

A Multivariate Econometric Forecast and Structural Dynamics Assessment of India's Citrus Peel Export Trajectories

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ABSTRACT

India occupies a prominent position among global citrus producers, yet its export trajectory in citrus-derived by-products—most notably citrus peel—has exhibited a sustained contraction over the past decade. This study undertakes a comprehensive econometric interrogation of India's citrus peel export performance spanning 2014–2024, deploying methodological instruments such as Compound Annual Growth Rate (CAGR), descriptive statistical profiling, and linear trend estimation to delineate long-term trade dynamics and project forward-looking scenarios.

Empirical evidence reveals a contractionary pattern, with export volumes registering a negative CAGR of -4.52% and export values declining at -3.17% , underscoring a

structural erosion of international competitiveness. Forecast simulations indicate that, under prevailing systemic conditions, export earnings are likely to approach a critical inflection point by 2028. Importantly, the negative projections generated by linear trend models are interpreted as methodological artifacts rather than literal manifestations of negative trade flows, highlighting the limitations of unidimensional forecasting frameworks.

Despite India's substantial citrus output estimated at 16–17 million tons annually—the sector's export potential remains constrained by entrenched structural bottlenecks. These include pervasive post-harvest losses, deficiencies in cold-chain infrastructure, escalating logistics costs, and the absorptive pull of robust domestic

consumption. The findings accentuate the imperative for a multi-pronged policy and infrastructural response: integrated post-harvest management systems, modernization of logistics and supply-chain networks, and targeted export-support interventions. Such measures are critical not merely to arrest the downward trajectory but to reposition India's citrus peel exports within a more resilient and globally competitive framework.

Keywords: *Citrus peel exports, Global citrus producers, Citrus peel exports, Export trajectory, Econometric interrogation*

1. Introduction

Citrus fruits constitute one of the most economically consequential horticultural commodities cultivated in India, with extensive production concentrated across Maharashtra, Madhya Pradesh, Punjab, Rajasthan, and Haryana. Nagpur—renowned as the “Orange City”—functions as a strategic hub within the national citrus economy, particularly in the cultivation and trade of mandarins. With an annual output estimated at 14–17 million tons, India consistently ranks among the foremost global producers of citrus. Yet, paradoxically, its integration into international citrus trade networks remains marginal, as domestic consumption absorbs the bulk of fresh produce, leaving only a limited surplus for export.

The citrus processing industry generates substantial volumes of peel as a residual by-product, endowed with high industrial utility owing to its concentration of essential oils, flavonoids, pectin, carotenoids, and dietary fiber. Globally, citrus peel derivatives are embedded across pharmaceutical, food-processing, and cosmetic value chains, underscoring their latent economic potential.

Despite this, India's citrus peel exports have exhibited pronounced volatility and a discernible downward trajectory over the past decade, signaling structural inefficiencies and competitive erosion.

Interrogating the determinants of this decline is critical for repositioning India's citrus by-product sector within global trade. This study therefore undertakes a systematic evaluation of historical export performance in citrus peel, employing trend analysis and predictive modeling to illuminate long-term dynamics and assess the implications of entrenched structural constraints. By situating India's citrus peel exports within both domestic production realities and international demand structures, the analysis seeks to advance a nuanced understanding of trade competitiveness and to identify pathways for sustainable valorization of citrus by-products.

2. Objectives of the Study

The study aims to:

1. Examine the historical export performance of India's citrus peel between 2014 and 2024.
2. Measure the growth trajectory using Compound Annual Growth Rate (CAGR) and descriptive statistical indicators.
3. Evaluate export volatility through statistical dispersion measures.
4. Develop forecast projections up to 2035 using linear trend modelling.
5. Identify structural, climatic, logistical, and policy-related constraints influencing export performance.

3. Review of Literature

Recent academic literature emphasizes the growing significance of citrus peel as a sustainable bio resource and industrial raw material.

Ali, Hussain, and Zaman (2022) highlight the potential of orange peel waste (OPW) in the development of functional foods, including beverages, yogurts, and extruded snacks. Their research also discusses advanced extraction techniques for isolating essential oils, carotenoids, and pectin, and explores bio-conversion processes capable of producing high-value compounds such as lactic acid, biogas, and bioethanol. These findings reinforce the economic viability of citrus peel within the framework of a circular bio economy.

