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A multiple regression and instability analysis of Indian dry chilli exports

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Abstract

India stands as the premier global producer, consumer and exporter of spices, with dry chilli being a strategically significant crop that accounts for thirty-five to forty percent of worldwide production. This comprehensive study meticulously evaluates the statistical growth, market instability and macroeconomic factors directly influencing India's dry chilli exports over a twenty-year period from 2004-05 to 2023-24. Employing analytical tools such as compound annual growth rates, the Cuddy-Della Valle instability index and multiple linear regression, the analysis conclusively reveals that overall export quantity and value experienced highly significant growth rates of 6.92 per cent and 12.38 per cent, respectively. Although the pace of growth markedly decelerated during the second decade (2014-2024), the export value instability significantly decreased, thereby securing a more stable revenue stream for the nation. Market-specific trends showcase explosive, stabilized growth in China, heavily contrasted by volume contractions or plateaus within traditional markets like Sri Lanka, Thailand and Malaysia, albeit with improved overall market stability. Finally, the robust regression model practically demonstrates that total global demand alongside international pricing positively drive export performance, while rising Indian export prices and increased domestic production negatively impact total export volumes primarily due to international price sensitivity and domestic consumption.

Keywords: Dry Chilli, Export Performance, Compound Annual Growth Rate, Instability Analysis, Multiple Linear Regression

Introduction

India has evolved from prioritizing domestic food security to establishing itself as a dominant force in global agricultural trade, achieving a historic export high of USD 51.86 billion in FY25. This growth is driven by a strategic shift from the cereals-focused Green Revolution to a horticulture-driven "Golden Revolution," heavily supported by bodies like the Agricultural and Processed Food Products Export Development Authority (APEDA). Spices remain a cornerstone of this expanding export basket, generating USD 3.79 billion. Utilizing its diverse agro-climatic zones, India produces 70-75 per cent of the world's spices across roughly 4.5 to 5.0 million hectares, making it the premier global producer, consumer and exporter. Despite facing localized challenges such as climate volatility and stringent international quality standards, the sector continues to expand to meet rising global demand for natural, traceable and value-added agricultural products (Anon., 2026; Spices Board, 2024). Among these high-value exports, the common hot chilli (*Capsicum annuum* L.) is the most strategically significant spice crop, prized globally for its capsaicin-driven pungency and capsanthin-derived colour. Cultivated extensively across tropical and subtropical regions, chilli is heavily traded internationally to supply the food processing, pharmaceutical and oleoresin industries. India completely dominates this global landscape, contributing 35-40 per cent of the total worldwide production. In 2024, India produced over 2.9 million metric tonnes of dry chilli, drastically outpacing other major producers like China and Thailand. Cultivating this delicate crop requires precise environmental conditions-ideally well-drained loam soils and warm temperatures between 15°C and 35°C-making advanced post-harvest management and climate-resilient farming practices essential to minimizing losses and sustaining long-distance export viability (Pandit *et al.*, 2020; FAO, 2024; Singh and Kumar, 2025) [5, 8]. Within India, chilli is cultivated over 8 to 10 lakh hectares, with production heavily concentrated in states like Andhra Pradesh, Telangana, Madhya Pradesh and Karnataka.

This geographical diversity yields highly sought-after regional varieties tailored for distinct commercial applications. Prominent cultivars include the widely exported Guntur Sannam (S4) and highly pungent Teja, alongside Byadgi and Kashmiri varieties, which are prioritized for natural color extraction and paprika oleoresins. The country also hosts unique biodiversity hotspots cultivating niche, ultra-pungent variants like the Bhut Jolokia (*Capsicum chinense* Jacq.). While 80-85 per cent of India's chilli output is consumed domestically, the remainder fuels a massive export pipeline. Driven by the export of whole dry chillies, powders and high-value oleoresins to primary markets such as China, Bangladesh, Thailand and the USA, chilli remains a vital driver of India's rural economy and agricultural export strategy (Geetha and Selvarani, 2017; Pandit *et al.*, 2020; FAO, 2024; Spices Board, 2024)^[4, 5].

Objectives

1. To analyse the growth and instability in the export of dry chilli from India
2. To identify the factors influencing the export of dry chilli from India

Methodology

Secondary data regarding the area, production, price and exports of dry chilli over a period of time was collected from various official websites, including APEDA (<https://apeda.gov.in/>), the Spices Board of India and FAOSTAT. Twenty years of dry chilli export data from India (2004-2005 to 2023-2024) was utilized to assess the growth and instability in the export of dry chilli and identify the factors influencing its export.

