



ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2026): 4.97
IJAFS 2026; 8(6): 500-504
www.agriculturaljournals.com
Received: 14-04-2026
Accepted: 17-05-2026

Jenish Ranpariya
MBA, Post Graduate Institute
of Agri-business Management,
Junagadh Agricultural
University, Gujarat, India

Nisha M Thaker
Associate Professor, Post
Graduate Institute of Agri-
business Management,
Junagadh Agricultural
University, Gujarat, India

Jagruiti D Bhatt
Associate Professor, Post
Graduate Institute of Agri-
business Management,
Junagadh Agricultural
University, Gujarat, India

Raj Patel
MBA, Post Graduate Institute
of Agri-business Management,
Junagadh Agricultural
University, Gujarat, India

Corresponding Author:
Jenish Ranpariya
MBA, Post Graduate Institute
of Agri-business Management,
Junagadh Agricultural
University, Gujarat, India

Competitiveness, trade direction, and exporter constraints: A statistical analysis of Indian dry chilli exports

Jenish Ranpariya, Nisha M Thaker, Jagruiti D Bhatt and Raj Patel

DOI: <https://www.doi.org/10.33545/2664844X.2026.v8.i6g.1633>

Abstract

India is a dominant global player in the spice sector, with dry chilli being its most strategically significant crop. This study analyses the export competitiveness, trade direction and exporter constraints of Indian dry chilli over a twenty-year period (2004-05 to 2023-24) using Revealed Comparative Advantage (RCA), the Markov-chain approach and Garrett's ranking technique. The RCA analysis reveals that India maintains an immense and uninterrupted comparative advantage in the global dry chilli market, consistently scoring well above the baseline threshold across the two decades. Furthermore, the transitional probability matrix indicates a massive structural pivot in target markets. While traditional markets like Sri Lanka and the USA exhibited extreme volatility and low retention rates, China experienced an explosive surge, cementing itself as India's premier and most stable competitive destination with an overwhelming 93.86 per cent market retention rate. Finally, Garrett's ranking of fourteen constraints identified economic volatility-specifically the uncertainty in dry chilli pricing and currency rate fluctuations-as the most severe challenges burdening Indian exporters, whereas product quality and financial transfer delays were deemed minor concerns.

Keywords: Indian dry chilli, Export competitiveness, Revealed Comparative Advantage, Markov-chain approach, Garrett's ranking technique

Introduction

India occupies a position of global dominance in the spice sector, acting as the world's largest producer, consumer and exporter. The country accounts for approximately 70-75 per cent of global spice production, spanning an agricultural area of 4.5-5.0 million hectares with an annual output of 10-11 million tonnes. Supported by diverse agro-climatic zones, India cultivates a wide matrix of spices, including turmeric, ginger, cumin, coriander and pepper. While 85-90 per cent of this massive yield satisfies domestic culinary, pharmaceutical and cosmetic industries, the remaining surplus is exported to over 180 countries, cementing the sector's role as a high-value pillar of Indian agriculture (Spices Board, 2024).

Among these commodities, the common hot chili (*Capsicum annum L.*) stands out as the most strategically significant crop, leading all other spices in both cultivation area and production volume. Cultivated across more than 120 countries, chili is highly valued in the global processed food, pharmaceutical and oleoresin industries due to its distinctive biochemical properties: capsaicin, which drives its intense pungency and capsanthin, a powerful antioxidant responsible for its vibrant red colour. Globally, dry chilis dominate international trade, with India leading global output ahead of other major producers like China and Mexico (FAO, 2024; Pandit *et al.*, 2020; Singh and Kumar, 2025; Spices Board, 2024) ^[7, 9]. On the domestic front, India accounts for 35-40 per cent of global chili production, dedicating nearly 8-10 lakh hectares to the crop, which yields an annual green chili equivalent of 7.5-8.0 million tonnes. Production is highly concentrated in states like Andhra Pradesh, Telangana, Madhya Pradesh and Karnataka, with the Guntur region of Andhra Pradesh serving as the premier international hub for trading and processing. India's geographical diversity has fostered unique regional varieties tailored to specific commercial niches, ranging from the high-color, low-pungency Byadgi chili (favoured for paprika oleoresin extraction) to the well-balanced Guntur Sannam and the hyper-pungent Bhut Jolokia of Northeast India (Pandit *et al.*, 2020) ^[7].