Similarly, Sonawane, Patil, and Chinchore (2024) emphasize the biochemical composition of orange peel, noting its high concentration of flavonoids such as hesperidin and naringin, as well as essential oils like limonene and linalool. Their study demonstrates the antimicrobial and antioxidant properties of citrus peel extracts and discusses extraction methods such as Soxhlet extraction and aqueous processing techniques.

Dadwal and Gupta (2023) examine recent developments in citrus bioflavonoid encapsulation and highlight the increasing demand for natural antioxidants and functional ingredients in global food systems. Their work suggests that countries producing large volumes of citrus should prioritize value-added processing rather than exporting raw agricultural residues.

From an agronomic perspective, Anbalagan et al. (2021) note that India's citrus productivity remains relatively low compared with leading producers such as Brazil, China, and the United States. Yield constraints arise from limited availability of disease-free planting material, pest

infestations, and abiotic stresses including drought and salinity.

Hu et al. (2024) further demonstrate that insect pests significantly reduce citrus yield and fruit quality, increasing the likelihood of export rejection due to stringent international phytosanitary standards.

Kaur et al. (2025) identify climate-induced fruit splitting as another factor affecting citrus productivity. Their findings show that rising temperature, rainfall variability, and humidity levels increase fruit damage, thereby reducing the availability of export-grade produce. Collectively, these studies suggest that technological, climatic, and structural factors play a critical role in shaping the international competitiveness of citrus by-product exports.

In addition to studies focusing on biochemical and industrial applications of citrus peel, several studies emphasize the importance of export competitiveness and agricultural trade performance.

Balassa (1965) introduced the concept of Revealed Comparative Advantage (RCA), which is widely used to evaluate the export competitiveness of agricultural commodities in global markets. Similarly, Porter (1990) highlights the role of supply chain efficiency, infrastructure, and innovation in determining international trade competitiveness.

Recent agricultural trade studies also emphasize the importance of value chain development, export logistics, and post-harvest management in improving competitiveness of horticultural exports. Incorporating these perspectives strengthens the analytical framework for understanding India's citrus peel export performance.

4. Data Sources

The study relies exclusively on secondary data sources obtained from internationally recognized trade databases and national repositories. Export statistics for citrus peel were collected from the World Integrated Trade Solution (WITS) database for the period 2014–2024.

Supplementary information on production trends, post-harvest losses, and agricultural conditions was obtained from government reports, horticultural databases, and international agricultural research publications.

5. Research Methodology

To evaluate the export dynamics of India's citrus peel sector, the study employs a quantitative analytical framework combining descriptive statistics and econometric forecasting techniques.

5.1 Compound Annual Growth Rate (CAGR)

CAGR is used to measure the average annual growth rate of export quantity and export value over the study period. It provides a standardized measure of long-term performance by smoothing year-to-year fluctuations.

5.2 Descriptive Statistical Analysis

Key statistical indicators were calculated to assess the stability and variability of export performance:

- Mean (Average export level)
- Standard Deviation (Year-to-year variability)
- Coefficient of Variation (Relative volatility)

These indicators provide insights into export stability, volatility, and structural fluctuations.

5.3 Trend Analysis and Forecast Modelling

A linear regression trend model was employed to project future export values from 2025 to 2035. The model assumes that historical trade patterns provide a basis for estimating future trajectories under unchanged structural conditions.

To estimate the long-term export trend, a simple linear regression model was used:

$$Y = a + bt$$

Where:

Y = projected export value of citrus peel

a = intercept of the regression equation

b = slope coefficient representing the annual change in export value

t = time variable representing the year of observation

The model estimates the long-term directional movement in export values based on historical data.