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 overall study period was divided into three sections for detailed analysis:

- **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 the specific objectives of the study and based on the nature and extent of data availability, analytical tools were employed. These included compound growth rate analysis and multiple linear regression.

Compound Growth Rate Analysis

The compound growth rate of export quantity and export value of dry chilli was estimated using the following exponential functional (Rudrapur and Hiremath, 2024)^[7].

$$Y = ab^t e^t$$

Where,

Y = Dependent variable for which the growth rate is estimated (export quantity and value)

a = Intercept/Constant

b = Regression coefficient

t = Time variable

e^t = Error term

The compound growth rate was obtained by converting the equation into its logarithmic form as follows:

$$\log Y_t = \log a + t \log b + \log e_t$$

Where,

Y_t = Quantity / Value / Unit value of dry chilli in the t^{th} year

t = Time period in years (1, 2, ..., n)

Then, the compound annual growth rate (CAGR) in percentage was computed using the following relationship:

$$\text{CAGR} = (\text{Anti log of } \log b - 1) \times 100$$

Where,

CAGR = Compound annual growth rate in per cent.

Instability Analysis

To study the variability in the export of dry chilli, an index of instability was used as a measure of variation. First, the Coefficient of Variation (CV) was calculated using the following formula:

$$CV = \left[\frac{\sigma}{\bar{x}} \right] \times 100$$

Where,

σ = Standard deviation

$\bar{x}$ = Arithmetic mean

Because the trend coefficient of the series was found to be significant, the variation around the trend, rather than the variation around the mean, was used as the index of instability. The Cuddy-Della Valle instability index was calculated as follows (Cuddy and Della Valle, 1978)^[2].

Cuddy della valle instability index

$$IX = CV \times \sqrt{1 - \bar{R}^2}$$

Where,

CV = Co-efficient of variation

$\bar{R}^2$ = Adjusted co-efficient of determination

This index is zero when all values are stable at a given level or are changing at a constant rate. A higher value of this index indicates greater year-to-year fluctuation around the trend.

Multiple Linear Regression Analysis

In order to identify the factors affecting the export of dry chilli from India, a multiple regression analysis was carried out using the Ordinary Least Square (OLS) estimation procedure. On the basis of the best fit, a log-linear form was selected (Pearson, 1896).

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + u$$

Where,

Y = India's export of dry chilli (MT)

x_1 = Dry chilli Production in India (MT)

x_2 = Total world export of dry chilli (MT)

x_3 = Indian export price of dry chilli (US\$/tonne)

x_4 = World export value (US\$/tonne)

x_5 = Exchange rate (Rs/US\$)

a = Intercept

u = error term

$b_1, b_2, \dots, b_5$ = Regression Coefficients

Results and Discussion

Growth and Instability of Dry Chilli Exports from India

Based on the data presented in Table 11 the growth and instability of India's dry chilli exports over a 20-year span divided into two periods. The data reveals that while both export quantity and value experienced positive, highly significant compound annual growth rates overall-at 6.92 per cent and 12.38 per cent respectively-the pace of growth was markedly stronger during Period I (10.94 per cent for

quantity and 18.86 per cent for value) compared to Period II. Concurrently, instability metrics, particularly the Cuddy-Della Valle Index, indicate that while the volatility of export volumes remained relatively consistent across the two decades, the instability of export value significantly decreased in Period II (18.27 per cent to 8.95 per cent), suggesting that India achieved more stable revenue from dry chilli exports in the latter decade despite a slower growth rate.

Table 1: Growth and instability of dry Chilli exports from India

Period	Particulars	Export Quantity(tonnes)	Export Value (USD)
Period I (2004-5 to 2013-14)	CAGR (%)	10.94***	18.86***
	CV (%)	32.12	46.32
	CDVI (%)	12.75	18.27
Period II (2014-15 to 2023-24)	CAGR (%)	5.15**	10.17***
	CV (%)	19.49	29.58
	CDVI (%)	13.23	8.95
Overall (2004-05 to 2023-24)	CAGR (%)	6.92***	12.38***
	CV (%)	38.07	59.37
	CDVI (%)	14.25	17.31

Note:

1. ** and *** indicate significance at 5 per cent and 1 per cent respectively.
2. CAGR- Compound annual growth rate.
3. C.V.- Coefficient of variation.
4. CDVI- Cuddy-Della Valle index.

