Structural pattern and growth analysis of rice production in Odisha

Abstract

Even though rice has high importance for food security and agricultural GDP in the agrarian economy of Odisha, production is constrained by several factors. The trends, patterns, and instability of key production parameters such as area, yield need to be studied to suggest insightful measures for the development of rice cultivation in the state. The resource use efficiency also assumes significance to determine the profitability of rice production. The study used both secondary and primary data and analyzed trend, instability, and resource use efficiency using compound annual growth method (CAGR), Cuddy-Della Valle Instability Index, and Cobb-Douglas production function respectively. While the area under rice in Odisha marked a negative annual growth (-0.18), the yield and productions have shown significant positive growth of 1.95 and 1.76% respectively for the period of 1960-2019. In respect of instability in production and productivity, moderate variability was observed. However, for the area, the instability is very less. The production function analysis has shown excessive usage of significant resources like labor, fertilizers, and pesticides. The ratio of marginal value product and marginal factor cost for these inputs were much less than one, thus suggesting resource use optimization for profit maximization. The considerable variability in rice production, area and productivity in Odisha should be responded with strategic and sustainable measures.

Key words: agricultural GDP, CAGR, Cuddy-Della Valle Instability Index and Cobb-Douglas production function

1. Introduction

Rice is one of the most important cereal crops in the world. India has the largest area under rice placed next to China in respect of production (Pathak et al., 2018). Rice feeds more than half the world's population and therefore the demand for rice increases with the rising trend of a population. Odisha is an agrarian state leading in rice production in the country and it used to supply a sizable amount of rice grain to the central pool of food stocks. Rice covers about 69% of the cultivated area and is the major crop, covering about 63% of the total area under food grains (Agriculture Statistics, Odisha, 2018). Rice in Odisha is now grown on an area of 4.4 million hectares, which accounts for 91% of the area under cereals and contributes about 94% of total cereal production in the state (Das et al, 2014). It is the staple food of almost the entire population of Odisha; therefore, the state economy is directly linked with improvements in the production and productivity of rice in the state. Odisha has a contribution rate of 5.5% from the total rice production of India. In Odisha, rice is grown under diverse ecosystems and a wide range of climatic conditions. The system of cultivation is determined by the land situation, soil type, class of rice, season, intensity and distribution of rainfall, irrigation resources, and availability of labor. Odisha has three systems of rice cultivation: dry, semi-dry, and wet (Dar et al., 2020). The dry system accounts for 18% of the rice area and the rest is shared by semi-dry and wet systems. It is important to increase the production and productivity of rice by adopting improved technology as well as efficient use of available resources (Venkateshwaralu B. 1994). For this attempts must be taken up to improve technical efficiency in production (Gulati et al., 2021).

However, rice production in the state is plagued with low productivity of 1.5-ton ha (MOSPI, 2015-16) against the national average yield of 2.4 tons per ha. Besides, rice in Odisha is constrained by several yield-limiting abiotic and biotic stresses. The efficiency of resources used in rice cultivation needs a relook for boosting rice production and productivity (Deka N. 2000). Any actionable remedial measures to improve upon rice production, therefore, need critical analysis of the trend in area production and yield of rice in the state. Such scientific assessment will help rationalize structural improvement in rice cultivation. Against this backdrop, the present study aims at achieving the objectives of (a) assessing the trend and instability in the area, production, and yield of rice in Odisha vis-à-vis India and (b) measuring resource use efficiency in rice cultivation in Odisha.

2. Materials and methods

Data and its sources

This study undertaken in 2021 was for the whole state of Odisha and used secondary data obtained from different reliable sources like state agriculture statistics databook (2020), governmental website, and state economic survey (2021). The primary data required for fitting the production function were collected from 400 samples, randomly drawn from four districts (100 from each district). One district from each of those four physiographic zones was randomly chosen. Subsequently, 2 blocks from each of these four districts were randomly selected and finally, 50 farmers from each of these blocks were included to collect the required data. The questionnaire was pre tested, and trained enumerators collected the data in paper based questionnaire.

