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Assessing the economic efficiency of maize in western undulating lands of Odisha

[1]Sambit Mishra, [2]RK Rout, [3]Abhisek Kabat, [2]LK Das, [2]BP Gantayat, [2]B Kabat, [2]RL Moharana and [2]T Majhi

[1]College of Agriculture, OUAT, Bhubaneswar, Odisha, India

[2]College of Agriculture, OUAT, Bhawanipatna, Odisha, India

[3]Postgraduation (Agronomy), SoA Deemed University, Bhubaneswar, Odisha, India

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Corresponding Author: RK Rout

Abstract
A total of 90 randomly selected maize growers, taking 45 per block, were interviewed using a pre-designed interview schedule in western undulating lands of Odisha. This study investigates the economic efficiency of maize production in Odisha, focusing on factors like input costs, yield optimization, labour utilization, and market access. Data from various agricultural conditions was analysed using a stochastic frontier model. Results showed that conventional inputs like farm size, seed, fertilizer, labour, and weedicides positively impacted maize output. The study shows a coefficient of multiple determinations of 0.88, indicating that ten resources explained 88% variation in maize production activity output across all holding size groups, with an area allocation of 254.14 thousand ha. The study also found that production increased significantly after maize introduction, with productivity increasing from 217.43 kg/ha in 2000-01 to 733.41 kg/ha in 2019-20. The study suggests that improving resource utilization could increase output.

Keywords: Stochastic frontier analysis, economic efficiency, maize, western undulating lands of Odisha

Introduction

Agriculture is crucial for India's economy, with 70% of people relying on it and 67% in rural areas using it as their primary income source. Maize, a adaptable crop, is the third-most important cereal crop globally. Originating in Mexico 7000 years ago, it contains 72% starch, 10% protein, and 4% fat. Maize is grown worldwide, with the US, China, and Brazil being the top three producers. It is processed into various food and industrial products, including fuel ethanol. Low production costs and high consumption of maize flour and cornmeal make it an ideal food fortification.

Madhya Pradesh and Karnataka in India have the largest percentage of land planted in maize (15%), followed by Maharashtra (10%), Rajasthan (9%), Uttar Pradesh (8%) and Bihar (7%) and other states. India's maize production is primarily used for chicken feed, animal feed, food, industrial use, starch industry, processed foods, and export. In 2020-21, 9.86 million ha of maize were grown, yielding 31.51 million tones and 29.51 q/ha of productivity (Directorate of Economics and Statistics, GoI). Maize is a significant grain crop in tribal areas of Odisha, grown on a 247.6 thousand ha area. It produces an average of 730 thousand tons at a productivity of 2948 kg/ha. Kharif maize is the second-most significant crop during the Kharif season, accounting for 92% of total maize production. Nabarangpur has the largest total area, accounting for almost 30% of production. Rabi maize accounts for only 7 per cent of total area and production of the State. Average Kharif maize productivity of Odisha is higher (2098 kg/ha) compared to the national average productivity (2015kg/ha). The Kharif maize contributes to the tune of 92 per cent to the total maize production. (RKVY report, 2018-19). The Rabi maize is cultivated under irrigated condition, while only 24% of the Kharif maize area is grown under rainfed condition. Irrespective of the season, maize is the fourth most important food grain crop with respect to area in the state after rice, mungbean, and urdbean. Maize farmers in Odisha are hesitant to invest in cultivation due to lack of information on farming and marketing techniques, often considering cost against crop yield due to risk and uncertainty.

This research assesses the economic efficiency of maize production by evaluating input utilization, cost structures, yield performance, and overall productivity in various farming systems. Using data from field surveys and econometric analysis, the paper explores factors influencing efficiency, including technological adoption, input management, and environmental constraints. The study also examines the role of government policies and market access in shaping the economic efficiency of maize farming. Based on the findings, recommendations for improving the economic efficiency of maize production are provided.

