Does adoption of improved agricultural practices reduce production costs? Empirical evidence from Bundelkhand region, Uttar Pradesh, India

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The present study assessed the effect of improved agricultural technologies disseminated under the ambitious Farmer FIRST Programme on production costs of major crops in Bundelkhand region, Uttar Pradesh, India. The findings show that the average real cost during 2017–18 to 2020–21 declined, leading to an increase in the net return to cost ratio from farming. Technological interventions at the farmer's field resulted in a gradual decline in the share of seed, fertilizer and plant protection chemicals in the cost of cultivation. The price elasticity of factors, estimated by fitting the translog function, suggests that policies for controlling input price inflation, particularly wage rate, will be imperative in reducing the cost of farming. The results on the elasticity of technical substitution between labour and machinery highlight the need for devising suitable farm mechanization strategies which may be affordable in the small farm situation as well. The panel data estimate of negative cost elasticity of yield indicates that productivity growth plays a vital role in absorbing the increase in production cost.

Keywords: Agricultural practices, empirical framework, price elasticity, production cost, technological interventions.

THE Indian economy is growing at a sound pace and so is the use of technology in the growing sectors of the country. Nonetheless, the share of agriculture in the economy has gradually declined to less than 15% due to the high growth rate of the secondary and tertiary sectors. The importance of agriculture in India's economic and social fabric goes well beyond this indicator. Majority of the Indian population is still dependent on and practising agriculture as their primary source of income.

Indian agricultural policies have been in a continuous engagement with the farming infrastructure, improved agricultural practices and socio-economic upliftment of farming communities since independence. Despite the spectacular rise in agricultural production over the years, the farming communities in India continued to languish in poverty[1]. The economic unviability of the crop production sector, particularly for small and marginal farmers is leading to an agrarian crisis, which can have a detrimental effect on the future of agriculture in the country[2].

In India, agricultural development through improved technological interventions has been spread over time and in regions. Much literature is available on the impact of improved agricultural technologies through various outcome indicators like production, productivity, cropping intensity, farm income, etc. However, assessment of the impact on cost of farming assumes significant importance because rising production cost has become one of the underlying reasons for farm distress, particularly in largely cultivated rainfed areas. It is also important to ascertain the impact of promoted technologies on the change in the level of input use and its effect on cultivation cost. Such an assessment is useful in devising suitable strategies for controlling the rising production cost in agriculture.

Srivastava *et al.*[3] using secondary data attempted to analyse changes in production cost at the national level. However, field-level evidence of changing costs due to technological interventions has been poorly explored. Moreover, for a vast and agro-climatically diverse country like India, covering all the 500+ districts in a single study does not reveal the crucial regional dimensions for policy planning[4].

The present study, therefore, using the example of the Farmer FIRST (Farm, Innovations, Resources, Science and Technology) Programme (FFP) (The Farmer FIRST Programme (FFP) was launched by the Indian Council of Agricultural Research, New Delhi in 2016 to promote farmer-participatory, location-specific technological applications for sustainable agriculture and livelihood security.) aims to examine changes in the real cost of crop cultivation of the beneficiaries. Under

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Table 1. Technological interventions under the Farmer FIRST Programme

Technology	Description
Crop varieties	Wheat (RAJ-4179), black gram (Shekhar-2), green gram (PDM-139 (Samrat)) and groundnut (GG-2)
Cultivation practices	Summer ploughing, farmyard manure (FYM) application, soil test-based micronutrient application ($ZnSO_4$ at 20–25 kg ha^{-1}), line sowing, seed rate, irrigation during critical crop stages, integrated weed management practices
Farm machinery	Seed drill, groundnut decorticator, power-operated thresher-cum-grader
Plant protection measures	Seed treatment with fungicides and biofertilizers, use of biorationals

FFP, a broad set of technologies and cultivation practices like the improved variety of crops, line sowing of seeds, optimum irrigation during critical stages, balanced use of fertilizers, and use of biorationals are being promoted among the farmers (Table 1), making it an ideal situation for impact analysis of technological interventions. This paper also examines the effects of factor prices, factor substitution and technological interventions on production cost by estimating the price elasticity of input use, elasticity of factor substitution and yield elasticity of cost in selected crops respectively.

