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Shifting Crop Production Costs in India: Impact of Input Prices, Substitution, and Technological Advancements

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ABSTRACT: The study has analyzed the economics of crop cultivation at an aggregate level over the past 25 years, identifying the sources of cost escalation and assessing the impact of factor prices, substitution, and technological changes on production costs. The findings indicate that an uneven change in gross returns compared to costs has led to varying rates of return from crop enterprises during this period. Notably, between 2007-08 and 2014-15, average cost inflation peaked at 13%, with more than half of this increase driven by rising labour costs alone. Additionally, at the aggregate level, the use of physical inputs increased only marginally, with a significant portion of the rise in cultivation costs attributed to higher input prices. The study's estimation of a negative and inelastic demand for inputs suggests a substantial opportunity to reduce costs by controlling input prices, particularly labour wages. The elasticity of substitution analysis indicated imperfect substitution between labour and machinery, with current levels of farm mechanization insufficient to counter wage-driven cost inflation in Indian agriculture. Therefore, it is essential to promote appropriate farm mechanization, especially through the development of cost-effective machinery suitable for small farms and improving access to such equipment through custom hiring. The study also highlighted a slow rate of yield improvement, which has not kept pace with the rising costs.

KEYWORDS: Crop Cultivation, Labour Wages, Farm Mechanization, Yield Improvement

I. INTRODUCTION

The agriculture sector, which employs 64% of the rural workforce, plays a crucial role in enhancing the overall welfare of rural communities. According to the latest Situation Assessment Survey of Agricultural Households conducted by the National Sample Survey Office (NSS-SAS), nearly half of farmers' income is derived from crop cultivation. Therefore, the economic viability of crop production is essential to maintain the interest of the farming community. In this context, accurate information on the cost of cultivation (COC) is indispensable. It helps farmers make informed decisions about resource allocation among different crops and enables an assessment of farm profitability, which, in turn, influences their willingness to invest in agriculture.

Over the past five decades, Indian agriculture has undergone significant shifts in input use, moving away from traditional inputs like human labor, bullock labor, farm-grown seeds, manure, and traditional irrigation methods, toward modern inputs such as improved seeds, chemical fertilizers, farm machinery, and extensive use of tubewells for irrigation. It is crucial to evaluate how these transitions have impacted crop production costs and the profitability of crop enterprises. Additionally, it is important to determine whether changes in COC are due to alterations in the level of input use or their prices. As the relative prices of production factors change, farmers may partially substitute one factor for another (e.g., replacing farm labor with machinery) to maximize profits. Understanding the effect of factor substitution on cultivation costs is essential for developing strategies to control cost inflation in the country.

While most studies in the current literature have used cost concepts as supplementary tools to estimate farm profitability, assess the economic viability of technologies, or evaluate the impact of policy reforms (such as subsidies or minimum support prices) on production costs, few studies (e.g., Sen and Bhatia, 2004; Raghavan, 2008) have comprehensively focused on the changing structure of COC in recent years. A well-designed study on the economics of crop production is particularly important, given the positive turnaround in Indian agriculture since 2004-05 (Chand, 2014). Against this backdrop, the present study examines changes in average real COC and relative profitability at the aggregate level over the past 25 years, identifies the sources of cost inflation, and analyzes the contributions of various

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factors to rising COC. The paper also evaluates the effects of factor prices, factor substitution, and technological improvements on production costs by estimating the price elasticity of input use, elasticity of factor substitution, and yield elasticity of cost for selected crops.

II. DATA AND METHODOLOGY

The study utilizes state-level aggregate and unit-level data on the cost of cultivation, collected under the Comprehensive Scheme on Cost of Cultivation of Principal Crops by the Directorate of Economics and Statistics, Ministry of Agriculture & Farmers Welfare, Government of India. Currently, COC data is collected for 21 principal crops across major producing states in the country. For this study, consistent time series data was used for gram and arhar from the pulses group, rapeseed & mustard and groundnut from the oilseeds group, and sugarcane and cotton among other cash crops. These crops accounted for 66.11% of the gross cropped area (GCA) in India in 2014-15. The state-wise area covered under these selected crops is also provided. To evaluate the effects of factor prices and factor substitution, plot-level data for the selected crops were analyzed for the period 2000-01 to 2012-13. The technological effects on production costs were assessed using state-level panel data for the same period.