Table 5.1: EXPORT QUANTITY AND VALUE OF INDIA’S CITRUS PEEL 2014 – 2024

YEAR	EXPORT QUANTITY (METRIC TONS)	PERCENTAGE %	EXPORT VALUE (USD THOUSAND)	PERCENTAGE %
2014	265.27	8.45	473.32	10.67
2015	565.88	18.03	890.95	20.09
2016	364.00	11.60	506.78	11.43
2017	249.05	7.94	440.21	9.93
2018	386.34	12.31	391.79	8.84
2019	541.92	17.27	492.00	11.09
2020	253.22	8.07	379.62	8.56
2021	73.73	2.35	161.97	3.65
2022	28.83	0.92	69.97	1.58
2023	242.45	7.73	284.91	6.42
2024	167.12	5.33	342.92	7.73
TOTAL	3137.80	100	4,434.44	100

(Data Source:-World Integrated Trade Solution)

PERFORMANCE TOOLS	EXPORT QUANTITY	EXPORT VALUE
MEAN	285.25	391.79
SD	170.31	212.21
CV	1.67	1.90
CAGR	-4.52	-3.17

The export statistics reveal different phases over the last ten years. The first notable peak occurred between 2013 and 2016, with an 8.45% share in quantity (265.27 MT) and a 10.67% share in value (473.32 USD Thousand). The highest points were reached in 2014 - 2015, with 18.03% in quantity and 20.09% in value. During 2016 - 2019, exports maintained high volumes but lower values, with 2016 - 2017 showing 7.94% and 2018 - 2019 around 8.84% in quantity, and 17.27% and 9.93% in value, respectively, indicating a shift towards higher volume but lower value. This trend reversed slightly in the following year, with both metrics dropping below previous levels. Between 2021 and 2022, exports declined by 0.92% in quantity and 1.58% in value, a decrease associated with the pandemic's impact, totaling 8.07% in quantity and 8.56% in value during 2019-2022. In 2022 - 2024, the data reflect a drop to 7.73% in quantity (242.45 MT) and

6.42% in value (342.92 USD Thousand), indicating a higher value per kilogram despite lower volumes, followed by a slight increase in 2023- 2024 with 7.73% in quantity and 5.33% in value.

The Compound Annual Growth Rate (CAGR) in India’s citrus peel exports from 2014 to 2024 results in a negative CAGR of -4.52% in export quantity and -3.17% in export value. The smaller decline in export value compared to quantity suggests that prices remained relatively stable, possibly due to inflation or improved quality standards.

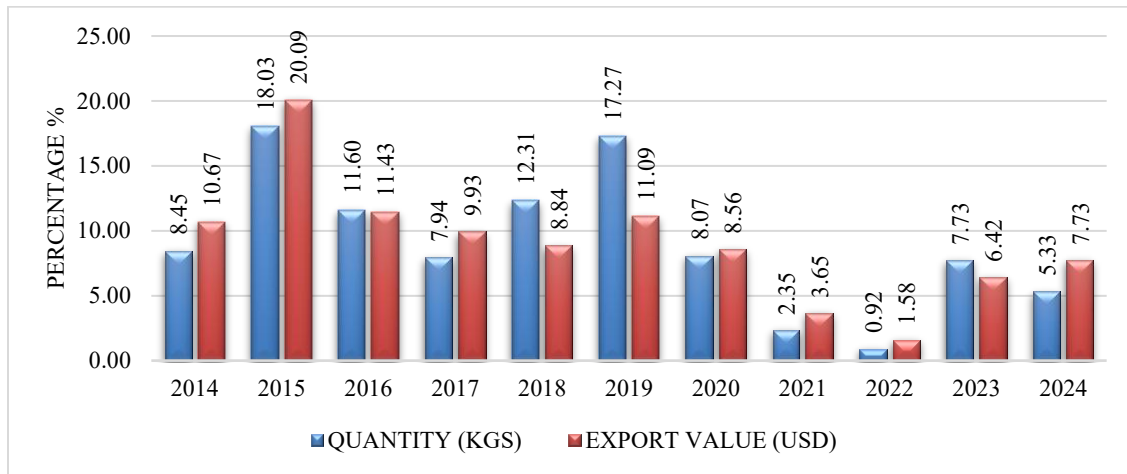
The mean export quantity between 2014 and 2024 is **285.25 MT**, and the mean export value is **391.79 USD thousand**. These averages represent the annual level of citrus peel exports over the ten-year period. The typical annual export performance of India’s citrus peel during this period.

The Standard Deviation (SD) in Export Quantity is **170.31 MT** and in Export Value is 212.21 USD Thousand shows a large change from year to year, meaning export performance is inconsistent.

The Coefficient of Variation (CV) $CV = (\text{Standard Deviation} / \text{Mean}) \times 100$ is 59.7% for export quantity and 54.2% for export

value, showing high variability compared to the mean. The coefficient of variation expressed in percentage terms indicates substantial volatility in export performance. Values above 50% suggest significant fluctuations in export quantities and earnings over the study period, reflecting instability in India's citrus peel export sector.