2.1 Trend analysis

Compounded annual growth rate (CAGR) of key parameters—area and production and productivity was estimated for four distinct decades starting with 1960-70, 1970-80, 1990-00 and 1960-2019.The formula for CAGR estimation is an exponential growth function and given as

$$y_t = ab_t U_t$$

Where,
y_t = Variable under consideration at time period t

t = Time element which takes the value 1, 2, 3……n
a and b are parameters to be estimated where b = (1+g), where g is the rate at which y grows every year with respect to its value in the preceding year
U_t = Disturbance term

After logarithmic transformation of equation (i) the linear form is

$$\log y_t = \log a + t \log b + \log U_t$$

This could be expressed as,

$$y_t = a + tb + U_t$$

Where,
y_t= log y_t; a= log a; b = log b and U_t = log U_t
The estimate of compound growth rate can be written as,

$$g = (\text{antilog } b - 1)\, 100$$

Significance of coefficients were tested by t-statistic and significance of the model was tested in terms of R_2 value

2.2 Instability measurement

For the measurement of instability these indicators, Cuddy-Della Valle Instability Index was constructed and interpreted. This index is an enhancement over widely use coefficient of variation method to measure instability in a time series data. The Cuddy-Della Valle instability index (1978) de-trends and shows the exact direction of instability.

CDVI = CV*(1-Adjusted R^2)0.5

Adjusted R^2 is determined from the time series regression. It is the coefficient of multiple determinations adjusted for degrees of freedom.

Categorization of index values

For a structured interpretation of the index outcome, following four categories that is normally followed in agricultural research was followed to rank the instability index values.

0-15 = Low Instability
>15-30 = Medium Instability
>30 = High Instability

2.3 Resource use efficiency

Production function fitting

Cobb-Douglas production functions were selected based on number of theoretically significant variables it is circumscribing, the coefficient of multiple determination R^2 and Mallow's Cp criteria. The models with maximum theoretically relevant variable, high R^2 and low Cp were selected for each crop. The general form of Cobb-Douglas equation is given by,

$$Y = \beta_0 \times \prod_{i=1}^{n} X_i^{\beta} \times e^{u}$$

Where,
Y = output/quintal
Xi = vector of inputs
βi = Estimated coefficient of i_{th} input
β0 = Intercept
u = Error term
The allocative efficiency of significant inputs was measured through MVP approach. Firstly, a Cobb-Douglas production function was fitted and coefficient of the regressors (representing elasticity of the production) were estimated. Then the resource use efficiency or the allocative efficiency was calculated using

AE=MVP$_{X\,i}$ / MFC$_{xi}$

$$MVP_{xi} = \beta_i \left(\frac{\overline{Y}}{\overline{X}_i} \right)$$

Where,
$\overline{X}$= Geometric mean of i_{th} Input
$\overline{Y}$= Geometric mean of output
$_i$ = Estimated coefficient of i_{th} input
MVP = Marginal Value Product
MFC = Marginal Factor cost (Price per unit of input)

3. Results and Discussion

3.1 Trends in area, yield and production of rice in Odisha vis-à-vis India

At the national level, the compound annual growth rate (CAGR) of rice area during the period 1960-70, 1970-80, 1990-00 and 1960-2019 were highly significant at 1 percent level (Table 1) of probability whereas in Odisha the estimated area growth rate was the negative and significant indicating reduction in area under rice over the years. The yield trend of the rice however has shown a positive and significant growth rate (1.95%) between 1960 and 2019 for Odisha and it was being 1.9% and statistically significant at all India suggesting a similar growth trend in terms of yield both at state and national level. The highest growth (4.99) in the state yield however was recorded in the decade of 2000-10 when it was just 1.64% at the national level. Even though average national rice productivity has always been higher than that of Odisha, the state growth rate has been estimated to be higher than India, barring a few occasions such as the decades of 1970-80 and 1990-00 when a negative growth in Odisha was noticed. Both the cases can be attributed to the recurring droughts in Odisha. Interestingly unlike in Odisha, there was no negative growth rate in yield observed in India.

