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Mapping the trade direction of Indian rice export with Markov chain analysis

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ABSTRACT

Rice exports play an important role in strengthening India's position in the global rice market and contributing to agricultural trade. The magnitude and direction of rice exports provide an understanding of the growth and stability of India's export performance and the major markets for Indian rice. Therefore, the study assessed the magnitude and direction of rice exports from India, with particular emphasis on the major export markets for Basmati and non-Basmati rice. The study used secondary data on rice production and exports collected from the Agricultural and Processed Food Products Export Development Authority (APEDA) for a period of 20 years, from 2005–06 to 2024–25. Markov chain analysis was employed to examine the direction and changes in rice export markets. The direction of trade analysis using the Markov chain approach indicated relatively stable export markets for Indian Basmati rice, with retention probabilities of 0.78 for Iraq and 0.76 each for Saudi Arabia and the United Arab Emirates (UAE). In contrast, non-Basmati rice markets showed relatively greater instability, with lower retention probabilities for major importing countries. The findings suggest that increasing rice production and exportable surplus, maintaining stable export policies, and diversifying export markets can help strengthen India's rice export performance.

Keywords: Rice, Markov chain, Instability, Trade, Export

Introduction

During 2024–25, the performance of rice in India showed a significant improvement compared with the previous year. The total area under rice increased from 47.82 million hectares in 2023–24 to 51.27 million hectares in 2024–25, representing an increase of about 7.19 per cent. Rice production increased substantially from 137.82 million tonnes to 150.18 million tonnes, growth of approximately 8.97 per cent and indicating a record level of production during 2024–25. Similarly, the productivity of rice improved from 2,882 kg per hectare in 2023–24 to 2,899 kg per hectare in 2024–25, showing an increase of about 0.59 per cent.

India maintained its strong position in the international rice market during 2024–25. The total quantity of rice exported reached approximately 20.19 million metric tonnes, while the value of rice exports was about US\$ 12.47 billion. Overall, the increase in area, production and productivity during 2024–25 reflects favourable growth in the rice sector and strengthened the availability of rice for both domestic consumption and export markets, thereby highlighting the continued importance of rice in India's agricultural economy and international trade.

Objective

- To assess the magnitude and direction of rice export in India.

Methodology

The study was based on secondary data collected from official sources APEDA. Data on rice production and exports were collected for a period of 20 years, from 2005–06 to 2024–25. The study period was divided into Period I (2005–06 to 2014–15), Period II (2015–16 to 2024–25), and the Overall Period (2005–06 to 2024–25).

Magnitude and direction of rice export

The Markov chain model was used to study changes in the export share of Indian rice among different importing countries over time. It shows whether a country retains its export share or shifts to other markets. The transition probability matrix gives the probability of movement from one market to another. The diagonal values show the probability of retaining the same market share; therefore, a higher diagonal value indicates greater market stability. The analysis assumes that the export share in the current period depends on the share in the previous year, which can be denoted algebraically as:

$$E_{jt} = \sum_{i=1}^r E_{it-1} P_{ij} + e_{jt}$$

$$P^* \geq 0$$

Where,

E_{jt} = Export of rice during the period t to j^{th} country

E_{it-1} = Export of i^{th} country during the year $t-1$

P_{ij} = Probability that export will shift from i^{th} country to j^{th} country

e_{jt} = Error term, which is statistically independent of E_{it-1}

r = Number of importing countries

t = Number of years considered for the analysis

Transitional probabilities P_{ij} , which can be arranged in a $(c \times r)$ matrix, have the following properties

$$\sum_{i=1}^n P_{ij} = 1 \text{ and } 0 \leq P_{ij} \leq 1$$

Thus, the estimated probability of retention share of each country during the period t may be obtained by multiplying the export of those countries in the previous period $t-1$ with the transitional probability matrix.