Material and methods

Study area and sampling

The analyses were based on primary survey data collected from Jhansi district, Bundelkhand region, Uttar Pradesh, India. Bundelkhand falls in the semi-arid tropics and the majority of the population in the region is dependent on crop/livestock-based activities. Around one-third of the geographical area is covered by degraded forests, permanent pastures, fallows and wastelands[5]. The prevalent undulating topography, hard-rock geology, low soil fertility, scarce groundwater resources along with poor and erratic rainfall lead to frequent droughts and crop failure in this region[6].

Jhansi district receives an average annual rainfall of around 880 mm, of which *kharif* season (June–September) has around 90% of the annual precipitation and the rest 10% is distributed during the remaining eight months. The present study used both purposive and random sampling approaches to draw sampled respondents. The first stage of the sampling approach involved purposively selecting five villages, namely Pali, Palinda, Datanagar, Dhimarpura and Parbai (hereafter called treated villages), as all the project activities were focused within the physical boundary of these villages. The second stage involved randomly selecting farm households within the physical boundary of these villages. Household heads were stratified based on the land-size category in each village and then the probability proportional to size method was used to draw sample households from each village. With the help of a well-structured and pretested interview schedule, data on the production and cost of cultivation of four major crops in the study area, namely wheat, groundnut, black gram and green gram were collected for the period 2017–18 to 2020–21.

Empirical framework

The changes in average cost and return from crop cultivation were examined by expressing them realistically using the consumer price index for agricultural labour (CPI_AL). Transcendental logarithmic (translog) cost function was fitted to estimate the effect of price elasticity of factor demand and elasticity of technical substitution between factors (labour and machine) on the cost of cultivation of selected crops. The function can be represented as follows

$$\ln C = a_0 + \sum_{i=1}^{N} a_i \ln z_i + a_y \ln y + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} a_{ij} \ln z_i \ln z_j$$

$$+\sum_{i=1}^{N} a_{iy} \ln z_i \ln y + \frac{1}{2} a_y a_y \ln y \ln y.$$

The function takes z and y as its regressors and returns minimum cost (C). The total number of factors considered is indicated by N, z is a vector of factor prices, y indicates level of production and as are the parameters of the function.

The elasticities of substitution can be calculated by

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

$$\sigma_{ij} = \frac{a_{ij} + S_i S_j}{S_i S_j} \quad i \neq j.$$

The price elasticities can be calculated by

$$\eta_{ij} = \sigma_{ij} S_j.$$

Seed, fertilizer, machinery, irrigation and labour were the inputs considered in the empirical analysis. The model consisted of four share equations for the factors, except irrigation. The coefficient of irrigation was estimated using homogeneity constraint in the model[7].

The effect of improved technological interventions gets manifested in crop yield. The relation between crop yield and production indicates the impact of the promoted technologies on the cost of production. However, the production cost is also influenced by factor prices. Therefore, the cost response model was developed and the yield elasticity of