Production-wise, the annual growth rate was more in India (2.3%) than in Odisha (1.76). The negative growth rate was further corroborated by the negative yield rate in the same decades (1970-80 and 1990-00). The high and significant production and yield growth rate in Odisha during 2000-10 despite a reduction in area, suggests a high production favorably induced by a good monsoon. Noticeably, between 1960 and 2019, India registered an area growth rate of 40% but a shrink in the rice area is reported in Odisha (1.8% CAGR). The almost equal CAGR of yield in both India and Odisha and the state's lesser growth rate in production in comparison to India can be partially explained by rice area contraction in

Odisha.
Since crop diversification is a strategic priority of both state and central government because of socio-economic and climatic challenges, it is anticipated that the rice area will not rise substantially in the coming years. It is therefore imperative that policy actions should direct towards boosting productivity to log a positive production growth rate to feed the increasing population. This priority becomes more relevant as yield wise India compares very poorly with other major rice-producing. State production expansion driven by yield enhancement and subsequent market and export supports will be policy imperative in the coming years.

The continual positive growth in rice production since 2000 in both Odisha and India tends to create market glut and price stagnation but at the same time offers opportunities in terms of export expansion. An increased production binds government to procure more paddy at minimum support price (MSP) however, appropriate policy supports can enhance rice (non-Basmati) export for the benefit of the state and its farmers.

Table 1: Trends in area, yield and production of paddy in India and Odisha

Decade	**India**			**Decade**	**Odisha**		
	Area	**Yield**	**Production**		**Area**	**Yield**	**Production**
1960-70	0.76 ***	1.14 NS	1.91 NS	1960-70	-	-	-
1970-80	0.91 ***	1.64 NS	2.56 *	1970-80	-0.86 **	-0.26 NS	**-1.13 NS**
1980-90	0.6 NS	3.59 ***	4.21 ***	1980-90	0.4 NS	3.56 NS	**3.98 NS**
1990-00	0.78 ***	1.08 **	1.87 ***	1990-00	0.16 NS	-1.45 NS	**-1.29 NS**
2000-10	0.11 NS	1.64 **	1.75 *	2000-10	-0.03 NS	4.99 *	**4.96 ***
2010-19	0.06 NS	1.5 ***	1.56 ***	2010-19	-0.88 **	2.9 NS	**1.99 NS**
1960-2019	**0.4*****	**1.9*** **	**2.3*** **	**1970-2010**	**-0.18 *** **	**1.95 *** **	**1.76 *** **

Note: "***", "**" and "*" represents significance level at 1%, 5% and 10% level of Probability

3.2 Area, Yield and Production instability

The findings of the Cuddy-Della-Valle instability index for different parameters have been presented in Table 2. For measurement of instability coefficient of variation (CV) sometimes overestimates the value but Cuddy-Della- Valle method of calculation of instability indicated the exact direction of instability. The three categories of instability of different levels are used to order the variability of study parameters. The index value with (0-15) indicates a low instability while the medium instability value ranges from 15 to 30 and more than 30 index measurement tells a high degree of instability. The findings of the study pointed out that in the case of the area it is in the range of low instability both at the state and national level. It signifies that even there is a positive area growth as reported above, not much inter-decade variation was found and it is in sync with the general pattern elsewhere as it is difficult to substantially increase the area under rice because an assured irrigation facility is a precondition. Even though, a stable yield is found at the national level, the same in Odisha was relatively unstable since the index ranges from 11.56 to 18.42 (Table 2). A medium degree of instability was observed for production in Odisha and it is an obvious outcome resulting from a similar level of yield instability.