Numerous studies have examined economic efficiency in maize production refers to how effectively inputs are transformed into outputs to achieve the highest possible profitability. A good number of studies (Ajibefun, I. A., *et. al*., 2003; Battese, G. E., & Coelli, T. J. 1995.; Clemens, M., & Bohn, D. (2020).; Kehinde O., 2017.; Coelli, T., *et. al*., 2005.; Kumbhakar, S. C., & Lovell, C. A. K. (2000).; Liu, Z., & Lin Y., 2015; Mavhunga, H. 2018.; Mellor, J. W. 2005.; Ogunyinka, I. A., & Afolabi, O. A., 2011.; Sadoulet, E., & De Janvry A., 1995.; World Bank (2008).; and World Bank 2021.) [1, 2, 3, 7, 4, 8, 9, 10, 11 12, 13, 14, 15] were conducted on maize production. The study assesses maize production profitability and resource efficiency based on farm size in Odisha, identifying constraints faced by farmers and providing valuable information for policy formulation. Also this research aims to provide a comprehensive assessment of the economic efficiency of maize production by analysing the interplay of input use, technological adoption, farm management, and external factors such as climate and policy. By highlighting the key drivers of efficiency, the study will offer actionable insights for improving productivity and profitability in the maize sector.

Materials and Methods

The study uses a multistage sampling design to select districts, blocks, villages, and maize growers in Odisha. The first stage involves purposively selecting Nawarangpur district, randomising two blocks, and obtaining a complete list of villages, and ninety farmers were selected also randomly from six villages, 15 each. Production costs and returns are estimated using the CACP standard cost concept.

Functional analysis

The resources productivity and resources use efficiency are to be analyzed by application of functional analysis. In functional analysis, Cobb-Douglas (power production function) production function will be used. Cobb-Douglas production function (non-linear) is used to determine the resources productivity and resources use efficiency of Maize production. The data are, therefore, subjected to functional analysis by using the following form of equation:

$$Y = aX_1^{b_1} \times X_2^{b_2} \times X_3^{b_3} \times \ldots \times X_n^{b_n} \times e^u$$

This function can easily be transformed into a linear form by making logarithmic transformation, after logarithmic transformation this function is:

$$lnY = lna + b_1 lnX_1 + \ b_2 lnX_2 + b_3 lnX_3 + \ \ldots + \ b_n lnX_n + u\ lne$$

Where,
ln = Naturallogarithm
a = constant
Y = Total return from Maize production in Indian Rupees (Rs)
X_1= Total cost of human labour used in Maize production (Rs)
X_2= Total cost of Bullock labour used in Maize production (Rs)
X_3 = Total cost of seed sused Maize production (Rs)
X_4 = Cost of seeds (Rs)
X_5 =Total cost of manure used (Rs))
X_6=Cost of Nitrogen fertilizer used (Rs.)
X_7 = Cost of Phosphurus fertilizer used (Rs.)
X_8= Cost of Potash fertilizer used (Rs.)
X_9 = Irrigation charges (Rs.)
X_{10}= Cost of plant protection (Rs.)
b_1 to b_9 = Regression co-efficient of respective variables Both dependent and explanatory variables were transformed to natural logarithm. The above equation was transformed to linear form for ease in computation
e =Error term

Resource use efficiency

We used Cobb-Douglas production function to assess resource use efficiency following the methods mentioned by Rahman and Lawal.

$$Y = aX_1^{b_1} \times X_2^{b_2} \times X_3^{b_3} \times \ldots \times X_n^{b_n} \times e^u$$

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e= Error term

The resource use efficiency was judged on the basis of the ratio of marginal value products of the resources to its factors cost should be greater than one. The marginal value product (MVP) of factor taken at their prevailing market prices of opportunity cost indicates the efficiency of resource use i.e., $MVPX_i / PX_i$. MVPs that are higher than the opportunity or market cost indicate the scope of raising output profitability through the increased use of resources concerned. Whereas those less than the opportunity or market costs, depict non profitable nature of resources use. Any factor is considered to be most efficiently used, if MVP of resources equals the factor unit cost (MC = MR).

