***Original Research Article***

# "Mapping the Trade Direction of Indian Rice with Markov Chain Analysis"

**Abstract:** Agriculture is a cornerstone of India's economy, with rice being a critical crop that ranks second globally, feeding over half of the world's population and serving as a staple in Southeast Asia. This study explores the direction of India's rice trade using Markov Chain Analysis, following an examination of the compound annual growth rate (CAGR) in rice exports to various global regions. Results reveal a 2.26 per cent CAGR in rice production, while export values surged by 16.8 per cent annually. Specifically, the CAGR for rice exports to Iraq and Iran reached 58.6per cent and 46.47per cent, respectively. In quantity, India's rice exports grew by 10.82 per cent, with Iraq and Iran at 44 per cent and 34 per cent. The Transitional Probability Matrix for 2001-2022 indicates strong regional retention, with Africa maintaining 78per cent of trade value and Asia 93.7 per cent, and similar trends in quantity, where Asia retained 92.6 per cent and Africa 89.1 per cent. These findings highlight India's potential to diversify rice exports and strengthen its global competitive edge, urging a focus on enhancing processing, transportation, and quality standards for wider market appeal.

**Keywords:** Direction of Trade, Export Performance, India, Markov Chain Analysis, Rice

## Introduction:

Agriculture is the most vital occupation in India, with over 58 per cent of the population depending on it for their livelihood. It is not only the oldest and largest sector but also the backbone of the nation's economy, forming the core around which the entire economic structure revolves. Despite its declining share in the state's GDP, agriculture remains a crucial sector, especially in rural areas. The government continually formulates and implements various schemes to boost agricultural productivity. Globally, rice holds the second position in terms of importance and is a critical food crop for India. It feeds more than half the global population and is the staple diet for most people in Southeast Asia. About 90 per cent of the world's rice production and 91 per cent of the total area under rice cultivation is concentrated in Asia. India leads the world in rice cultivation and ranks second only to China in production.

After maize, rice is the second most important cereal crop worldwide, with global production of milled rice standing at around 510 million metric tonnes. Asia remains the leading region for rice production. According to FAO data, China was the top rice producer in 2021, followed by India and Bangladesh. Major rice exporters include India, Vietnam, and Thailand, with India leading the world, exporting 18.75 million metric tonnes in 2021-2022. Vietnam followed with 6.5 million metric tonnes. On the import front, the Philippines and China are the largest rice importers. Retail prices for white rice have surged in recent years, with global consumption of milled rice reaching approximately 510.3 million metric tonnes in 2021-2022. China, the top consumer, consumed nearly 155 million metric tonnes, while India ranked second with 103.5 million metric tonnes during the same period (FAOSTAT, 2022).

The issue of self-sufficiency complicates the decision on how much rice India should export, as the balance between domestic production and consumption must be carefully considered (Madhu *et al.,* 2023). With recent instances of export bans on rice by countries, this article explores the direction of India's rice trade using Markov Chain Analysis, after assessing the compound annual growth rate of rice exports from India to various regions globally.

## Materials and Methods:

**Period of study:** The Data pertaining to the analysis of direction of trade of rice from India both in value and quantities were taken from 2001-2002 to 2022-2023.

**Nature and Sources of Data:** The time series data pertaining to the Exports of rice from India to the rest of the world region wise was collected from the Ministry of Commerce and Industry, Government of India and APEDA.

## Analytical Framework:

The compound annual growth rate (CAGR) was computed based on time series data on area, production and productivity of rice and exports of rice from India for 20 years of study period *viz.,* 2001 to 2022 using log-linear production function. Compound growth rate was estimated to study the percentage increase or decrease in the selected parameter. The following exponential growth function was used:

$$Y = ab^t u_t \quad ---------- (1)$$

In the log form, the above function (1) was formulated as:

$$Log\ Y_t = Log\ a + t\ Log\ b + Log\ u_t \quad ----------(2)$$

Where,

$Y_t$ = Dependent variable for which growth was estimated (*i.e.* area, production, productivity

a = Intercept or constant

b = Regression/Trend coefficient

t = Periods in years (1, 2, 3…20)

u = Error terms with zero mean and constant variance

The compound growth rates "r" was computed using the following formula.

$$CAGR\ (r) = [\ Antilog\ (log\ b) - 1\ ] \times 100 \quad ---------- (3)$$

Where,

r = Compound annual growth rate.

