1097 | 64.25 |
| West Bengal | 5527 | | | | | | | | | | 5527 | 9690 | 57.03 |
| Total | 38820 | 30099 | 5219 | 5120 | 4654 | 2214 | 4202 | 4586 | 10952 | 4811 | 110677 | 189303 | 58.47 |
| India | 44238 | 32078 | 8797 | 6242 | 7652 | 3398 | 5104 | 5405 | 12660 | 5565 | 131139 | 198360 | 66.11 |
| Per cent | 87.75 | 93.83 | 59.33 | 82.04 | 60.82 | 65.15 | 82.32 | 84.84 | 86.50 | 86.45 | 84.40 | | |

Data source: Directorate of Economics and Statistics, Ministry of Agriculture & Farmers Welfare, Government of India