The economic vitality of the Indian chili sector is heavily reliant on a delicate balance between domestic consumption and international trade. Approximately 80-85 per cent of the national harvest is retained for household cooking and industrial processing within India, while the rest is exported as dry red chilis, powders and high-value oleoresins. In 2024, India's dry chili exports generated substantial global revenue, with major buyers including China (importing over 186,000 tons), followed by Bangladesh, Thailand, Sri Lanka and the USA. To optimize these returns, the industry has increasingly shifted toward value-added products like essential oils and blended spices, which fetch higher premium prices in volatile global markets (FAO, 2024; Geetha and Selvarani, 2017; Spices Board, 2024) [8].

Despite its strong market presence, the chili sector faces critical vulnerabilities that threaten long-term sustainability. Chilies are environmentally sensitive, requiring strict temperature ranges (15°C to 35°C) and well-drained soils; extreme weather exceeding 40°C or water stagnation triggers severe flower and fruit drop. Furthermore, the crop is highly susceptible to devastating pests like thrips, mites and aphids, alongside severe price volatility and stringent international quality compliance standards regarding chemical residues. Addressing these challenges through modern post-harvest preservation, organic cultivation and institutional backing from the Spices Board of India remains paramount as global consumer demand transitions toward natural, traceable and premium spice products (Geetha and Selvarani, 2017; Pandit *et al.*, 2020; Singh and Kumar, 2025; Spices Board, 2024) [5, 7, 9].

Objectives

- To analyse the export competitiveness of Indian dry chilli
- To estimate the direction of trade of Indian dry chilli in the international market
- To study the constraints faced by dry chilli exporters in India

Methodology

Primary data was collected by using structured questionnaire. The information related to constraints of dry chilli exports was collected from 10 exporting company. Secondary data regarding the area, production, price and exports of dry chilli over a period of time was collected from website <https://apeda.gov.in/>, spices board of India and FAOSTATE etc. Twenty years (2004-2005 to 2023-2024) dry chilli export data of India was used to find out the export competitiveness in dry chilli and the direction of trade and changing pattern in export of dry chilli.

Period of Study

The data regarding production, export quantity, value of export, domestic price and international price of dry chilli in India was collected for the years 2004-05 to 2023-24. The period was divided into three periods,

- **Period 1:** (2004-05 to 2013-14)
- **Period 2:** (2014-15 to 2023-24)
- **Overall period:** (2004-05 to 2023-24)

Statistical Analysis

According to requirement of the specific objectives of the study and based on nature and extent of availability of data,

RCA index, markov-chain approach and garret's ranking technique was used.

Revealed Comparative Advantage

The revealed comparative advantage was used to assess the comparative advantages of Indian dry chilli export. It measures a country's relative advantage or disadvantage in exporting a specific product compared to the world. It helps in analyzing export competitiveness (Balassa, 1965) [2].

$$RCA_{ij} = (X_{ij}/X_{it}) / (X_{wj}/X_{wt})$$

Where,

RCA_{ij} = Revealed comparative advantage of the i^{th} country's j^{th} commodity

X_{ij} = value of country i^{th} export of product j

X_{it} = country i^{th} total export value

X_{wj} = World export value of product j

X_{wt} = world's total exports value

If $RCA > 1$, then the country has a revealed comparative advantage in that commodity, $RCA < 1$, then the country has a revealed comparative disadvantage in that commodity and $RCA = 1$ shows comparative neutrality.

Markov-Chain Approach

The trade direction of dry chilli was analysed by using the first order Markov chain approach. Central to Markov chain analysis is the estimation of transitional probability matrix P . The elements P_{ij} of the matrix P indicate the probability that export was switched from country i to country j with the passage of time. The diagonal elements of the matrix measure the probability that the export share of a country was retained. Hence, an examination of the diagonal elements indicates the loyalty of an importing country to a particular country's export (Markov, 1906) [6].