**Direction of trade:**

The trade direction was examined by using Markov chain analysis. This method analyses structural change in any variable whose progress through time can be measured as of single variable outcome. Markov chain analysis involves developing a transitional probability matrix 'P', whose elements, $P_{ij}$ indicate the probability of exports switching from country 'i' to country 'j' over time. The diagonal elements $P_{ij}$ where i=j, measure the probability of a country retaining its market share or in other words, the loyalty of an importing country to a particular country's exports. The traditional probabilities $P_{ij}$ can be arranged in a (c*n) matrix.

In the context of current applications, structural changes were treated as a random process with the selected importing countries for the selected medicinal and aromatic plants under study. The assumption that the average export of each of the rice from India amongst importing countries in any period depends only on the export in the previous period and this dependence is same among all the periods. This is algebraically expressed as

$$E_{ij} = \sum_{i=1}^{n} [\, Ei_{t-1}] \, P_{ij} + e_{jt}$$

Where,

$E_{ij}$ = exports from India to the $j^{th}$ country in the year t, $E_{it-1}$ = exports of $i^{th}$ country during year t-1

$P_{ij}$ = the probability that exports were shift from $i^{th}$ country to $j^{th}$ country

$e_{jt}$ = the error term which is statistically independent of $E_{it-1}$, n = the number of importing countries

The transitional probabilities $P_{ij}$ which can be arranged in a (c*n) matrix, have the following properties.

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

Thus, the expected export share of each country during period 't' is obtained by multiplying the exports to those countries in the previous period (t-1) with the transitional matrix.

The transitional probability matrix (T) was estimated using linear programming (LP) framework by a method referred to as Minimization of Mean Absolute Deviation (MAD).

$$\text{Min, } OP^* + I\, e$$

Subject to

$$X\, P^* + V = Y$$

$$G\, P^* = 1$$

$$P^* \geq 0$$

Where,

P* is a vector of the probabilities $P_{ij}$ , O is the vector Zones

I is an appropriately dimensional vector of areas, E is the vector of absolute errors

Y is the proportion of exports to each country, X is block diagonal matrix of lagged valued of Y, V is the vector of errors, G is a grouping matrix to add the row elements of P arranged in P* to unity

Prediction of quantity of selected Rice was made by using the Transitional Probability Matrix.

$$B_t = B_0 * T$$

$$B_{t+i} = B_{t+i-1} * T$$

Where,

$B_0$ = quantity exported in base year, $B_t$ = quantity exported in next year (prediction)

T = Transitional Probability Matrix

The values in the transition probability matrix has different interpretations. The value of diagonal elements indicates the probability of retention of the previous year's values, while values in the columns reveal probability of gain of a particular country from other competing countries, values in row reveal probability that a country might lose to other competing countries in respect of rice exports.

## Results and Discussion:

The Compound Annual Growth Rates (CAGR) of India's rice sector, covering area, production, productivity, and exports, provide a clear picture of its growth patterns over the years. From 1967 to 2022, the area under rice cultivation grew modestly by 0.35 per cent per year, while between 1990 and 2022, this rate slowed further to 0.13 per cent. This indicates that while the area devoted to rice initially expanded, more recent years have seen a plateau, likely due to land limitations, urbanisation, and shifting focus toward other crops. The growth in production and productivity has been more substantial. During 1967-2022, rice production rose by 2.26 per cent and productivity by 1.90 per cent annually. From 1990 to 2022, however, production growth slowed to 1.64 per cent, and productivity to 1.50 per cent, suggesting that while yields improved, growth rates have moderated, possibly due to challenges like soil health, water scarcity, and climate changes.