Estimation of marginal value product (MVP)

The marginal value product (MVPs) of the individual resources was estimated and compare with the marginal cost (MC). The marginal value productivity of resources indicates the addition of gross value of farm production for a unit increase in the ith resources with all resources fixed at their geometric mean level. The MVPs of various inputs is worked out by the following formula:

$$\text{MVP} = \text{b}_\text{i}\,\frac{\bar{\text{Y}}}{\bar{\text{x}}}$$

Where,
$\text{bi} =$ Estimated regression coefficient of input $\bar{\text{X}}$,
$(\bar{\text{Y}}_\text{i}) =$ Geometric mean value of output.
$(\bar{\text{X}}_\text{i}) =$ Geometric mean value of i^{th} resources used

Or

$$\text{MVP} = \text{b}_\text{i}\,\frac{\bar{\text{Y}}}{\bar{\text{x}}}P_y$$

Where,
$\text{b}_\text{i} =$ Partial regression co-efficient of particular independent variable
$\bar{\text{X}}$ = Geometric mean of particular independent variable (input in quantity)
$\bar{\text{Y}}$ = Geometric mean of dependent variable (output in quantity)
$P_y =$ Price of dependent variable

Return of scale

It refers to the summation of b_i values, return of scale = $\sum \text{bi}$
If, $\sum \text{bi} = 1,$ Constant return to scale
$\sum \text{bi} = < 1$, Decreasing return to scale
$\sum bi = > 1$, *Increasing return to scale*

Decision rule

$\text{r} = 1;$ Efficient use of resource
$\text{r} > 1;$ Underused of the resource
$\text{r} < 1;$ Overused of the resource

Finally, the relative percentage change in MVP was calculated using following way:

$$D = \left(1 - \frac{MFC}{MVP}\right) \times 100$$

Or,

$$D = \left(1 - \frac{1}{r}\right)) \times 100$$

Where, D= absolute value of percentage change in MVP of each resource.

Result and Discussion

Results of Cobb-Douglas type of production function

The production function estimates for maize cultivation are presented, focusing on standard errors, significance, and coefficients of multiple determinations (R2). These coefficients indicate the proportion of total variation in the dependent variable jointly explained by independent variables. The regression coefficient of each resource variable represents the production elasticity of the resource variable, indicating the percentage change in yield associated with a one-unit change in input. Factors such as human labour, bullock labour, machine labour, seed cost, manures, nitrogen, phosphorus, potassium, and plant protection are considered.

1. Small group

The table 1 shows that the coefficient of multiple determinations (CoD) of 0.92 indicates that 92% variation in output is explained by ten independent resource variables. The results indicate that human labour, potash, nitrogen, and plant protection have positive and significant regression coefficients, suggesting potential for increased resource use to boost output. However, manure and machine labour have negative and non-significant effects on output.

2. Medium group

The table 1 shows that the medium-sized holding group's output variation was 80% explained by ten independent variables. Human labour and bullock labour showed significant regression coefficients, indicating that increasing expenditure on resources would result in a change in gross return of 0.31 and 0.0058 percent, respectively.