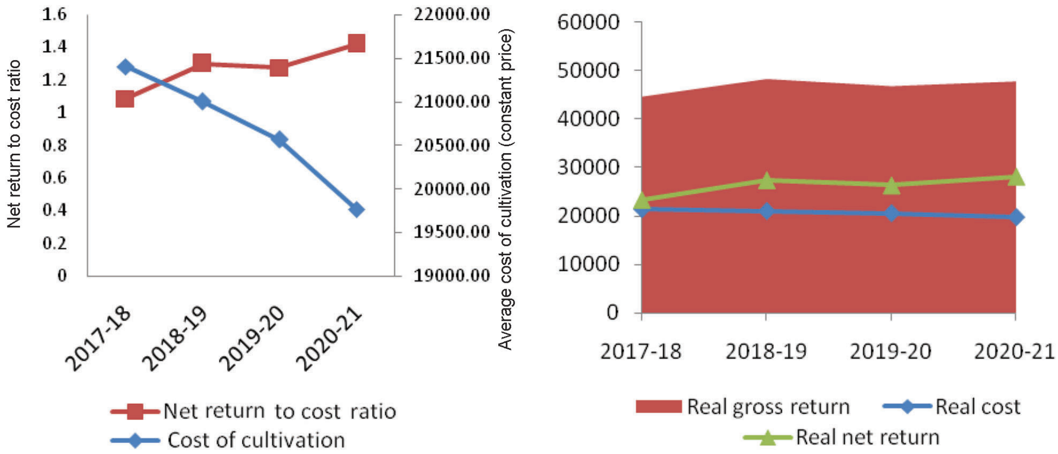

Figure 1. Changes in average cost of cultivation and returns at constant price. Source: Authors' estimate based on field data.

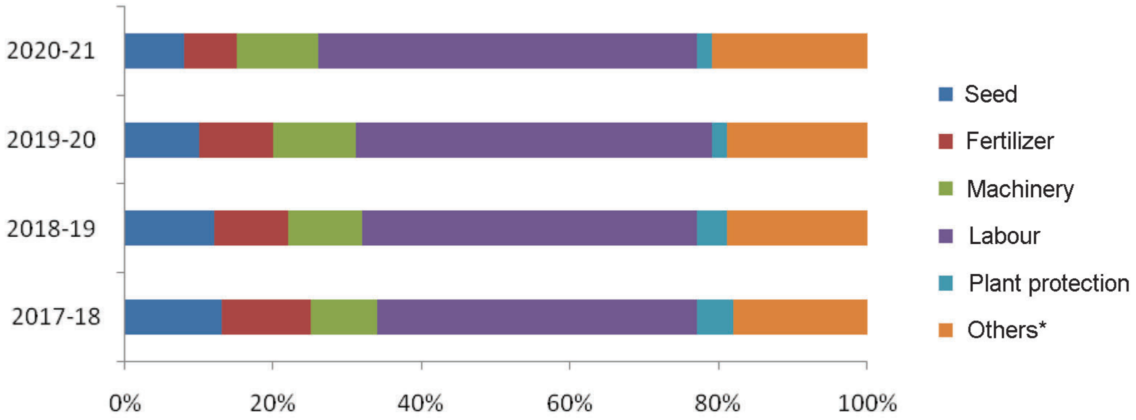

Figure 2. Changing share of inputs in cost of cultivation of major crops in the study area. *Others includes farmyard manure, depreciation, interest on working capital and miscellaneous expenses on other inputs.

production cost for the selected crops by fitting log-linear panel cost functions for the period 2017–18 to 2020–21 was estimated. The model takes the functional form as

$$\ln(C_{pkit}) = \beta_0 + \beta_1 \ln(P_{\text{Seed}})_{ikt} + \beta_2 \ln(P_{\text{Fertilizer}})_{ikt} + \beta_3 \ln(P_{\text{Machinery}})_{ikt} + \beta_4 \ln(P_{\text{Irrigation}})_{ikt} + \beta_5 \ln(P_{\text{Labour}})_{ikt} + \varepsilon_{ikt},$$

where C_{pkit} is the production cost (Rs/q) of the kth crop of the ith farmer in the tth year. P_{Seed}, $P_{\text{Fertilizer}}$, $P_{\text{Machinery}}$, $P_{\text{Irrigation}}$ and P_{Labour} represents unit prices of the respective factors. β_s is the time-invariant coefficient and ε is random error term.

The Hausman test inferred that the fixed effects model was more consistent than the random effects model[8–10]. In order to control the effects of unobserved cross-sectional variables and to capture year effects, the regression equation was estimated with two-way fixed effects models, i.e. cross-section and period fixed effects specifications.