On the export front, the CAGR of rice exports in terms of value saw impressive growth between 1990 and 2022, increasing by 16.84 per cent annually. Region-wise, exports to Oceania grew the fastest at 24.21 per cent, followed closely by Africa at 23.15 per cent, while Europe experienced the slowest growth, with a 12.32 per cent annual increase. This data indicates that Indian rice has steadily gained a larger global presence, especially in Oceania and Africa. Overall, these trends show that India's growth in rice production is increasingly driven by improvements in productivity rather than expansion in the cultivation

area. With strong export performance, especially in newer markets, the challenge now is to sustain this growth through investments in agricultural technology, better water management, and sustainable practices to meet both domestic demand and growing export opportunities.

**Table 1: CAGR of Rice Area, Production and Productivity of rice in India:**

| CAGR | 1967-2022 | 1990-2022 |
|---|---|---|
| Area | 0.358 % | 0.130 % |
| Production | 2.265 % | 1.642 % |
| Productivity | 1.901 % | 1.509 % |

**Table 2: CAGR of rice exports of India from 1990-2022 in value**

| | |
|---|---|
| world | 16.840 % |
| Africa | 23.152 % |
| America | 14.515 % |
| Asia | 16.545 % |
| Europe | 12.323 % |
| Oceania | 24.213 % |
| others | -9.330 % |

The major rice importing countries from India were Iran, Saudi Arabia, UAE, Iraq, Bangladesh, Nepal, Yemen and Kuwait. According to the table 3, the CAGR of rice Exports in terms of value to the top most countries which were selected based on the last ten years average of rice Exports by value from India, among which Iraq showed 58.46 per cent growth, Iran shows 46.47 per cent and Nepal showed 30.71 per cent during the time period 2001-2022.

**Table 3: CAGR of rice exports of India from 2001-2022 in value**

| | |
|---|---|
| Iran | **46.479 %** |
| Saudi Arabia | 10.369 % |
| UAE | 15.869 % |
| Iraq | **58.464 %** |
| Bangladesh | 10.192 % |
| Nepal | **30.718 %** |
| Yemen | 21.147 % |
| Kuwait | 11.364 % |
| Others | 15.206 % |

In Table 4, we present the Transitional Probability Matrix derived from the Markov Chain Analysis, focusing on rice exports from India to various regions around the world from 2001 to 2022. In this matrix, cells that coincide with the same region or country indicate the retention capacity of trade for that specific region over the given time period. If the value in a

cell equals 1, it signifies that the region has maintained 100 per cent retention during this timeframe; conversely, a value of 0 indicates no retention at all. The horizontal rows reflect the trade losses experienced by each region or country listed in the columns, while the columns indicate the potential trade gains from the regions or countries represented in the rows.

According to the analysis, Africa has successfully retained 78 per cent of its trade during the period from 2001 to 2022, with the remaining losses distributed among Asia, America, and Europe-16 per cent, 3.3 per cent, and 1.8 per cent, respectively. In a similar vein, Asia managed to retain an impressive 93.7 per cent of its trade, losing only 3 per cent each to America and Europe. In contrast, America retained a mere 12.3 per cent of its trade, losing a substantial 86.1 per cent to Africa. Europe fared somewhat better, retaining 58.8 per cent of its trade from India but still losing 41 per cent to Africa. Oceania, on the other hand, retained 49.2 per cent of its trade while losing 50.8 per cent to Africa. Overall, this analysis indicates that Africa has emerged as a significant beneficiary of Indian rice exports, gaining major trade that was lost by America, Europe, and Oceania during the 2001-2022 period in terms of export value.