Noticeably, when comparing India and Odisha together, yield and production in India did not show much variation against Odisha. The high decadal variation in area and production in Odisha as noted above corroborate with the reported instability in yield. This essentially suggests diving deeper and finding out the drivers of growth instability (yield and production) in Odisha to take suitable course correction measures. The state-level instability in yield and production assumes high significance as it is directly linked with the product price realization by farmers. The frequent occurrence of abiotic stresses like drought, flood in Odisha is often cited as major drivers for variability in yield and production. Thus any measures implemented for a stable production augmentation should reckon these determinants. The recent research innovation offers several rice varieties that are considered resilient to two major climatic events (drought and flood) in Odisha. Dissemination and increased uptake of such climate-resilient varieties may help farmers mitigate the severity of submergence, water deficit and harvest a reasonable yield. Adoption of modern varieties that exhibit more resistance to yield-limiting major diseases and pests can also be impactful to achieve high production and productivity with a lesser instability.

Table 2: Cuddy-Della-Valle instability index for paddy production in India and Odisha

Decades	**India**			**Decades**	**Odisha**		
	Area	**Yield**	**Production**		**Area**	**Yield**	**Production**
1960-70	1.51	8.52	9.71	1960-70			
1970-80	1.76	8.24	9.77	1970-80	3.09	13.53	**14.98**
1980-90	2.87	4.82	7.33	1980-90	2.94	16.06	**18.32**
1990-00	1.05	2.71	3.2	1990-00	1.3	11.56	**12.2**
2000-10	3.19	4.81	7.15	2000-10	1.6	16.87	**17.79**
2010-19	**1.11**	**2.37**	**2.38**	**2010-20**	**2.52**	**18.42**	**19.69**

4. Allocative Resource Use Efficiency

4.1 Production function and statistical significance of inputs

The functional relationship between output and inputs was established through a fitting Cobb-Douglas type production function. The estimates of Cobb-Douglas type production function were presented in table 3. The production elasticity for the area was 0.038 which was highly significant at a 5 percent level of probability. It means a one percent increase in a land area the output will increase by 0.038 percent. The production elasticity associated with hired labor, fertilizer, insecticides, and pesticides were 0.023, 0.303, and 0.006 respectively.

These were not only positive but also highly significant at a 1 percent level of probability. The negative value of production elasticity with highly significant indicated that there was excess use of these resources for production. The coefficient of multiple determination R^2 value 0.72 indicated that the paddy production was explained by the independent variable 72 percent, thus fitted production function is a fit model with high explanatory strength.

Table 3. Estimates of Cobb-Douglas type production function for paddy production in Odisha

Particulars	Estimate	Standard Error
Intercept	2.246***	**0.137**
Crop area in ha (x1)	0.038**	**0.013**
Family labour in man-hours (x2)	0.003	**0.012**
Hired labour (x3)	0.023***	**0.003**
Hired animal labour in hours (x4)	-0.006***	**0.001**
Owned Animal labour in hours (x5)	-0.003*	**0.001**
Seed in Kg. (x6)	0.001	**0.016**
Fertilizer in Kg. (x7)	0.303***	**0.016**
Manure in Qtl. (x8)	-0.001	**0.002**
Insecticides in rupees (x9)	0.006***	**0.001**
Machine in hours (x10)	0.034**	**0.011**
R^2	0.72	
Adjusted R^2	0.71	
Number of Observations	449	
F- Statistics	**68.17*** **	

Note: "***", "**" and "*" represents significance level at 1%, 5% and 10% level of probability

4.2 Resource use efficiency

A farm is said to be operating in an efficient resource use regime when the ratio of marginal value product to marginal factor cost is one or more. If the ratio is less than one, then the resource is excessively used or over-utilized hence decreasing the quantity use of that resource increases profits. If the ratio is greater than one, then the resource is underused or is being underutilized hence increasing its rate of use will increase profit level. These decision rules are followed to ensure resources are used optimally and it makes the production function efficient for profit maximization.

The input use efficiency for various inputs was presented in Table 4. It was observed that the value of resource use efficiency or allocative efficiency in all the inputs was less than one indicating excessive use or overutilization of resources. In some cases, high usage of inputs such as labor, manure, is less than one thus suggesting a negative relation with output and increasing losses associated with the injudicious application of these inputs. Among all inputs, fertilizer proved to be most efficient even though the MVP and MFC ratio is less than one that strongly recommends cutting down the quantity.