In the context of the current application, major importing countries of dry chillis was considered. The average exports to a particular country were a random variable which depends only on the past export to that country, which can be denoted algebraically as,

$$E_{jt} = \sum_{i=1}^n (E_{it-1} \times P_{ij} + e_{jt})$$

Where,

E_{jt} = Export from India to j^{th} country during the year t

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

P_{ij} = Probability that the exports were shifted from i^{th} country to j^{th} country

e_{jt} = The error term which is statistically independent of E_{it-1}

t = Number of years considered for the analysis

n = Number of importing countries

The transitional probabilities P_{ij} , which can be arranged in a $(C \times R)$ matrix have the following properties:

$$0 \leq P_{ij} \leq 1$$

$$\sum_{i=1}^n P_{ij} = 1 \text{ for all } j$$

Thus, the expected export shares of each country during the period ' t ' were obtained by multiplying the export to these countries in the previous period ($t-1$) with the transitional probability matrix.

Garrett's Ranking Technique

The Garret's ranking technique was used to study the constraints faced by exporters (Garrett, 1969) [4].

The Garret's ranking technique was calculated through the following formula:

$$\text{Per cent position} = \frac{100 (R_{ij} - 0.5)}{N_j}$$

Where,

R_{ij} = Rank given to the i^{th} constraint by the j^{th} individual

N_j = Number of constraints ranked by the j^{th} individual

By referring to the Garret's table, the per cent positions estimated was converted into scores.

$$\text{Mean score} = \frac{\text{Total Garrett Score}}{\text{Number of Respondents}}$$

Thus, for each factor, the scores of the various respondents were added and then the mean value was estimated. The attribute with the highest mean value was considered as the most important constraint and the others was followed in descending order.

Results and Discussion

Export Competitiveness

The data presented in Table 1 shows India's Revealed Comparative Advantage (RCA) in the export of dry chillies from the 2004-2005 fiscal year through 2023-2024. With RCA values consistently remaining far above the baseline threshold of 1, the table demonstrates India's immense and sustained competitive dominance in the global dry chilli market over the past two decades. The index shows some fluctuation, starting at its lowest recorded point of 9.872 in 2004-2005, surging to a peak of 18.959 in 2009-2010 and subsequently stabilizing to a strong 13.611 by the 2023-2024 period. Ultimately, this uninterrupted streak of exceptionally high figures highlights a deeply entrenched and highly specialized export capability within this specific agricultural sector.

Table 1: Revealed Comparative Advantage of India in dry Chilli export

Year	RCA
2004-2005	9.872
2005-2006	16.551
2006-2007	14.436
2007-2008	14.640
2008-2009	16.042
2009-2010	18.959
2010-2011	15.887
2011-2012	13.169
2012-2013	11.265
2013-2014	13.013
2014-2015	14.695
2015-2016	15.933
2016-2017	15.748
2017-2018	13.764
2018-2019	15.678
2019-2020	16.637
2020-2021	14.744
2021-2022	13.522
2022-2023	14.580
2023-2024	13.611

Expanding on the data provided in Table 2, a closer review of India's Revealed Comparative Advantage (RCA) in dry chilli exports highlights a massive structural pivot in target

markets over the twenty-year period. While the USA represents a bedrock of stability-maintaining an uninterrupted RCA above 1.0, fluctuating mildly between 1.227 and a peak of 2.895 in 2010-2011-the Asian markets demonstrate extreme volatility and shifting trade alignments. Traditional strongholds like Malaysia and Sri Lanka, which initially posted impressive early-decade RCA peaks of 5.885 (2005-2006) and 2.618 (2008-2009) respectively, suffered severe, long-term contractions, with both nations eventually plummeting below the crucial 1.0 comparative advantage threshold by the end of the timeline. Conversely, exports to China and Thailand exhibit aggressive market penetration; Thailand successfully crossed into comparative advantage territory by 2010-2011, while China, which languished near zero for over a decade, experienced an explosive, unprecedented surge starting in 2017-2018, skyrocketing to a dominant RCA of 5.852 by 2019-2020 and cementing itself as India's premier competitive destination for dry chillies by 2024.

