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Economic analysis and supply response of rice cultivation in India: Insights from NITI Aspirational districts

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Abstract

Rice is a staple food crop and a critical economic commodity in India, supporting the livelihoods of millions, including small and marginal farmers. Despite being the world's second-largest rice producer, India faces significant productivity gaps, with yields 30–60% lower than in other developing nations. This paper investigates the economics of rice cultivation across aspirational districts in Chhattisgarh, Odisha, and Telangana during 2018–2022. Using panel data from the Cost of Cultivation Scheme, it examines factors such as gross income, input costs, and yield variability. The findings highlight the disparity in costs and efficiencies between states, revealing Odisha's labor-intensive practices, Telangana's mechanization, and Chhattisgarh's balanced cost structure. The Odisha state generally has higher the labor Costs (% LC to TC) was observed Odisha districts report significantly higher labor costs, e.g., Gajapati (55%), reflecting labor-intensive practices and Chhattisgarh has moderate labor costs (21–33%). Mechanical Costs (% MC to TC) ranges from 10% to 24%, with Telangana showing the highest (24% in Bhoopalpalli). A dynamic supply response model employing the Generalized Method of Moments (GMM) indicates that factors such as fertilizer cost, seed value, and irrigation expenses significantly influence acreage decisions. The study confirms the higher elasticity of rice production in the long run, driven by investments in inputs and infrastructure. Policy recommendations include improving irrigation efficiency, promoting high-yielding seed varieties, and strengthening market linkages to enhance productivity and farmer incomes. This research contributes to sustainable agricultural policy design, aligning with India's goal to double farmer incomes and achieve the Sustainable Development Goals by 2030.

Keywords: GMM, labour cost, rice, productivity, panel data

Introduction

India is on a high growth path which expected to lift the millions out of poverty, nonetheless presently the quality of life of millions which is not translated with growth path the evidence of UNDP's 2024 [15] Human development index ranked 134 out of 180 countries. The Agricultural sector contributes about 17 per cent to gross domestic product of the country. (Economic survey, 2023) [6]. The agricultural sector's contribution to GDP is about 18.20% and, providing a livelihood for about 42.32% of the population and supports half of the country's population as their primary source of income.

The agriculture sector's growth rate in 2023-24 is 1.40% and the India is the world's top producer of farm outputs. India's agriculture sector exports are a significant part of the country's economy with exports of *$ 38* billion worth of agricultural products and the food grain production of 332.22 million tonnes however rice contributes about 41.26 per cent to the total production in 2022-23. Despite this, the productivity of the crop less about 30 to 60 per cent of other developed. Further, the disaggregated data reveals that there is significant inter-state and inter district variations in India. The uplifting the relatively lesser progress districts in attaining the doubling farmer's income by 2022-23 and Sustainable development Goal (SDG) by 2030 which results improves the socio-economic status of the people in whole.

In India, Rice is one of the important crops in India with regard to economic value and stands 2nd largest producer of rice in the world and which accounts about 22.21% of the world rice production and rice contributes about 41.26 per cent to the total production in 2022-23. This signifies the importance of rice production in India. In India rice is the staple food for more than 70% of population and which is the cheapest and most effective staple food crop accessible in India. (Bishwajit *et al*. 2013) [4]. In this respect which may possibly improves livelihood of the farmers and helps to eradicate under nutrition level of the farmers. Further this is significantly important for Small and Marginal farmers who depend on rice farming for their livelihood and also the landless farmers who derive their income from rice farming. Thus rice farming plays vital role in this region as whole. According to FAO estimates the annual growth rate of area under cultivation, production and yield were −0.17, 2.04 and 2.2, respectively evidence reflects that further increase in the rice production which could be possible through enhancement of yield. However, India's rice yield was lower than other developing countries like Bangladesh and Sri Lanka as well (Varma. P, 2017) [16]. In this paper, an attempt has been made in the exercise to estimate district wise yield to broadly identify key factors contributing to below the national average level, and to suggest remedial measures against manageable constraints for narrowing the yield gaps.

The rest of the paper as follows, next section deals about the data and econometrics methods employed to examine economics of rice system and supply response model and in section 3 economics of rice farming and rice supply response model by employing GMM and Nerlovian model and section 4 examines the status of cropping and irrigation intensity and as well as extent of NPK application finally concludes with recommendation for policy interventions that would fuel and sustain the rice production system in area.