**Table 4: Transitional Probability Matrix of rice region wise from 2001-2022 in Value**

| | Africa | America | Asia | Europe | Oceania | Others |
|---|---|---|---|---|---|---|
| Africa | **0.781** | 0.033 | 0.166 | 0.018 | 0.001 | 0.000 |
| America | 0.861 | **0.123** | 0.000 | 0.000 | 0.016 | 0.000 |
| Asia | 0.000 | 0.030 | **0.937** | 0.030 | 0.004 | 0.000 |
| Europe | 0.410 | 0.000 | 0.000 | **0.588** | 0.000 | 0.003 |
| Oceania | 0.508 | 0.000 | 0.000 | 0.000 | **0.492** | 0.000 |
| Others | 0.000 | 0.000 | 0.000 | 0.952 | 0.000 | **0.048** |

The top eight countries importing rice from India, based on export value from the last decade, include Iran, Saudi Arabia, UAE, Iraq, Bangladesh, Nepal, Yemen, and Kuwait. As evident from Tables 5 and 6, Iran retained a significant 83.5 per cent of its trade with India during the period from 2001 to 2010, losing only 16.5 per cent to Saudi Arabia. However, this retention capacity declined during 2011 to 2022, where it stood at just 31 per cent, with a substantial portion lost to Saudi Arabia at 40.9 per cent. In contrast, Saudi Arabia managed to retain 57.6 per cent of its trade in the earlier period but saw a drop to 32.5 per cent in the later period, losing 30.5 per cent of its trade to other countries between 2001 and 2010, and more than 50 per cent to both the UAE and Iraq during 2011-2022.

During this later period, Iraq completely lost all its trade, while Nepal, Yemen, and Kuwait faced significant losses, with Nepal losing 86.7 per cent, Yemen 66.1 per cent, and Kuwait 31.4 per cent of their trade to the UAE, which had a retention capacity of 67.8 per cent in the earlier period. However, during 2011-2022, the UAE's retention capacity dropped drastically to just 16.4 per cent, losing a major portion to Iran at 68.4 per cent. Additionally, Bangladesh, Nepal, and Yemen lost all their trade, indicating that these markets have become increasingly unstable for Indian rice exports. Specifically, Bangladesh's losses were primarily to Iran, Nepal's trade largely shifted to other countries, and Yemen lost 66.6 per cent of its trade to Nepal, with respective losses of 79.0 per cent and 72.4 per cent. Furthermore, the "Others" category retained 83.7 per cent of its trade, losing only 10 per cent to Saudi Arabia, along with smaller portions to the UAE and Bangladesh during the 2011-2022 period in terms of the value of rice exports from India. These patterns highlight the changing dynamics of rice trade and the varying levels of stability among key importing countries.

**Table 5: Transitional Probability Matrix of rice exports from India to top 8 countries 2001-2010 in Value**

| | Iran | Saudi Arabia | UAE | Iraq | Bangladesh | Nepal | Yemen | Kuwait | Others |
|---|---|---|---|---|---|---|---|---|---|
| Iran | **0.835** | 0.165 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Saudi Arabia | 0.000 | **0.576** | 0.000 | 0.000 | 0.000 | 0.000 | 0.055 | 0.064 | 0.305 |
| UAE | 0.081 | 0.000 | **0.678** | 0.004 | 0.000 | 0.000 | 0.000 | 0.237 | 0.000 |
| Iraq | 0.000 | 0.000 | 1.000 | **0.000** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Bangladesh | 0.000 | 0.530 | 0.204 | 0.000 | **0.198** | 0.000 | 0.000 | 0.068 | 0.000 |
| Nepal | 0.000 | 0.000 | 0.867 | 0.000 | 0.000 | **0.000** | 0.000 | 0.133 | 0.000 |
| Yemen | 0.000 | 0.000 | 0.661 | 0.099 | 0.000 | 0.068 | **0.172** | 0.000 | 0.000 |
| Kuwait | 0.000 | 0.537 | 0.314 | 0.016 | 0.000 | 0.000 | 0.046 | **0.087** | 0.000 |
| Others | 0.000 | 0.088 | 0.000 | 0.000 | 0.239 | 0.024 | 0.007 | 0.000 | **0.642** |