Results and discussion

Cost of cultivation and returns from farming

Figure 1 depicts the changes in the average cost of cultivation and returns from selected crops in the study area over the study period. The declining trend in cost is encouraging and is indicative of the rational use of inputs by farmers in crop cultivation. A decrease in cost is further accompanied by an increase in real returns that implies productivity gains by the farmers in the study villages. A slight dip in returns in 2019–20 has been primarily attributed to untimely rainfall during the maturity period of the *kharif* crops that caused substantial yield loss.

Changes in factor share in cost of cultivation

Figure 2 depicts changes in the share of inputs in the average real cost over the study period. The share of labour dominates the total cost of cultivation over the years; however, a gradual shift from labour to machinery can be observed. The declining share of seed, fertilizer and plant protection is according to our expectation because ensuring the use of improved varieties, line sowing and balanced use of fertilizers by the farmers were among the major agronomic interventions under FFP in the study villages. Adoption of biorational control measures for pests, diseases and weeds resulted in a decline in the share of plant protection chemicals by 3%.

Price elasticity and factor substitution

Actual use of inputs is also influenced by their prices. Such effects can be predicted from the price elasticity of inputs used in crop cultivation. Table 2 presents the estimated price elasticity of inputs. Unsurprisingly, the average estimated price elasticity varied across the inputs and selected crops. The negative and less-than-unity value of the estimated elasticity indicate that the demand for inputs price-inelastic. This implies that an increase in the price of factors would lead to a less proportionate decline in their use. Therefore, rising input prices will accentuate the cost of cultivation of crops. In the present study, a decline in the average cost of farming over the years reflects a substantial decrease in inputs used by the farmers. This reduction is mainly attributed to the balance use of inputs by the farmers in crop cultivation. Price inelasticity of factors also indicates that policies for controlling input price inflation will be imperative in reducing the cost of cultivation of crops.

It is important to note that labour, which has the highest share in the average cost of cultivation (Figure 2), exhibits the lowest price elasticity among all the inputs in all the crops. This result is in agreement with that of Srivastava *et al.*[3], and suggests that labour use management in crop farming will reduce production costs to a large extent. Similarly, crop production with the rational use of seeds will result in cost savings for the farmers. Therefore, agronomic practices like the use of recommended seed rates and line sowing should be strategically promoted among the farmers to economize production at the macro scale. The price elasticity values for machinery indicate that the cost-reducing effect of machines would be the lowest among all inputs.

Factor substitution between technically feasible inputs like labour and machinery is another well-acknowledged method of cost control. For example, if the relative price of labour (wage rate) in comparison to machines increases, farmers will prefer using machines for various farm operations. In our analysis, the elasticity of technical substitution between labour and machinery was positive, but less than unity (Table 3), indicating that the two factors are inelastic substitutes for each other. In other words, it is technically not feasible to replace all labour operations of farms with machines. The inelastic substitution between labour and machines along with inelastic demand for labour appropriately explain why the share of labour in the cost of cultivation has increased over the years in the study area.

Inelastic substitution between the two factors signifies a lack of efficient labour-saving farm machinery as well as its suitability and accessibility among the farmers. Therefore, efforts are needed to develop suitable farm-efficient machinery. Easing credit availability and promoting institutional innovations like custom hiring centres would be imperative in improving the economic access to machinery in farm operations.

Table 2. Price elasticity of inputs used in crop production

Inputs	Wheat	Black gram	Green gram	Groundnut
Seed	–0.23	–0.18	–0.19	–0.21
Fertilizer	–0.36	–0.35	–0.31	–0.33
Machinery	–0.47	–0.41	–0.44	–0.69
Irrigation	–0.39	–0.27	–0.33	–0.09
Labour	–0.21	–0.19	–0.17	–0.16

Source: Authors' estimate based on field data.