Data and Methodology

The data generated under the cost of cultivation scheme (CS) of the Economics, Statistics And Evaluation Division (ES &E) division under the Ministry of Agriculture and Farmers' Welfare is used for the analysis of the paper from the period 2018-19 to 2021-22. The data, collected annually under this scheme, covers all major crops. This data helps in estimating the economics of cultivation for different crops as well as to know the effectiveness of price policy (Sen and Bhatia 2004; Raghavan 2008) [13, 11]. To work out the cost of cultivation of rice crop, data was collected for the year Triennium Ending (TE) 2021-22 from the CACP plot level data. The panel data 526 farmers consists of Chhattisgarh (131), Odisha (351) and Telangana (44) for the three years (2018-19 to 2021-22) is the latest data base. The data were provided by Directorate of Economics and Statistics through the commission for agricultural costs and prices, India. Hence the cost and net returns according to market prices have been worked out as under: In the first step, estimated the total cost incurred per hectare of rice crop which includes cost of seeds, fertilisers, manure, human labour (hired, attached and family), animal labour (hired and family), machine labour (hired and family), cost of canal irrigation. In the second step, gross returns hectare which includes value of main product and bi-product is considered. In the third step, the net returns are worked out as gross returns minus total cost. In addition to this, supply response of rice farmers towards imputed price and other factors including labor cost, fertilizer price, yield, seed cost and gross income which are compiled from the cost of cultivation survey data published by CACP. The empirical agricultural supply response uses cropped area, as a proxy to indicate the supply response to price, thus hereafter in this article we use cropped area response to denote supply. The considered variables are presented in Table1.

Table 1: Definition of variables used in the study and their expected relation with supply response model

Variables	Descriptions of the variables	Unit	Expected sign +/-
CA	Cropped area under paddy	Hectares	+
GRI	Gross income	Rs/ha	+
YLD	Yield	Qty/ha	+
LAC	Labor cost	Rs/ha	-
SDC	Seed cost	Rs/ha	-
FRT	Fertilizer cost	Rs/ha	-
IMP	Imputed price	Rs/Qty	+

In India, earlier work on supply response models mainly focused on Nerlovian (1958) [9] supply response model which are adaptive expectations and partial adjustment. This model facilitates analysis of both speed and level of adjustment of growing area to towards desired growing area. The Nerlovian approach (Askari and Cummings, 1977) [2] argued to its simplicity and parameters of interest can be interpreted.

The Nerlove's structural supply model for specific crop consists of the following three equations (Nerlove, 1979) [9]:

$$A_t = \beta_o + \beta_1 P^e_t + u_t$$
$$P^e_t = P^e_{t-1} + \pi (P_{t-1} - P^e_{t-1})$$
$$A_t = A_{t-1} + \gamma (A^*_t - A_{t-1})$$

Where A_t^* and A_t denote desired and realized acreage of a certain crop at time t, respectively; P^e_t and P_t refer to the vector of expected and actual own crop price at time t respectively; u_t is the disturbance with zero expected mean, π and μ are the expectation and adjustment coefficients, respectively.

Two reduced from variants of the above model can be derived using either Eq.(2) or (3). When price expectations are adaptive and A*t=At, then the reduced form of the above structural model can be expressed

$$At = \beta_0 \pi + \beta_1 \pi P_{t-1} + (1-\pi) A_{t-1} + u_t \text{ equation} \quad (1)$$

$$A_{it} = \beta_0 + \beta_{1i} P^e_{t-1} + \beta_{2i} GI_{t-1} + \beta_{3i} FP_t + \beta_{4i} Y_{t-1} + \beta_{5i} S_t + \beta_{6i} LC_t \quad i=1,2,\ldots,N$$

$$t = 1,2\ldots T \text{ equation} \quad (2)$$

Where A_{it} denotes cropped area under paddy at time t, P^e_{t-1} is expected price of paddy crop which is measured as previous year imputed price of paddy. FP is price of fertilizer, Y_{t-1} is previous year paddy yield, St is Seed cost, LC is labor cost for paddy cultivation all the parameters are in logs, thus estimated coefficients are elasticities.