**Table 6: Transitional probability Matrix of rice exports from India to top 8 countries 2011-2022 in Value**

| | Iran | Saudi Arabia | UAE | Iraq | Bangladesh | Nepal | Yemen | Kuwait | Others |
|---|---|---|---|---|---|---|---|---|---|
| Iran | **0.314** | 0.409 | 0.000 | 0.000 | 0.036 | 0.000 | 0.090 | 0.095 | 0.056 |
| Saudi Arabia | 0.000 | **0.325** | 0.276 | 0.309 | 0.000 | 0.000 | 0.000 | 0.073 | 0.017 |
| UAE | 0.684 | 0.052 | **0.164** | 0.000 | 0.000 | 0.000 | 0.077 | 0.023 | 0.000 |
| Iraq | 0.000 | 0.000 | 0.000 | **0.317** | 0.332 | 0.273 | 0.000 | 0.000 | 0.079 |
| Bangladesh | 0.666 | 0.171 | 0.074 | 0.010 | **0.000** | 0.002 | 0.072 | 0.005 | 0.000 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nepal | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | **0.000** | 0.210 | 0.000 | 0.790 |
| Yemen | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.724 | **0.000** | 0.000 | 0.276 |
| Kuwait | 0.646 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.076 | **0.149** | 0.129 |
| Others | 0.000 | 0.108 | 0.022 | 0.000 | 0.033 | 0.000 | 0.000 | 0.000 | **0.837** |

Table 7 represents the compound annual growth rate of rice exports from India by quantity which is to the world increased by 10 per cent whereas to Africa and Oceania increased by 17.33 per cent and 18.83 per cent respectively from 1990-2022 and from table 8 it is evident that exports to Iraq increased by 44.18 per cent and to Iraq by 34 per cent, for Bangladesh only 1.68 per cent increase in exports of rice from India in terms of quantity.

**Table 7: CAGR of rice Exports from India by Quantity**

| CAGR | **1990-2022** | **2001-2022** |
|---|---|---|
| World | 10.820 % | 9.907 % |
| Africa | 17.338 % | 13.684 % |
| America | 8.858 % | 10.749 % |
| Asia | 9.519 % | 8.603 % |
| Europe | 7.137 % | 7.654 % |
| Oceania | 18.832 % | 16.382 % |
| Others | - | -15.670 % |

**Table 8: CAGR of Rice Exports from India by Quantity**

| CAGR | **2001-2022** |
|---|---|
| Iran | 34.158 % |
| Saudi Arabia | 3.569 % |
| Bangladesh | 1.684 % |
| Nepal | 22.779 % |
| UAE | 8.780 % |
| Iraq | 44.183 % |
| China | 38.459 % |
| Yemen | 12.590 % |
| Others | 6.715 % |

The Transitional Probability Matrix of rice exports from India, presented in Table 9, reveals significant insights into trade dynamics across different regions from 2001 to 2022. According to the data, Africa has retained a robust 89.1 per cent of its trade with India, while Asia has maintained an even higher retention rate of 92.6 per cent. In stark contrast, both Oceania and America faced complete losses in their trade relationships, with Oceania losing all its trade to Africa and America losing all its trade to Asia during the same period. Europe

retained 48.0 per cent of its trade but experienced a notable loss of 50.3 per cent to Asia. Meanwhile, other regions managed to retain only 5.7 per cent of their trade, losing a staggering 94.3 per cent to Europe.