Less remunerative rice production in Odisha is an agricultural concern for decades. Several measures including farm mechanization, irrigation facilities, price support, seed availability, etc have been emphasized in recent times to make rice production reasonably profitable for farmers. However, the study revealed, the profitability of rice cultivation can be enhanced through judicious resource application. The current excess usage of inputs can be rationalized to make the production cost-efficient, thus more profitable.

Table 4. Input use efficiency for various inputs used in paddy production in Odisha

Resource	Ratio of MVP and MFC
Family Labour	**0.0002**
Casual Labour	**0.0000**
Hired Animal Labour	**-0.0004**
Owned Animal Labour	**-0.0082**
Seed	**0.0005**
Fertilizer	**0.2625**
Manure	**-0.0028**
Insecticide	**0.0005**

Machine	**0.0010**

5. Recommendations and Conclusion

Rice will remain a key agriculture growth driver in Odisha. Nevertheless, increasing rice production needs to be considered in the context of huge water requirements and thus the resultant climate effect and need to augment non-paddy crops to meet domestic needs (e.g pulses and oilseeds). The increasing trend of production expansion and yield increase over the last six decades shows the rice research outcomes and technology adoption in Odisha. The decadal higher productivity in Odisha as against the national estimates signifies a better growth in rice apparently driven by the adoption of technologies like modern variety adoption and improved management practices. Policy measures need to be effected to maintain and amplify this growth rate. Findings of the Cuddy-Della Valle instability index pointed out that in India the instability (yield and production) is low whereas in Odisha during 2000-10 and 2010-20 there was a medium range of instability in paddy production and therefore it calls for strategic and well-targeted measures that can mitigate the instability causing potential risks.

The estimates of Cobb-Douglas production function found out that production elasticities associated with the area, hired labor, fertilizer, insecticide, and machinery were highly significant and also positive, thus any policy measures directing towards rice production improvement, need sufficient consideration of these useful resources. The resource use efficiency quotient for all resources was estimated to be less than one, thereby suggesting overuse of these resources like labor, fertilizer, pesticides to maximize the profit from rice cultivation. Farmers' knowledge enhancement, agronomic literacy, and capacity building on improved and sustainable crop management practices can attain desired efficient resource employment at the farm level.

Declaration of conflict of interest

The authors declare there is no conflict of interest while conducting the research and preparing the manuscript.

References

- Pathak H, Nayek AK, Jena M, Singh ON, Samal P, Sharma SG (2018) Rice Research for Enhancing Productivity, Profitability and Climate Resilience. ICAR-National Rice Research Institute, Cuttack, Odisha, India, pp 2-44.
- Das S.R. "Rice in Odisha" 2012. IRRI Technical Bulletin Los Baños (Philippines): International Rice Research Institute, no. 16, Pp.31, 2012. http://books.irri.org/TechnicalBulletin16_content.pdf
- Odisha Agriculture Statistics, Directorate of Agriculture and Food Production, Odisha, 2018.
- Dar M. H., Waza S. A., Shukla S., Zaidi N. W., Nayak S., Hossain, M., Singh U. S., "Drought tolerant rice for ensuring food security in Eastern India" Sustainability, vol. 12, no. 6, pp. 2214, 2020. https://doi.org/10.3390/su12062214

- Hoda A., Gulati A., Wardhan H. Rajkhowa P., “Drivers of Agricultural Growth in Odisha,” in Revitalizing Indian Agriculture and Boosting Farmer Incomes, 2021. India Studies in Business and Economics. Springer, Singapore. https://doi.org/10.1007/978-981-15-9335-2_9

- Venkateshwaralu B. 1994. “Complexities of Rice production in Eastern India”, Paper presented at a workshop on "Strategies for Increasing Rice Production at Bhubaneswar during February. Organized by MANAGE, Hyderabad, O.U.A.T., constraints to yield of rice in Mayurbhanj District. Department of Agriculture Economics, O.U.A.T., Bhubaneswar, Orissa.
- Deka N. 2000. “Determinants of instability and efficiency in rice production under rainfed agriculture in Assam”, Assam Agricultural University Jourhart, Assam.
-