The data presented in Table 2 reveals a dramatic acceleration and stabilization in India's dry chilli exports to China over a two-decade span. Analysing the overall period (2004-05 to 2023-24), both export quantity and value demonstrated highly significant compound annual growth rates (CAGR) of 38.00 per cent and 42.31 per cent, respectively. When dividing the data into two distinct phases, it becomes evident that Period II (2014-15 to 2023-24) experienced explosive growth compared to Period I, with the CAGR for export value surging from 36.83 per cent

to an impressive 84.20 per cent. Crucially for trade competitiveness, this period of rapid volume and value expansion was accompanied by a marked decline in market volatility; the Cuddy-Della Valle Index (CDVI) for export value dropped substantially from 77.83 per cent in Period I to 38.17 per cent in Period II, demonstrating that the recent decade has yielded not only significantly higher but also much more stable revenue streams for Indian dry chilli exports to the Chinese market.

Table 2: Growth and instability in dry Chilli exports from India to China

Period	Particulars	Export Quantity (tonnes)	Export Value (USD)
Period I (2004-5 to 2013-14)	CAGR (%)	35.26**	36.83**
	CV (%)	120.77	115.29
	CDVI (%)	83.65	77.83
Period II (2014-15 to 2023-24)	CAGR (%)	74.14***	84.20***
	CV (%)	81.45	82.35
	CDVI (%)	40.66	38.17
Overall (2004-05 to 2023-24)	CAGR (%)	38.00***	42.31***
	CV (%)	143.06	146.79
	CDVI (%)	68.44	66.63

Note:

1. ** and *** indicate significance at 5 per cent and 1 per cent respectively.
2. CAGR- Compound annual growth rate.
3. C.V.- Coefficient of variation.
4. CDVI- Cuddy-Della Valle index.

Based on the data presented in Table 3 the growth and instability of India's dry chilli exports to Sri Lanka from 2004-05 to 2023-24. Over the entire twenty-year span, exports demonstrated significant overall positive trends, yielding compound annual growth rates (CAGR) of 2.86 per cent for quantity and 7.13 per cent for value. However, analysing the data across two distinct decades reveals a sharp deceleration in trade momentum; while Period I (2004-05 to 2013-14) enjoyed strong, highly significant growth in both export volume (8.19 per cent) and value

(12.31 per cent), Period II (2014-15 to 2023-24) experienced a contraction in export quantity (-2.20 per cent) alongside stagnant, statistically non-significant growth in export value (3.60 per cent). Despite this significant downturn in growth during the latter decade, the underlying instability of the trade-as measured by the Cuddy-Della Valle Index (CDVI)-remained relatively contained, with quantity instability hovering around 7 per cent for both periods and value instability actually showing a slight improvement from 21.04 per cent in Period I to 17.46 per cent in Period II.

Table 3: Growth and instability in dry Chilli exports from India to Sri Lanka

Period	Particulars	Export Quantity (tonnes)	Export Value (USD)
Period I (2004-5 to 2013-14)	CAGR (%)	8.19***	12.31***
	CV (%)	23.52	38.04
	CDVI (%)	7.03	21.04
Period II (2014-15 to 2023-24)	CAGR (%)	-2.20**	3.60NS
	CV (%)	9.75	20.00
	CDVI (%)	7.48	17.46
Overall (2004-05 to 2023-24)	CAGR (%)	2.86***	7.13***
	CV (%)	20.78	39.87
	CDVI (%)	14.69	20.26

Note:

1. ** and *** indicate significance at 5 per cent and 1 per cent respectively.
2. CAGR- Compound annual growth rate.
3. C.V.- Coefficient of variation.
4. CDVI- Cuddy-Della Valle index.
5. NS = non-significant

Based on the data presented in the Table 4 the growth and stability of India's dry chilli exports to Thailand across two distinct decades. Over the entire 20-year span (2004-05 to 2023-24), the trade exhibited highly significant overall growth, with compound annual growth rates (CAGR) of 24.85 per cent for export quantity and 30.20 per cent for export value. However, this overarching success masks a dramatic deceleration; Period I (2004-05 to 2013-14) was characterized by explosive, highly significant growth (CAGRs of 73.93 per cent for quantity and 79.52 per cent for value), whereas Period II (2014-15 to 2023-24) saw a

severe plateau, with export volume experiencing a non-significant decline (-1.18 per cent) and value growth dropping substantially to 4.43 per cent. Despite this sharp halt in expansion during the latter decade, the trade benefited from a massive reduction in market volatility, as evidenced by the Cuddy-Della Valle Index (CDVI) plunging from over 36 per cent in Period I to roughly 11 per cent for both volume and value in Period II, indicating a shift from volatile, hyper-rapid expansion to a highly stabilized, albeit stagnant, trade environment.