Trends in the average cost and return from crop cultivation were examined by constructing an all-India level aggregated time series of selected crops across major producing states, using crop area in respective states as a weight. The concept of Cost A1+ imputed value of family labor (Cost A1+FL) was used to represent the cost. Both cost and return figures were expressed in real terms, adjusted using the Consumer Price Index for Agricultural Labourers (CPI_AL). The relative profitability of a crop enterprise was analyzed by examining the ratio of Cost A1+FL to the value of gross output from 1990-91 to 2014-15. Based on structural changes in the cost-output ratio, crop performance was assessed during three distinct sub-periods. To estimate annual cost inflation and identify the sources of change in COC over time, a cost index (with 2004-05 as the base year, indexed to 100) was constructed. The relative contribution of different factors to cost inflation was then estimated using a specified formula.

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

where, Zit = Contribution of i[th] factor in cost inflation in the i[th] year data over a long time period is available only for a few crops.

The impact of factor prices and factor substitution on the cost of cultivation (COC) was assessed by estimating the price elasticity of factor demand and the elasticity of technical substitution between factors (such as labor and machinery) in the selected crops. The price elasticity of factor demand measures how the usage of inputs responds to changes in their prices, while the elasticity of technical substitution illustrates how changes in the relative prices of factors influence the share of these factors in production and the distribution of income. These elasticities were estimated by applying the transcendental logarithmic (translog) cost function to the selected crops for the period from 2000-01 to 2012-13. The translog functional form is known for its ability to capture various characteristics of a cost function as implied by economic theory, making it a widely used tool for analyzing production relationships. Before applying logarithmic transformations, the function was:

$$\prod_{i=1}^{N} w_i^{\frac{1}{2}\sum_{j=1}^{N} a_{ij} \ln w_j}$$

$$C = a_0 y^{a_y} y^{\frac{1}{2} a_{yy} \ln y} \prod_{i=1}^{N} w_i^{a_i} \prod_{i=1}^{N} w_i^{a_{iy} \ln y} . \quad \dots (2)$$

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 limitation of the previous model is its non-linearity in parameters. A common approach to address this issue, especially with power functions like the translog cost function, is to take logarithms. This transformation linearizes the

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parameters, allowing the use of standard statistical techniques for estimation. In the empirical analysis, five production factors were considered: labor, machinery, seeds, fertilizer, and irrigation. The model included four share equations, each corresponding to the factors of labor, machinery, seeds, and fertilizer, while the coefficient for 'irrigation' was estimated using a homogeneity constraint within the model.

When analyzing the impact of technological improvements on production costs, it was assumed that these improvements are reflected in crop yield. Therefore, the effect of technological advancements on production costs can be assessed by estimating the relationship between crop yield and production cost. In this study, the yield elasticity of production cost for the selected crops was estimated 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 the following equation:

Production cost = f(crop yield, seed prices, fertilizer prices, labour wages, machine use prices, irrigation prices, animal useprices, trend) … (3)

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

III. RESULTS AND DISCUSSION

3. 1 Trends in Cost and Returns

The trends in average real COC and return from the selected crops during the past 25 years are depictedin Figure 1. The average real COC witnessed a steadyrise with annual growth rate of 2.14 per cent over thepast 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 viewis whether increase in cost is accompanied by at leasta 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 producing 100 rupees of output to historically lowestlevel 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