The transitional probability matrix is estimated in a linear programming framework by applying the mean absolute deviation method in which the objective function is to minimize the sum of absolute errors, subject to the constraints of the equation, the row sum condition, and the non-negativity condition. It is as follows:

$$\text{Min, } OP^* = P^* + Ie$$

Subject to,

$$XP^* + V = Y$$

$$GP^* = 1$$

Where,

P^* = Vector of the probabilities P_{ij}

0 = Vector of Zones

I = Identity matrix

e = Vector of absolute errors

Y = Vector of export of each country

X = A block diagonal matrix of lagged values of Y

G = A grouping matrix to add the row elements of P arranged in p^* to unity

n = Number of time periods considered for the analysis

r = Number of importing countries

V = Vector of error

After calculating the transitional probability matrix, the expected shares of export were calculated by

$$Y_{jt} = (j = 1, 2, 3 \dots r)$$

Where,

Y_{jt} = Predicted proportions of j^{th} country's share at time ' t '.

Y_{t-1} = Observed proportion of i^{th} country share at time ' $t-1$ '.

P_{ij} = Estimated transitional probability matrix.

The transition probability matrix shows how export shares move between importing countries. Diagonal elements show the probability of retaining export share in the same market. Row elements indicate the probability of losing share to other markets, while column elements indicate the probability of gaining share from other markets.

Results and Discussion

Table 1. Growth, Variability and Instability in Rice Production and Export Performance in India:

		Area	Production	Productivity	Export Quantity (MT)	Export Value (Rs.lakh)	Value per unit quantity (Rs./tonnes)
Period I	CGR	0.07	1.74*	1.46**	12.83**	16.70**	11.26***
	CV	2.22	6.53	6.7	57.91	48.15	30.88
	Instability index	2.22	6.48	3.63	41.86	57.35	29.45
Period II	CGR	1.64	3.8*	0.36	8.46***	10.52***	5.53***
	CV	5.52	11.54	2.62	30.48	32.32	16.20
	Instability index	5.48	11.35	2.28	10.12	2.68	15.82
Overall Period	CGR	0.55	2.37*	0.05	10.06***	10.78***	7.37***
	CV	4.86	15.08	5	54.23	55.32	38.17
	Instability index	4.84	14.93	4.98	19.66	52.86	36.99

(***, **, and * denotes significant at 1%, 5 % and 10% level of significance respectively)

The Table No.1 represents the comparative growth, coefficient of variation (CV), and instability of rice area, production, productivity, export quantity, export value and value per unit quantity in India during Period I, Period II and the overall period. During Period I, rice area recorded a very low growth of 0.07 per cent, while production and productivity increased by 1.74 and 1.46 per cent, respectively. Export quantity, export value and value per unit quantity recorded relatively higher growth rates of 12.83, 16.70 and 11.26 per cent, respectively. During Period II, area and production registered higher growth of 1.64 and 3.80 per cent, while productivity increased only marginally by 0.36 per cent. Export quantity, export value and value per unit quantity increased by 8.46, 10.52 and 5.53 per cent, respectively. The CV and instability index showed that exports were more variable and unstable during Period I, particularly for export value,

which recorded an instability index of 57.35 per cent. In Period II, instability declined considerably for export quantity and export value to 10.12 and 2.68 per cent, respectively. However, production instability increased from 6.48 per cent in Period I to 11.35 per cent in Period II. Overall, during the entire study period, rice area, production and productivity recorded growth rates of 0.55, 2.37 and 0.05 per cent, respectively, whereas export quantity, export value and value per unit quantity showed substantially higher growth rates of 10.06, 10.78 and 7.37 per cent, respectively. The overall CV was highest for export value 55.32 per cent, followed by export quantity 54.23 per cent, indicating considerable variation in India's rice exports. Similarly, export value recorded the highest overall instability 52.86 per cent, followed by value per unit quantity 36.99 per cent and export quantity 19.66 per cent. Production showed comparatively moderate instability 14.93

per cent, while area and productivity were relatively stable. The results indicated that India's rice exports expanded at a considerably faster rate than domestic rice area and productivity during the study period, although export performance experienced substantial variation and instability. The significance levels indicated that production growth was significant at the 10 per cent level in Period I and Period II as well as in the overall period; productivity growth was significant at the 5 per cent level in Period I; export quantity and export value growth were significant at the 5 per cent level in Period I; and export quantity, export value and value per unit quantity were significant at the 1 per cent level in Period II and the overall period.