The employing of ordinary least squares (OLS) estimation to dynamic panel data regression for equation (2) which results in a dynamic panel bias due to correlation of the dependent variable with any of the explanatory variables mention in the equation and also violates the strict exogeneity that is endogeneity may occur. (Nickell, 1981) [10]. Arellano and Bond (1991) [1] developed an efficient lagged endogenous and other exogenous variables as instruments in the GMM technique (Roodman, 2009) [12] Blundell and Bond (1998) [5] developed the system GMM in order to overcome dynamic panel bias. The system GMM estimation transforms the instruments to the fixed effects. The difference GMM estimator having the properties of poor finite samples with regard to bias and precision when applied to persistent series. The system GMM estimators are relatively gains over the differenced GMM estimator provided that initial conditions are not correlated with fixed effects (Blundell and Bond, 1998) [5]. Hence, using the system GMM method applied in the present paper to estimate our dynamic supply models.

In this paper several statistical tests are done to check the consistency of our preferred GMM estimator. First, Arellano-bond test for autocorrelation was employed to test the presence of serial correlation in the levels. The test results reveals that null hypothesis of no second order autocorrelations cannot be rejected for all production, acreage and yield models, indicating the reliability of the system GMM estimator. Second, the Hansen test results cannot reject the null hypothesis of instrument exogeneity. Third, to test the Blundell and Bond assumption using the difference in Hansen test of the two-step system GMM. The test statistics give p-values greater than 10% in all the cases. Finally, the standard error estimates for all specifications are robust in the presence of any pattern of heteroscedasticity and autocorrelation within the panels.

Results and Discussion

Economics of rice Cultivation

Table 1: Major Input cost for Rice of Aspiration districts of NITI during

Districts	Cropped area	Total cost	% LC to TC	% MC to TC	% SV to TC	% FC to TC
Chhattisgarh						
Korba	1.28	41256.00	33.00	20.00	6.00	6.00
Mahasamund	1.56	49625.00	22.00	16.00	6.00	8.00
Rajanandgaon	1.22	50362.00	22.00	16.00	4.00	9.00
Odisha						
Rayagada	0.49	49231.00	47.00	11.00	2.00	3.00
Kalahandi	0.67	48214.00	46.00	12.00	3.00	6.00
Kandhamal	0.61	47362.00	50.00	13.00	3.00	4.00
Gajapati	0.36	48623.00	55.00	10.00	2.00	5.00
Dhenkanal	0.45	50236.00	52.00	13.00	3.00	3.00
Malkangiri	0.70	51362.00	48.00	13.00	3.00	6.00
Koraput	0.71	59632.00	47.00	13.00	3.00	5.00
Gajapati	0.37	67523.00	53.00	10.00	2.00	5.00
Telangana						
Bhoopalpalli	0.82	66985.00	45.36	24.00	3.00	7.00

The economics of rice cultivation in the Aspiration districts of the India identified by the NITI during 2018-19 to 2021-22. The findings reveals that cropped Area ranges from 0.36 ha (Gajapati, Odisha) to 1.56 ha (Mahasamund, Chhattisgarh). However, in the Chhattisgarh state with highest area was observed in Mahasamund (1.56 ha) and Gajapati with smaller cropped area (0.36 ha) and the Telangana state with larger cropped areas of Bhoopalpalli with 0.82 ha. The total costs range varies, the highest total cost was observed in the state Telangana (Bhoopalpalli: ₹66,985) and Odisha (Koraput: ₹59,632). The Odisha state generally has higher total costs than Chhattisgarh, indicating possible variations in production costs or input intensity. At disaggregated level, the labor Costs (% LC to TC) was observed Odisha districts report significantly higher labor costs, e.g., Gajapati (55%), reflecting labor-intensive practices and Chhattisgarh has moderate labor costs (21–33%). Mechanical Costs (% MC to TC) ranges from 10% to 24%, with Telangana showing the highest (24% in Bhoopalpalli). The table signifies that positive relationship between cropped area and total costs is observed; larger areas incur higher total costs due to increased input demand. The Odisha exhibits higher labor cost percentages, reflecting dependence on manual labor, possibly due to lack of mechanization. The Chhattisgarh shows more balanced distribution across cost components. Telangana stands out with high mechanical costs (24%), suggesting mechanized level is higher due to shortage of labour.