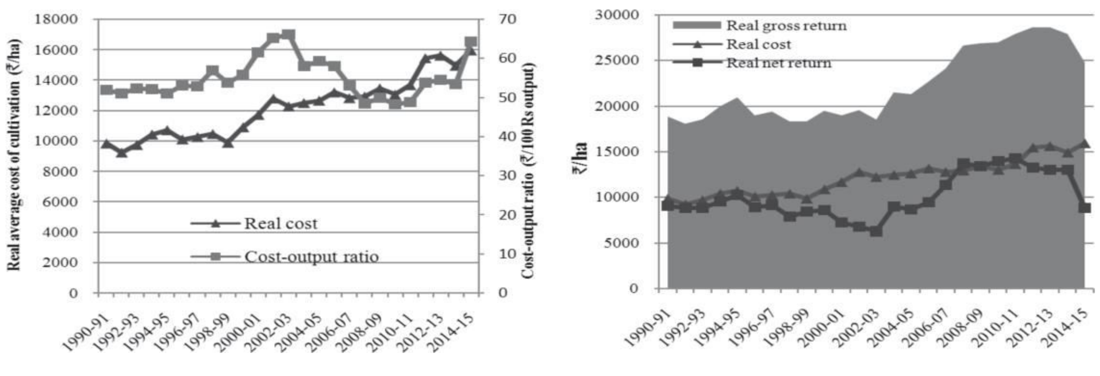

Figure 1. Trends in average cost and return from the crop cultivation in India

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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. Similarly, the cost of producing wheat in Karnataka was 3.7-times the production cost in Karnataka. 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.

3.2 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 CostA$_1$+FL witnessed a fluctuating trend 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 CostA1+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.

3.3 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 prices2. The trend in CostA1+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 marginally3, whereas COC at current prices witnessed a sharp increase which turned exponential after mid-2000. These changes imply that a large share of the increase in cost is attributed to the rising prices of the inputs.

3.4 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 operationsif 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 playeda 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 duringthe recent years (Table 2). Therefore, it is pertinent toevaluate the effect of substitution between labour andmachine use on crop budget. This was examined by estimating elasticity of technical substitution betweenlabour and machine (EoS) in cultivation of selected crops.

3.5 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 yieldof 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 costdue to one per cent change in crop yield. The estimatesof state –level panel cost functions for different cropsare 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 theregression captured the temporal changes in production cost due to the factors other than those included in themodel.

IV. CONCLUSIONS

The aggregate cost of production and output for ten major crops grown in India exhibited three distinct patterns between 1990-91 and 2014-15. From 1990-91 to 2002-03, there was a steady increase in the real cost of cultivation (COC), while the growth in crop output was relatively slower. This imbalance led to a decline in profitability and net returns in real terms during this sub-period. The following years, up until 2007-08, saw a significant acceleration in crop output growth, while the real cost of production reached historically low levels, resulting in high growth in crop profitability. However, this trend did not continue, and from 2007-08 to 2014-15, the growth in crop output was insufficient to offset the rising COC. Over the 25-year period since 1990-91, the aggregate cost of cultivation for the selected crops increased at a faster rate than crop output. The average annual inflation in COC peaked at 13% during 2007-08 to 2014-15, with more than half of this increase driven by rising labor costs. Consequently, managing labor costs alone could significantly reduce farmers' crop budgets. Additionally, the results indicated that the physical use of inputs increased at a slower rate, with the majority of the rise in COC attributed to higher input prices. The negative and inelastic demand for farm inputs explains the sharp rise in COC due to increasing input prices in recent years. Therefore, controlling input prices presents a significant opportunity to reduce costs, as it would lead to a less than proportionate increase in input use, resulting in lower overall COC. Beyond input prices, the elasticity of substitution (EoS) between labor and machinery plays a crucial role in influencing COC. The EoS between labor and machinery was positive but less than one across all crops studied, indicating imperfect substitution between these two factors. As a result, the share of labor in COC has increased in recent years, despite a decline in labor use for farm operations. The evidence suggests that the current level of farm mechanization is insufficient to counteract wage-driven cost inflation in Indian agriculture. Therefore, it is necessary to promote efficient and appropriate farm mechanization, particularly suited for small farms. Institutional innovations such as custom hiring centers and online platforms for machinery services, similar to taxi services, could help reduce COC. However, the possibility of perfect substitution between labor and machinery in Indian agriculture is limited. Therefore, efforts should focus on improving crop productivity to absorb

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the rising COC. The cost elasticity of yield indicated an inverse relationship between yield and production cost for all crops. However, the elasticity coefficient was low for most crops, except for wheat and rapeseed & mustard, suggesting that yield improvements have lagged behind the increase in COC over the past decade. This evidence points to the slow pace of technological advancement in Indian agriculture and underscores the need to accelerate efforts to increase yields at a faster rate to counter rising COC and maintain fair profit margins in crop cultivation

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