Table 2: Revealed Comparative Advantage of India in dry Chilli export to major export destinations

Year	China	Sri Lanka	Thailand	Malaysia	USA
2004-2005	0.050	1.846	0.032	2.484	1.905
2005-2006	0.127	2.404	0.106	5.885	1.512
2006-2007	0.129	1.810	0.220	4.047	1.721
2007-2008	0.044	2.410	0.685	3.155	1.810
2008-2009	0.236	2.618	0.693	4.478	1.839
2009-2010	0.537	2.473	0.361	5.409	1.876
2010-2011	0.476	2.443	1.118	3.195	2.895
2011-2012	0.629	1.110	1.309	2.436	1.398
2012-2013	0.120	1.263	1.779	1.693	1.294
2013-2014	0.115	1.376	2.222	1.430	1.227
2014-2015	0.094	1.846	2.498	1.590	1.517
2015-2016	0.073	2.108	2.555	1.621	1.502
2016-2017	0.209	0.997	2.791	1.036	1.264
2017-2018	1.263	1.302	1.948	0.957	1.302
2018-2019	5.487	1.491	2.262	0.892	1.366
2019-2020	5.852	1.383	1.845	0.943	1.375
2020-2021	5.777	1.051	1.496	0.737	1.492
2021-2022	3.897	1.348	1.796	0.754	1.313
2022-2023	4.262	0.959	1.801	0.758	1.380
2023-2024	4.782	0.826	1.434	0.560	1.387

The Direction of Trade

The data presented in Table 3 details the Transition Probability Matrix (TPM) for India's dry chilli export trade from 2004-05 to 2013-14, illustrating the statistical likelihood of major export destinations either retaining their market share or losing it to competing countries. The bolded diagonal values represent market retention rates, revealing that Thailand is the most stable destination, retaining approximately 66.38 per cent (0.6638) of its trade share, followed closely by the aggregate "Others" category at 58.91 per cent (0.5891). In stark contrast, Sri Lanka exhibits absolute market instability with zero retention (0.0000), losing its share predominantly to "Others" (0.6367) and Malaysia (0.3526). Furthermore, the off-diagonal figures highlight significant market volatility and shifting trade alignments across the decade; for instance, China shows a high probability of losing its share to Thailand (0.4796), while the USA demonstrates a strong tendency to shift its export share to Malaysia (0.4932) and Sri Lanka (0.2154), underscoring a highly dynamic and fluid international trade landscape for Indian dry chillies during this period.

Table 3: TPM of India's dry Chilli export trade during 2004-05 to 2013-14

From/To	China	Sri Lanka	Thailand	Malaysia	USA	Others
China	0.3085	0.0000	0.4796	0.0000	0.0000	0.2119
Sri Lanka	0.0107	0.0000	0.0000	0.3526	0.0000	0.6367
Thailand	0.0000	0.0000	0.6638	0.0000	0.0000	0.3362
Malaysia	0.0002	0.0126	0.0000	0.3376	0.3565	0.2931
USA	0.0000	0.2154	0.0000	0.4932	0.2914	0.0000
Others	0.0188	0.2945	0.0657	0.0000	0.0320	0.5891

The data presented in Table 4 outlines the Transition Probability Matrix (TPM) for India's dry chilli export trade over the decade spanning 2014-15 to 2023-24, detailing the likelihood of major international markets either retaining their import shares or losing them to competitors. The bolded diagonal values signify market retention, overwhelmingly highlighting China as the most stable and dominant destination, successfully retaining a massive 88.67 per cent (0.8867) of its trade share. In stark contrast to China's stability, traditional markets such as Sri Lanka (0.0287), the USA (0.1440), Thailand (0.1558) and Malaysia (0.1616) exhibit exceptionally low retention rates, indicating high market volatility. The off-diagonal figures reveal that a significant portion of the trade share from these volatile countries is shifting heavily toward the aggregated "Others" category-which captures shifts of 0.6158 from Sri Lanka and 0.5589 from Thailand-illustrating a recent global landscape defined by a single, highly concentrated anchor market in China surrounded by broad realignments and fragmentation across the rest of the world.