Table 10, outlines the Transitional Probability Matrix of rice exports from India to the top eight countries, based on the last decadal average value of exports from 2001 to 2022. For clarity in identifying decadal gains and losses for these countries, we conducted separate Markov Chain analyses for the periods 2001-2010 and 2011-2022, as shown in Tables 10 and 11. During the first period, Iraq lost all its trade to the UAE, while China's trade shifted to other regions. Yemen faced a significant loss of 91.9 per cent to the UAE. On the other hand, Iran retained only 58.3 per cent of its trade, losing 41.0 per cent to Saudi Arabia, which itself managed to retain less than half of its trade, redirecting the remainder to other regions. In comparison, the UAE demonstrated a strong trading position, retaining a majority of its trade at 71.4 per cent, while losing the remaining portion primarily to Iran. These findings underscore the shifting patterns in rice trade and the varying degrees of competitiveness among different countries.

**Table 9: Transitional Probability Matrix of rice exports in quantity from India to other regions from 2001-2022 by quantity**

| | Africa | America | Asia | Europe | Oceania | Others |
|---|---|---|---|---|---|---|
| Africa | **0.891** | 0.012 | 0.067 | 0.029 | 0.001 | 0.000 |
| America | 0.000 | **0.000** | 1.000 | 0.000 | 0.000 | 0.000 |
| Asia | 0.024 | 0.024 | **0.926** | 0.021 | 0.004 | 0.000 |
| Europe | 0.503 | 0.000 | 0.000 | **0.480** | 0.017 | 0.000 |
| Oceania | 1.000 | 0.000 | 0.000 | 0.000 | **0.000** | 0.000 |
| Others | 0.000 | 0.000 | 0.000 | 0.943 | 0.000 | **0.057** |

**Table 10: Transitional Probability Matrix of rice exports from India to top 8 countries in quantity from 2001-2010 in quantity**

| | Iran | Saudi Arabia | Bangladesh | Nepal | UAE | Iraq | China | Yemen | Others |
|---|---|---|---|---|---|---|---|---|---|
| **Iran** | **0.583** | 0.410 | 0.000 | 0.000 | 0.000 | 0.007 | 0.000 | 0.000 | 0.000 |
| **Saudi Arabia** | 0.000 | **0.449** | 0.000 | 0.000 | 0.057 | 0.020 | 0.000 | 0.088 | 0.386 |
| **Bangladesh** | 0.000 | 0.532 | **0.341** | 0.000 | 0.125 | 0.000 | 0.000 | 0.002 | 0.000 |
| **Nepal** | 0.000 | 0.000 | 0.000 | **0.431** | 0.000 | 0.000 | 0.000 | 0.009 | 0.561 |
| **UAE** | 0.286 | 0.000 | 0.000 | 0.000 | **0.714** | 0.000 | 0.000 | 0.000 | 0.000 |
| **Iraq** | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 | **0.000** | 0.000 | 0.000 | 0.000 |
| **China** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | **0.000** | 0.000 | 1.000 |
| **Yemen** | 0.000 | 0.000 | 0.000 | 0.080 | 0.919 | 0.001 | 0.000 | **0.000** | 0.000 |
| **Others** | 0.000 | 0.000 | 0.296 | 0.029 | 0.000 | 0.000 | 0.001 | 0.011 | **0.664** |

According to Table 11, China has successfully retained a significant majority of its trade, maintained an impressive 86.7 per cent share while lost only 13.3 per cent to other countries. In stark contrast, both Iraq and Yemen experienced a complete loss of their trade during the period from 2011 to 2022. Iran, however, demonstrated a more resilient trade position, gaining 43.7 per cent of its trade from Bangladesh and 59.6 per cent from the UAE. Similarly, Saudi Arabia capitalized on its trading relationships, securing 35.1 per cent of its trade from Yemen, along with 19 per cent from Iran and 13 per cent from Bangladesh. These figures highlight the shifting dynamics of trade relationships in the region, with certain countries managing to strengthen their positions while others face significant challenges.