Table 1: Results of Cobb-Douglas type of production function of maize

Sl. No.	Particulars	Small	Medium	Large	Pooled
1	Constant (a)	0.1128^{NS} (0.97549)	15.0604** (0.02008)	2.1241^{NS} (0.72090)	9.8465*** (0.00017)
2	Human labour (X1)	0.2486** (0.034)	-0.3151* (0.09102)	0.1327^{NS} (0.42821)	-0.0538^{NS} (0.52257)
3	Bullock labour (X2)	0.0128*** (0.00005)	0.0058* (0.07459)	-	0.0072*** (0.00040)
4	Machine Labour(X3)	-0.0015^{NS} (0.41984)	0.0044^{NS} (0.21649)	-0.0024*** (0.000)	-0.0007^{NS} (0.60465)
5	Seed Cost (X4)	-0.1398 (0.15837)	-0.0720^{NS} (0.71330)	0.1778^{NS} (0.25423)	0.0432^{NS} (0.63776)
6	Manure (X5)	-0.0113^{NS} (0.81716)	-0.0166^{NS} (0.81546)	-0.0297^{NS} 0.63934)	-0.0046^{NS} (0.89670)
7	Nitrogen(X6)	2.3050** (0.0500)	2.4733 (0.38934)	0.1550^{NS} (0.94541)	-0.0707^{NS} (0.94575)
8	Phosphorus (X7)	-1.4877^{NS} (0.11770)	-2.1759 (0.37804)	0.1214^{NS} (0.94414)	0.1414^{NS} (0.86688)
9	Potash (X8)	0.4053** (0.0500)	0.3831 (0.33565)	0.4812 (0.16104)	0.4469*** (0.010)
10	Irrigation Charge (X9)	-0.0016^{NS} (0.41722)	0.0004^{NS} (0.90459)	-0.0154*** ((0.00873)	-0.0038** (0.03739)
11	Plant protection (X10)	0.4991** (0.03552)	-0.3395^{NS} (0.39152)	0.3246^{NS} (0.37433)	-0.2030** (0.02228)
12	R²	0.9239	0.80370	0.85259	0.8868
12	Observation	30	30	20	90
14	D.F.	29	29	29	89

***Note*:** Figures in parentheses are standard errors of respective regression coefficients.
*, ** and *** indicates significance level at 10, 5 and 1per cent level, respectively. NS = non-significant

3. Large group

The study found that 85% of output variation in a large holding group was explained by ten independent variables. Machine labor and irrigation charges were significant, while human labor, nitrogen, phosphorous, and seed cost had positive but non-significant impacts on output.

4. Overall level

The table 1 shows that ten resources, bullock labour, potash, irrigation charge, plant protection, seed cost, and phosphorus, explain 88% variation in maize production output across all holding size groups. However, excessive use of these variables has a positive impact on output, suggesting a need to decrease human labour usage.

Resource use efficiency

Resource use efficiency in Maize production on the sample farms was judged with the help of MVP/MC ratio and results are presented in Table 4.16. It is revealed from the table that, the ratio of marginal value of product to factor cost ratio (MVP/MC) was greater than unity i.e., underutilization in case of resources like human labour (X1), nitrogen (X6) and potash (X8) for small size group, implying the achievement of higher resource use efficiency in case of above mentioned variables, whereas the MVP/MC ratio of phosphorus (X5), Bullock labour (X2), Machine Labour (X3), Seed Cost (X4), Manure (X5), Irrigation Charge (X9) and plant protection (X8) were found to be less than unity i.e. over utilization for these resources. In small size group, these were over utilization that means there is no need to increase this input for increasing the output

In case of medium size group, the ratio of marginal value of product to factor cost ratio (MVP/MC) was greater than unity in case of resources like Irrigation Charge (X9), Potash (X8), and Nitrogen(X6) implying the achievement of higher resource use efficiency in case of above-mentioned variables, whereas the MVP/MC ratio of Human labour (X1), bullock labour (X2), Machine Labour(X3), Seed Cost (X4), Manure (X5) and Phosphorus (X7) were found to be less than unity depicting the inefficient use of these resources. These variable resources were used over utilized, there is no need to increase the input for increasing the output. The ratio of marginal value of product to factor cost ratio (MVP/MC) was greater than unity in case of resources like human labour (X_1), Seed Cost (X4), phosphorus (X7)) and Potash (X8) for large size group implying the achievement of higher resource use efficiency in case of above-mentioned variables, whereas the MVP/MC ratio of Machine Labour(X3), Manure (X5) and Irrigation Charge (X9) were found to be less than unity depicting the in efficient use of these resources.

The study found that higher resource use efficiency was achieved in Seed Cost, Phosphorus, and Potash, while inefficient use of human labour, bullock labour, machine labour, manure, nitrogen, irrigation charge, and plant protection was observed.