Table 4: TPM of India's dry Chilli export trade during 2014-15 to 2023-24

From/To	China	Sri Lanka	Thailand	Malaysia	USA	Others
China	0.8867	0.0001	0.0000	0.0000	0.0701	0.0431
Sri Lanka	0.0000	0.0287	0.1920	0.1084	0.0552	0.6158
Thailand	0.0000	0.1531	0.1558	0.1089	0.0233	0.5589
Malaysia	0.0000	0.2381	0.1532	0.1616	0.0569	0.3903
USA	0.0000	0.2031	0.1954	0.0775	0.1440	0.3801
Others	0.1300	0.1344	0.1505	0.0377	0.0825	0.4649

The data provided in Table 5 presents the Transition Probability Matrix (TPM) for India's dry chilli export trade over the entire twenty-year period from 2004-05 to 2023-24, detailing the statistical likelihood of major markets retaining their import shares versus losing them to other nations. The bolded diagonal figures, which represent market retention, reveal that China is overwhelmingly the most stable and dominant destination, successfully retaining 93.86 per cent (0.9386) of its trade share over the two decades. Thailand (0.6193) and the aggregated "Others" category (0.6105) also demonstrate strong historical retention. Conversely, traditional markets like Sri Lanka (0.0824) and the USA (0.3000) exhibit extreme volatility; the off-diagonal figures show that Sri Lanka heavily lost its share to the "Others" category (0.6176), while the USA frequently saw its trade share shift toward Malaysia (0.3850) and Sri Lanka (0.2180). Ultimately, this comprehensive matrix underscores a long-term global landscape defined by China's ironclad market capture, contrasted against significant fluidity and realignment among India's other historical export partners.

Table 5: TPM of India's dry Chilli export trade during 2004-05 to 2023-24

From/To	China	Sri Lanka	Thailand	Malaysia	USA	Others
China	0.9386	0.0000	0.0048	0.0000	0.0232	0.0335
Sri Lanka	0.0000	0.0824	0.0000	0.1895	0.1105	0.6176
Thailand	0.0217	0.0000	0.6193	0.0000	0.0000	0.3590
Malaysia	0.0000	0.1035	0.0000	0.4813	0.2232	0.1920
USA	0.0000	0.2180	0.0000	0.3850	0.3000	0.0970
Others	0.0520	0.1967	0.0957	0.0000	0.0451	0.6105

The Constraints Faced by Exporters

The data provided in Table 6, which ranks fourteen specific constraints faced by dry chilli exporters based on their total and mean severity scores. According to the data, economic volatility poses the most significant challenge, with "Uncertainty in price of dry chilli" taking the top position (Rank I) with a leading mean score of 79.7, closely followed by the "Fluctuation of currency rates" (Rank II, 72.5). Operational and logistical hurdles also rank highly, as seen with "Competition among exporters" (Rank III) and the "High cost of transportation" (Rank IV). Conversely, constraints such as "Poor quality of dry chilli" (Rank XII) and a long "Money transfer process" (Rank XIII) received the lowest scores, indicating that while exporters struggle heavily with unpredictable market pricing and currency valuations, they are significantly less burdened by product quality or financial transfer delays.

Table 6: Constraints faced by dry Chilli exporters

Sr. No.	Constraints	Total score	Mean score	Rank
1	Competition among exporters	668	66.8	III
2	Uncertainty in price of dry chilli	797	79.7	I
3	Lack of adequate information about international market	496	49.6	VIII
4	High cost of transportation	661	66.1	IV
5	Fluctuation of currency rates	725	72.5	II
6	Inadequate timely transportation facility	414	41.4	X
7	Delayed payment	539	53.9	VI
8	Complex procedure for export	522	52.2	VII
9	Money transfer process is long	271	27.1	XIII
10	High cost of investment	466	46.6	IX
11	Unfavourable government policies	383	38.3	XI
12	Unavailability of dry chilli	545	54.5	V
13	Poor quality of dry chilli	274	27.4	XII
14	Other	239	23.9	XIV

Conclusion

In conclusion, the two-decade statistical analysis of Indian dry chilli exports highlights the country's unshakeable and highly specialized comparative advantage in the global market. The study reveals a profound structural pivot in international trade dynamics, characterized by a transition away from highly volatile traditional markets-such as

Sri Lanka and the USA-toward China, which has rapidly emerged as India's most stable and dominant export destination. Despite this robust international demand, Indian exporters remain significantly constrained by economic vulnerabilities, with unpredictable commodity pricing and fluctuating currency exchange rates posing the greatest threats to profitability, followed closely by high transportation costs and intense market competition. Ultimately, while India's competitive dominance in the dry chilli sector is secure, ensuring the industry's long-term sustainability will require targeted policy interventions and strategic planning to mitigate these critical economic and operational risks.

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