**Table 11: Transitional probability Matrix of rice exports from India to top 8 countries in quantity from 2011-2022**

| | Iran | Saudi Arabia | Bangladesh | Nepal | UAE | Iraq | China | Yemen | Others |
|---|---|---|---|---|---|---|---|---|---|
| **Iran** | **0.323** | 0.195 | 0.000 | 0.104 | 0.000 | 0.000 | 0.000 | 0.086 | 0.292 |
| **Saudi Arabia** | 0.000 | **0.368** | 0.000 | 0.000 | 0.290 | 0.342 | 0.000 | 0.000 | 0.000 |
| **Bangladesh** | 0.437 | 0.134 | **0.000** | 0.098 | 0.088 | 0.022 | 0.000 | 0.045 | 0.178 |
| **Nepal** | 0.000 | 0.000 | 0.000 | **0.551** | 0.016 | 0.188 | 0.010 | 0.033 | 0.201 |
| **UAE** | 0.596 | 0.000 | 0.000 | 0.015 | **0.344** | 0.000 | 0.000 | 0.045 | 0.000 |
| **Iraq** | 0.000 | 0.000 | 0.925 | 0.017 | 0.000 | **0.000** | 0.000 | 0.058 | 0.000 |
| **China** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | **0.867** | 0.000 | 0.133 |
| **Yemen** | 0.000 | 0.351 | 0.000 | 0.649 | 0.000 | 0.000 | 0.000 | **0.000** | 0.000 |
| **Others** | 0.000 | 0.088 | 0.125 | 0.000 | 0.000 | 0.000 | 0.000 | 0.015 | **0.771** |



## Conclusion:

The study aimed to identify the direction of rice trade by calculating the Compound Annual Growth Rate (CAGR) and the Transitional Probability Matrix using Markov Chain Analysis. We utilized time series data from reputable secondary sources, including the Ministry of Agriculture and Farmers' Welfare, the Ministry of Commerce and Industry, and the Directorate General of Commercial Intelligence and Statistics (DGCI&S). The findings revealed that the CAGR of rice production in India was 2.26 per cent, while rice exports in terms of value increased significantly by 16.8 per cent. Notably, Iraq experienced the highest CAGR at 58.6 per cent, followed by Iran at 46.47 per cent. In terms of quantity, the worldwide CAGR for rice exports rose by 10.82 per cent, with Iraq and Iran showing impressive rates of 44 per cent and 34 per cent, respectively.

The Transitional Probability Matrix for rice exports by value indicates that Africa retains a substantial 78 per cent of its trade, while Asia retains an impressive 93.7 per cent from 2001 to 2022. However, during the earlier period from 2001 to 2010, Iran maintained 83.5 per cent of its trade, while Nepal lost all its trade with other countries. In the later period of 2011 to 2022, Bangladesh, Nepal, and Yemen lost all their rice exports from India, and Iran's retention dropped to just 31.4 per cent. The analysis for rice exports in terms of

quantity showed that Asia retained 92.6 per cent of its trade and Africa retained 89.1 per cent during the same period, whereas regions like Oceania and America lost 100 per cent of their trade. Among the top countries, Iran and the UAE retained 58.3 per cent and 71.43 per cent, respectively, from 2001 to 2010, while Iraq, China, and Yemen lost all their trade with other countries. In contrast, during 2011-2022, China retained 86.7 per cent of its trade, but Iran's retention fell to just 32 per cent, with Iraq, Yemen, and Bangladesh losing 100 per cent of their rice exports from India. Based on these findings, the study recommends several strong policy measures to enhance India's rice export potential. Firstly, the government should invest in improving processing facilities to ensure that rice meets international quality standards, which will help increase demand in global markets. Secondly, enhancing transportation infrastructure is crucial to reduce logistics costs and improve supply chain efficiency, making Indian rice more competitive internationally. Thirdly, the government should promote research and development in rice cultivation techniques to boost productivity and resilience against climate change. Additionally, creating strategic trade partnerships with emerging markets can diversify export destinations, reducing dependence on traditional markets. Finally, training programs for farmers on quality maintenance and post-harvest practices will ensure that they can meet global demands effectively. By implementing these recommendations, India can strengthen its position as a leading player in the global rice market and maximize the economic benefits for its agricultural sector.

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