Markov chain analysis

Markov chain analysis was used to examine changes in the market shares of Indian Basmati rice among major importing countries during 2005–06 to 2024–25. The transition probability matrix (TPM) is presented in Table No. 2. The major markets considered were Saudi Arabia, Iraq, Iran, UAE and Yemen, with remaining countries grouped under “Others”. Diagonal values indicate the probability of retaining market share, while off-diagonal values indicate the gain or loss of market share among destinations. The results showed relatively stable export markets for Indian Basmati rice in some major destinations.

Table 2. Transitional Probability Matrix of Basmati Rice Export from India, 2005-06 to 2024-25

	SAUDI ARABIA	IRAQ	IRAN	UAE	YEMEN	Others
SAUDI ARABIA	0.76	0.00	0.00	0.16	0.02	0.06
IRAQ	0.00	0.78	0.10	0.00	0.05	0.07
IRAN	0.09	0.09	0.63	0.00	0.06	0.13
UAE	0.00	0.00	0.24	0.76	0.00	0.00
YEMEN	0.00	0.00	0.31	0.00	0.04	0.65
Others	0.10	0.01	0.03	0.00	0.06	0.80

Table 3. Transitional Probability Matrix of Non-Basmati Rice Export from India, 2005-06 to 2024-25

Table 2. showed that the Markov chain analysis, Iraq 0.78, Saudi Arabia 0.76, and the UAE 0.76 had relatively high retention probabilities, indicating greater stability in their market shares of Indian Basmati rice. Iran had moderate stability with a retention probability of 0.63, while Yemen was highly unstable with a very low retention probability of 0.04. The “Others” category recorded the highest retention probability of 0.80, indicating greater stability among the pooled markets. Overall, Iraq, Saudi Arabia, and the UAE were relatively stable major destinations, whereas Yemen experienced substantial shifts in export market share.

	Benin	Guinea	Cote.D. Ivoire	Togo	Bangladesh	Others
Benin	0.62	0.09	0.00	0.00	0.00	0.29
Guinea	0.27	0.47	0.00	0.26	0.00	0.00
Cote.D. Ivoire	0.00	0.00	0.00	0.02	0.98	0.00
Togo	0.03	0.04	0.10	0.08	0.00	0.75
Bangladesh	0.00	0.00	0.02	0.00	0.00	0.98
Others	0.04	0.03	0.06	0.02	0.02	0.77

Markov chain analysis was carried out, and the results are presented in Table No. 3., Benin was the most stable major market for Indian non-Basmati rice, with a retention probability of 0.62, followed by Guinea 0.47. The “Others” category recorded the highest retention probability of 0.77, indicating greater stability among the pooled markets. In contrast, Togo 0.08, Côte d'Ivoire 0.00, and Bangladesh 0.00 showed low or zero retention, indicating unstable market shares. Overall, the results revealed considerable variation in the stability and movement of Indian non-Basmati rice export shares across major importing destinations.

Conclusions

The Markov chain analysis indicated differences in the stability of export markets for Indian Basmati and non-Basmati rice during 2005–06 to 2024–25. In the case of Basmati rice, Iraq recorded a retention probability of 0.78, followed by Saudi Arabia and the UAE with 0.76 each, while Iran recorded moderate retention of 0.63. Yemen showed very low retention of 0.04, indicating considerable changes in its market share. The “Others” category recorded the highest retention probability of 0.80. For non-Basmati rice, the “Others” category recorded a retention probability of 0.77, followed by Benin 0.62 and Guinea 0.47. Togo recorded a low retention probability of 0.08, while Côte d'Ivoire and Bangladesh recorded zero retention probability. Overall, the results showed that Basmati rice had relatively stable major markets in Iraq, Saudi Arabia and the UAE whereas, the Markov

chain analysis indicated considerable variation in the stability of Indian non-Basmati rice export markets. Benin recorded the highest retention probability among the major identified markets at 0.62, followed by Guinea at 0.47, indicating relatively greater stability in these destinations. In contrast, Togo recorded a low retention probability of 0.08, while Côte d'Ivoire and Bangladesh recorded retention probabilities of 0.00, indicating complete movement of their export shares to other destinations. The “Others” category recorded a high retention probability of 0.77, indicating greater stability among the pooled markets. Overall, compared with Basmati rice, non-Basmati rice export markets exhibited greater variation in market-share retention, with several major destinations recording low or zero retention probabilities.

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