Table 4: Growth and instability in dry Chilli exports from India to Thailand

Period	Particulars	Export Quantity (tonnes)	Export Value (USD)
Period I (2004-5 to 2013-14)	CAGR (%)	73.93***	79.52***
	CV (%)	115.99	115.68
	CDVI (%)	37.65	36.74
Period II (2014-15 to 2023-24)	CAGR (%)	-1.18NS	4.43***
	CV (%)	11.26	17.16
	CDVI (%)	10.62	11.03
Overall (2004-05 to 2023-24)	CAGR (%)	24.85***	30.20***
	CV (%)	66.21	73.26
	CDVI (%)	38.54	37.07

Note:

1. *** indicate significance at 1 per cent.
2. CAGR- Compound annual growth rate.
3. C.V.- Coefficient of variation.
4. CDVI- Cuddy-Della Valle index.
5. NS = non-significant

The data presented in the Table 5 details the growth and instability of India's dry chilli exports to Malaysia over a twenty-year period (2004-05 to 2023-24), revealing an overall negative trajectory characterized by a significant long-term decline in export volume (a compound annual growth rate of -4.68 per cent) and a stagnant, non-significant shift in export value (-0.07 per cent). Breaking the data down by decade shows that trade performance worsened over time; while Period I (2004-05 to 2013-14) exhibited weak, non-significant positive growth for both quantity (1.12 per cent) and value (8.04 per cent), Period II (2014-15 to 2023-24) experienced a statistically significant

contraction in export volume (-5.21 per cent) alongside essentially flat value growth (0.47 per cent). However, despite this deteriorating growth pattern, the market volatility-as measured by the Cuddy-Della Valle Index (CDVI)-improved dramatically in the latter decade, with quantity instability plummeting from 26.18 per cent in Period I to just 9.95 per cent in Period II and value instability dropping from 28.59 per cent to 13.29 per cent, indicating that while India is exporting fewer dry chillies to Malaysia, the remaining trade flow has become highly stable.

Table 5: Growth and instability in dry Chilli exports from India to Malaysia

Period	Particulars	Export Quantity (tonnes)	Export Value (USD)
Period I (2004-5 to 2013-14)	CAGR (%)	1.12NS	8.04NS
	CV (%)	26.39	33.75
	CDVI (%)	26.18	28.59
Period II (2014-15 to 2023-24)	CAGR (%)	-5.21***	0.47NS
	CV (%)	18.82	13.36
	CDVI (%)	9.95	13.29
Overall (2004-05 to 2023-24)	CAGR (%)	-4.68***	-0.07NS
	CV (%)	38.43	28.93
	CDVI (%)	24.47	28.93

Note:

1. *** indicate significance at 1 per cent.
2. CAGR- Compound Annual Growth Rate.
3. C.V.- Coefficient of variation.
4. CDVI- Cuddy-Della Valle index.
5. NS = non-significant

The data presented in the Table 6 illustrates the growth and instability of India's dry chilli exports to the USA over a twenty-year period from 2004-05 to 2023-24. Overall, the trade demonstrated positive long-term growth, with a modest compound annual growth rate (CAGR) of 1.54 per cent for export quantity and a highly significant 10.00 per cent for export value. Breaking the timeline into two distinct decades reveals a favourable shift in both momentum and market stability; while Period I (2004-05 to 2013-14) saw stagnant, non-significant quantity growth (0.86 per cent) alongside high value growth (15.73 per cent), Period II

(2014-15 to 2023-24) achieved statistically significant, robust growth in both volume (5.66 per cent) and value (10.85 per cent). Most notably, market volatility improved dramatically over time, as demonstrated by the Cuddy-Della Valle Index (CDVI) plunging from 28.72 per cent for quantity and 29.39 per cent for value in Period I down to highly stable levels of 11.65 per cent and 9.89 per cent, respectively, during Period II, signalling a maturation into a much more reliable and steadily expanding export market for Indian dry chillies.