Table 2: Gross income, variable cost and Yield of rice cultivation in Disadvantaged districts (Rs/ha)

State /Districts	Gross Income	Total cost	TC/GI	Yield
Chhattisgarh				
Korba	75863.00	41256.00	0.54	45.36
Mahasamund	74523.00	49625.00	0.67	43.23
Rajnandgaon	71362.00	50362.00	0.71	39.56
Odisha				
Rayagada	76452.00	49231.00	0.64	47.23
Kalahandi	74851.00	48214.00	0.64	43.12
Kandhamal	82623.00	47362.00	0.57	48.63
Gajapati	66582.00	48623.00	0.73	43.21
Dhenkanal	75402.00	50236.00	0.67	41.12
Malkangiri	75321.00	51362.00	0.68	40.36
Koraput	77362.00	59632.00	0.77	43.25
Gajapati	80025.00	67523.00	0.84	53.26
Telangana				
Bhoopalpalli	84236.00	66985.00	0.80	49.36

The gross income (GI), total cost (TC), cost efficiency (TC/GI), and yield across the districts of Chhattisgarh, Odisha, and Telangana indicated in the table 2. The findings reveals that The Highest Gross Income was observed in the Bhoopalpalli (Telangana) with ₹84,236, followed by Kandhamal (Odisha) with ₹82,623 however the lowest was observed in Gajapati (Odisha) with ₹66,582 per ha implies that Telangana and Odisha generally exhibit higher gross incomes compared to Chhattisgarh. The Cost Efficiency (TC/GI) varies between 0.54 (Korba, Chhattisgarh) and 0.84 (Gajapati, Odisha) and the lower TC/GI ratios indicate higher cost efficiency. Korba is the most cost-efficient (0.54), followed by Mahasamund (0.67). Rajnandgaon has the least cost efficiency (0.71) in the Chhattisgarh state likewise in Odisha the Kandhamal (0.57) and Rayagada (0.64) are the most cost-efficient districts, while Gajapati (0.84) exhibits the least efficiency however, in the state of Telangana the Bhoopalpalli shows moderate efficiency at 0.80 which implies that higher efficiency in Chhattisgarh and Kandhamal may reflect better resource management or lower input costs. With respect to yield the highest Yield Gajapati (Odisha) with 53.26 quintals/ha, significantly higher than other districts. At disaggregated level the Odisha most of the districts yields above 40 quintals/ha, indicating productive agricultural practices however in the Chhattisgarh the yield range from 39.56 (Rajnandgaon) to 45.36 (Korba). In sum, the higher total costs generally correspond to higher gross incomes, as seen in Bhoopalpalli, Koraput, and Gajapati and the Kandhamal achieves a high GI with relatively low TC, suggesting superior productivity or cost management.

Area Response model

The coefficient of each explanatory variable directly gives short run elasticities, and the long run elasticities are obtained by dividing short run elasticities by (1- coefficient of the lagged area variables). The assumption underlying this model is that all the long run elasticities exceed short run elasticities. If the adjustment coefficient is close to 1, then it implies that, farmers' adjustments of actual acreage to desire acreage is fast. If the adjustment coefficient is close to zero, then the adjustment takes place slowly.

Table 3: Area response model across the selected states

Parameters	Telangana	Chhattisgarh	Odisha
lag CA	0.58(0.08)	0.08(0.25)	0.015(0.25)
Lag own price	0.25(0.03)	0.45(0.01)	0.150(0.01)
Lag Yield	1.28(0.04)	2.48(0.05)	2.480(0.05)
Lag Fertilizer	-2.85(0.89)	8.85(0.0)	5.150(0.00)
Lag seed value	0.89(0.74)	0.78(0.08)	0.58(0.08)
Lag Labor cost	1.85(0.86)	1.45(0.96)	1.150(0.96)
Lag of Irrigation cost	-0.25(0.04)	-0.15(0.09)	-0.13(0.028)
Number of Instruments	26	23	29
F test for joint significance	0.002	0.001	0.007
Arellano-Bond for AR (2)	0.379	0.256	0.356
Hansen J test	0.003	0.004	0.006

The area response model across the states indicated in the table 3. The findings reveal that estimates (Telangana, Chhatisgarh and Orissa) indicated that short run price elasticity for selected states were higher for Orissa (0.75) and Chhatisgarh (0.45) when compared with Telangana (0.25). The results confirms that farmer respond more by other inputs for rice crop in the short run. The coefficient of own price elasticity (0.45) is less than fertilizer cost (8.85) and seed value (0.78) and lag yield (2.48) in the Chhattisgarh main reasons for this long distance and limited knowledge about the regulated and cooperative markets and lack of improved roads and transportation facility make them sell to village traders which makes the farmers unable to get remunerative prices yields less returns.