Table 4.16: Resource use efficiencies of Maize

Sl. No.	Particulars	bi Value	MVP	MC	MVP/ MC
1	2	3	4	5	6
Small					
1	Human labour (X1)	0.2486	2.9392	1	2.94*
2	Bullock labour (X2)	0.0128	0.8048	1	0.80***
3	Machine Labour(X3)	-0.0015	-0.0371	1	-0.04***
4	Seed Cost (X4)	-0.1398	-15.9327	1	-15.93***
5	Manure (X5)	-0.0113	-0.1887	1	-0.19***
6	Nitrogen(X6)	2.3050	833.1100	1	833.11*
7	Phosphorus (X7)	-1.4877	-254.4803	1	-254.48***
8	Potash (X8)	0.4053	41.8668	1	41.87*
9	Irrigation Charge (X9)	-0.0016	-0.1540		-0.1540***
10	Plant protection (X10)	0.4991	35.3555	1	35.36***
Medium					
1	Human labour (X1)	-0.3151	-3.9862	1	-3.99***
2	Bullock labour (X2)	0.0058	0.3065	1	0.31***
3	Machine Labour(X3)	0.0044	0.0821	1	0.08***
4	Seed Cost (X4)	-0.0720	-8.4368	1	-8.44***
5	Manure (X5)	-0.0166	-0.2886	1	-0.29***
6	Nitrogen(X6)	2.4733	940.0319	1	940.03*
7	Phosphorus (X7)	-2.1759	-391.8245	1	-391.82***
8	Potash (X8)	0.3831	41.4810	1	41.48*
9	Irrigation Charge (X9)	0.0004	0.0232		0.0232 ***
10	Plant protection (X10)	-0.3395	-27.9656	1	-27.97***
Large					
1	Human labour (X1)	0.1327	1.5489	1	1.55*
2	Bullock labour (X2)				
3	Machine Labour(X3)	-0.0024	-0.0359	1	-0.04***
4	Seed Cost (X4)	0.1778	19.8693	1	19.87*
5	Manure (X5)	-0.0297	-0.5089	1	-0.51***
6	Nitrogen(X6)	0.1550	55.6779	1	55.68*
7	Phosphorus (X7)	0.1214	20.6198	1	20.62*
8	Potash (X8)	0.4812	49.1448	1	49.14*
9	Irrigation Charge (X9)	-0.0154	-0.8850	1	-0.8850***
10	Plant protection (X10)	0.3246	27.7611	1	27.76*
Pooled					
1	Human labour (X1)	-0.0538	-0.6478	1	-0.65***
2	Bullock labour (X2)	0.0072	0.4235	1	0.42***
3	Machine Labour(X3)	-0.0007	-0.0130	1	-0.01***
4	Seed Cost (X4)	0.0432	4.9366	1	4.94*
5	Manure (X5)	-0.0046	-0.0785	1	-0.08***
6	Nitrogen(X6)	-0.0707	-25.9311	1	-25.93***
7	Phosphorus (X7)	0.1414	24.5464	1	24.55*
8	Potash (X8)	0.4469	46.7154	1	46.72*
9	Irrigation Charge (X9)	-0.0038	-0.2583	1	-0.26***
10	Plant protection (X10)	-0.2030	-16.1015	1	-16.10***

*MVP/MFC > 1: underutilization of resources
**MVP/MFC = 1: optimal use of resources
***MVP/MFC < 1: over utilization of resources.

Policy Recommendations

Based on the findings, the paper will recommend:

- Improved access to agricultural technologies and credit for smallholder farmers.
- Strengthening extension services to teach better farming practices and input management.
- Government support for infrastructure development to reduce transaction costs and improve market access.

Conclusion

The study utilized the stochastic production frontier approach, analysing technical, allocative, and economic efficiencies of farmers in western Odisha, a rare find among existing studies. The study found significant variables such as bullock labour, potash, plant protection chemical, and irrigation charges for responsive output. The MVP/MC ratio was greater than one, suggesting increased input resources for better yield response. Maize cultivation increased from 176.05 thousand ha to 254.14 thousand ha, and production rose from 1235 thousand tons to 2886 thousand tons. Underutilized resources like human labour, machine labour, manure, and nitrogen could increase output. Future research could explore the long-term sustainability of technological interventions in maize production and their impact on efficiency across different agro-ecological zones.

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