Table 3. Elasticity of substitution between labour and machine use in selected crops

Crops	Wheat	Black gram	Green gram	Groundnut
Elasticity of substitution	0.67	0.53	0.56	0.49

Source: Authors' estimate based on field data.

Effect of technological interventions on cost of farming

Impact analysis of technological interventions on the cost of cultivation was based on the assumption that the adoption of improved promoted technologies by the farmers gets manifested in the crop yield. The econometric analysis supports the postulated inverse relationship between yield and outcome variable, i.e. production cost (Table 4). The negative cost elasticity of yield indicates that yield enhancement through technological interventions offers an opportunity to absorb the rising cost of production of crops. The less than unity value of yield coefficients shows that increase in yield results in less than the proportionate decrease (0.33–0.71%) in production cost. The yield effect on reducing cost was highest in the case of wheat and lowest for black gram.

Conclusion

Accentuating the cost of production in Indian agriculture is one of the major sources of agrarian distress. Ensuring respectable income in the farm sector needs adequate attention in devising and promoting costs-saving strategies in the farmer's field. The findings from the present study indicate that sensitizing farmers to the rational use of inputs and adopting improved agricultural practices can have an encouraging effect on the production cost of crops. Further,

Table 4. Regression estimates of log-linear cost function for different crops

Variable	Wheat	Black gram	Green gram	Groundnut
log (Yield)	–0.712* (0.049)	–0.336* (0.032)	–0.424* (0.026)	–0.632* (0.013)
log (Seed prices)	0.113** (0.051)	0.256** (0.123)	0.224* (0.013)	0.327* (0.019)
log (Fertilizer prices)	0.256* (0.002)	0.033 (0.152)	0.029 (0.031)	0.041 (0.037)
log (Labour wages)	0.121* (0.024)	0.241* (0.003)	0.483** (0.235)	0.386* (0.080)
log (Machine prices)	0.102* (0.171)	0.111** (0.049)	0.149 (0.081)	0.172* (0.001)
log (Irrigation rate)	0.131 (0.037)	0.012 (0.023)	0.007 (0.011)	0.063 (0.041)
Intercept	6.325* (0.334)	5.441* (0.423)	3.233* (0.782)	4.671* (0.782)
Cross-section: χ^2	127.89*	131.77*	129.41*	127.41*
Observations	516	346	424	364

Dependent variable: log(Cost of production). Method: Panel least squares. Effect specification: Cross-section fixed and period fixed. Source: Authors' estimate based on field data. Figures in parentheses show standard error. *Significant at 1%; **Significant at 5%.

human labour management in farm operations would be imperative for a substantial reduction in the crop budget of the farmers. Therefore, efficient and appropriate farm mechanization needs to be promoted. One of the possible ways forward in this direction is institutional innovation in providing farm mechanization to farmers based on custom hiring and uberization models that make farm machinery and equipment available as a service to farmers of all farm categories at their doorsteps at an affordable cost on a 'pay per use' basis. Further, as a perfect substitution between labour and machines in the Indian context is not possible, therefore efforts to bolster crop productivity would be crucial to counter the rise in production costs. The estimated negative cost elasticity of yield in the present study strongly supports this argument. Therefore, efforts towards accelerated seed replacement rate, revitalizing the seed chain with a focus on replacing varieties older than ten years with new ones, and incentivizing the public sector and facilitating the private sector to raise quality seed production to generate adequate supply will be crucial in accentuating crop output in unit time and space. Additionally, farmers must be encouraged to follow the recommended agronomic practices and to better calibrate the balance as well as level across different input uses.

The rigorous econometric analyses used in this study are crucial for understanding the field-level impacts of various sets of improved agricultural technologies and practices on production cost and net returns from farming. The evidence from Bundelkhand region, Uttar Pradesh, with its typical agro-ecological conditions, can offer important lessons for improving technological interventions for reducing production cost in semi-arid regions around the world which face similar challenges.

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