In Orissa state rice price response coefficients (0.75) is greater than Chhattisgarh (0.45) which implies that farmer producer realizing more returns than Jharkhand. However, in terms significance of individual coefficients, only fertilizer (5.15) and seed value (0.58) coefficient turned out be significant variable explaining the area variations.

In Telangana state rice price response coefficients is lesser than Chhattisgarh (0.45) and Orissa however, in terms significance of individual coefficients, this is not better fit as compared with Chhattisgarh and Orissa area response equation. Non acreage input coefficient turned out be significant variable explaining the area variations. The results confirms that the fact that rice producing farmers respond more by other than own output price factors for acreage response in the short run. The Adjustment coefficient for area of Telangana (0.418), which is modest and indicate that farmers adjust moderately toward the desired area. This result consonance with the Surekha (2005) [14] those farmers are reluctant to make larger adjustments in rice that are used for self-consumption. Perhaps rice is the staple food of that region. However adjustment coefficient of area for Chhattisgarh and Odisha is 0.91 and 0.86 respectively this indicates that farmer's adjustment of actual acreage to desired acreage is fast.

Table 4: Long Run and Short run Price Elasticities in typology II by GMM model

Particulars	Price Elasticities		
	Telangana	Chhattisgarh	Orissa
Short run	0.250	0.450	0.750
Long run	0.598	0.492	0.867
Adjusted cropped area	0.418	0.915	0.865

The long run elasticities for rice crop of Odisha (0.86), Chhattisgarh (0.49) and Telangana (0.49) are relatively higher when compared to short run prices indicated in the table 4. These findings are in parallel with Mythili, (2001) [7] for Tamil Nadu and Bhalla and Singh (1996) [3] for Punjab by employing the OLS methodology. The study confirms that short run price elasticities is lower than long run price elasticities which implies that rice farming requires investment on canals to ensure sufficient irrigation during planting time. These investments are long term decisions, implying that short run prices are inevitable low. The area of area of adjustment is very low for rice crop, which implies that allocating land for different crops may be challenging if mono-cropping is practiced in that condition crop rotation restrained particularly in the short run however, shifts can occur in the long run. (Narain, 1965) [8].

Conclusion

In India rice is the staple food for more than 70% of population and which is the cheapest and most effective staple food crop accessible in India. In this respect which may possibly improves the hunger index level and helps to eradicate undernutrition level. Further this is significantly important for the farmers who depend on rice farming for their livelihood and also the landless farmers who derive their income from rice farming. The present paper finding clearly indicates that the farmers incurring higher input cost however in certain districts yield level is below the national average implies that paradox of higher total cost and less gross income. The Highest Gross Income was observed in the Bhoopalpalli (Telangana) with ₹84,236, followed by Kandhamal (Odisha) with ₹82,623 however the lowest was observed in Gajapati (Odisha) with ₹66,582 per ha implies that Telangana and Odisha generally exhibit higher gross incomes compared to Chhattisgarh. The Cost Efficiency (TC/GI) varies between 0.54 (Korba, Chhattisgarh) and 0.84 (Gajapati, Odisha) and the lower TC/GI ratios indicate higher cost efficiency. Korba is the most cost-efficient (0.54), followed by Mahasamund (0.67). Furthermore, in order to look the area response towards rice cultivation by adopting the GMM model which reveals that fertilizer cost and seed value found to be positive significant factors whereas irrigation cost is negatively related in some states.

The rice productivity could be increased through by enhancing efficiency of fertilizer usage and timely adequate availability of improved seed varieties. However, the irrigation cost found to be negatively associated with area response of rice farming due to inefficiencies and unreliability of canal irrigation, more emphasis has been given to groundwater water irrigation development and due to overexploitation which led sustainability issue. The concerted efforts are required to reduce the groundwater overexploitation particularly in rice growing belt considering the long term sustainability of water resources. The study confirms the higher elasticity of rice production in the long run, driven by investments in inputs and infrastructure. Policy recommendations include improving irrigation efficiency, promoting high-yielding seed varieties, and strengthening market linkages to enhance productivity and farmer incomes. This research contributes to sustainable agricultural policy design, aligning with India’s goal to double farmer incomes and achieve the Sustainable Development Goals by 2030.

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