Table 6: Growth and instability in dry Chilli exports from India to USA

Period	Particulars	Export Quantity (tonnes)	Export Value (USD)
Period I (2004-5 to 2013-14)	CAGR (%)	0.86NS	15.73***
	CV (%)	28.86	54.08
	CDVI (%)	28.72	29.39
Period II (2014-15 to 2023-24)	CAGR (%)	5.66***	10.85***
	CV (%)	20.43	32.82
	CDVI (%)	11.65	9.89
Overall (2004-05 to 2023-24)	CAGR (%)	1.54*	10.00***
	CV (%)	24.39	54.42
	CDVI (%)	22.57	21.26

Note:

1. * and *** indicate significance at 10 per cent and 1 per cent respectively.
2. CAGR- Compound Annual Growth Rate.
3. C.V.- Coefficient of variation.
4. CDVI- Cuddy-Della Valle index.
5. NS = non-significant

Factors Influencing the Export of Dry Chilli

Based on the provided Table 7 multiple regression analysis identifying the key macroeconomic variables that influence India's dry chilli exports across 20 observations. The statistical model demonstrates an exceptionally strong fit, boasting an R^2 value of 0.938350 and an Adjusted R^2 of 0.916332. This indicates that the five independent variables included in the model collectively account for over 91 per cent of the variation in the volume of dry chillies exported, making it a highly reliable framework for understanding the underlying market dynamics driving the trade.

The data reveals that global market conditions and price competitiveness dictate India's export performance. The "Total world export of dry chilli" exerts a highly significant positive influence (with a p-value of 0.00007), demonstrating that Indian exports scale reliably alongside overall global demand. Furthermore, the interplay between domestic and international pricing is critical: the "World

export price" has a significant positive impact (coefficient of 223.8296), while the "Indian export price" shows a significant negative correlation (coefficient of -203.4569). This underscores that international buyers are highly price-sensitive; higher competing global prices make Indian shipments more attractive, whereas rising domestic export prices actively deter international sales.

Interestingly, the model highlights a somewhat counterintuitive relationship with domestic supply, as "Dry chilli production in India" holds a statistically significant negative coefficient (-0.0969). This suggests that sheer increases in domestic harvest volumes do not automatically translate to higher exports, a dynamic potentially caused by surging domestic consumption absorbing the excess supply. Lastly, while the "Exchange rate" displays a massive positive coefficient (1547.7169), its high p-value of 0.4989 renders it statistically non-significant within this specific dataset, indicating that currency fluctuations alone do not

reliably predict export volumes when compared to direct pricing and global demand factors.

Table 7: Factors influencing the export of dry Chilli

Sr. no.	Factors	Co-efficient	P-value
1	Intercept (a)	-205976.9308	0.0599
2	Dry chilli production in India (X_1)	-0.0969	0.0394**
3	Total world export of dry chilli (X_2)	0.6490	0.00007***
4	Indian export price of dry chilli (X_3)	-203.4569	0.0346**
5	World export price of dry chilli (X_4)	223.8296	0.0390**
6	Exchange rate (X_5)	1547.7169	0.4989
7	R^2	0.938350	
8	Adjusted R^2	0.916332	
9	Observations	20	

Note: ** and *** indicate significance at 5 per cent and 1 per cent levels of significance, respectively.

Conclusion

The statistical analysis of India's dry chilli exports over the twenty-year period from 2004-05 to 2023-24 illustrates a successful transition from volatile expansion to matured, stable revenue generation on the global stage. While the initial decade was characterized by rapid, highly volatile growth, the subsequent decade demonstrated slower yet significantly more stable export values across diverse international markets. Notably, exports to China experienced explosive growth alongside increased stability, compensating for volume contractions or plateaus in traditional markets such as Sri Lanka, Thailand and Malaysia. Furthermore, the study confirms that India's export performance is heavily reliant on global macroeconomic conditions; it scales positively with total world demand and international prices, whereas higher domestic production and elevated domestic export prices actively hinder international trade volumes due to rising internal consumption and high price sensitivity among global buyers. Ultimately, the data indicates that while India retains its dominance as a premier exporter, sustaining this position requires a strategic balance of competitive pricing and consistent supply to meet global demand amidst shifting regional market dynamics.

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