Figure 5.1: EXPORT QUANTITY AND VALUE OF INDIA'S CITRUS PEEL 2014 – 2024



TREND ANALYSIS

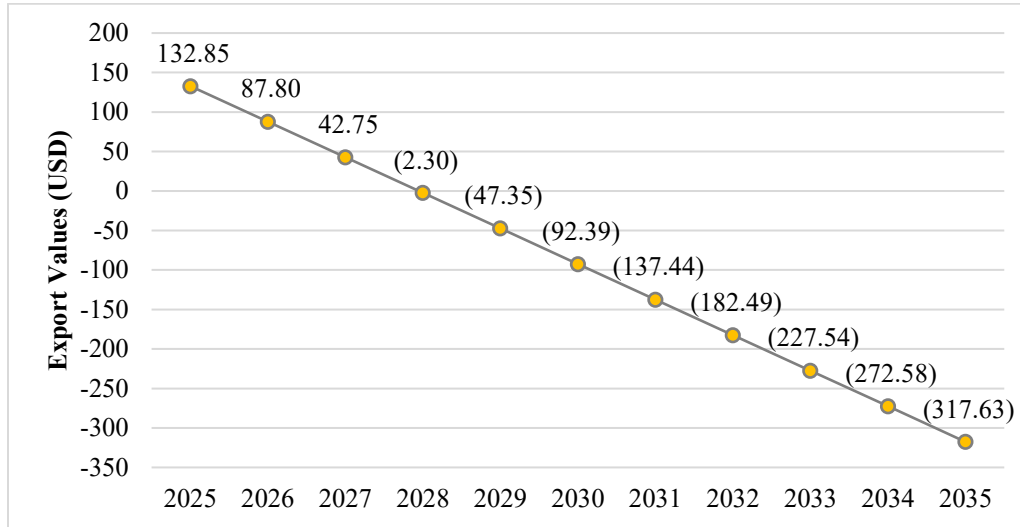
Citrus is a highly volatile commodity due to its perishability and climate sensitivity. Trend analysis forecasts India's future export values for 2025–2035, based on citrus peel export data from the World Integrated Trade Solution (WITS) database, covering 2014-2024.

Table 5.2: PROJECTED EXPORT VALUES OF INDIA'S CITRUS PEEL (2025 – 2035)

YEAR	EXPORT VALUE (USD THOUSAND)
2025	132.85
2026	87.80
2027	42.75
2028	-2.30
2029	-47.35
2030	-92.39
2031	-137.44
2032	-182.49
2033	-227.54
2034	-272.58
2035	-317.63

The projection from 2025 to 2035 indicates a significant decline. The value is high at 132.85 Thousand USD in 2025, then drops sharply to 87.80 Thousand USD in 2026 and further to 42.75 Thousand USD in 2027. In 2028, it turns negative at -2.30 Thousand USD, signifying a shift from profit to loss. Subsequently, the losses grow each year, reaching -317.63 Thousand USD by 2035.

Figure 5.2: PROJECTED EXPORT TREND OF INDIA'S CITRUS PEEL (2025 – 2035)



6. Empirical Results and Interpretation

The empirical analysis reveals significant volatility and an overall declining trend in India's citrus peel exports between 2014 and 2024.

The negative CAGR values (-4.52% for export quantity and -3.17% for export value) indicate a sustained contraction in export performance. While export value has declined at a slower pace than quantity, this discrepancy suggests that price adjustments or inflationary pressures may have partially offset declining volumes.

Descriptive statistical indicators further reveal the instability of export performance. The high standard deviation values demonstrate substantial year-to-year fluctuations in both export quantity and value. Similarly, the coefficient of variation exceeding 1 for both variables confirms a high level of volatility relative to the mean. This instability suggests that India's citrus peel export sector is highly sensitive to

external shocks, logistical disruptions, and climatic variability.

7. Forecast Data Analysis (2025–2035)

The regression-based projection indicates a sharp downward trajectory in export values over the next decade.

The model predicts that export value may decline from approximately USD 132.85 Thousand in 2025 to negative growth levels by 2028, signaling a potential structural collapse in export competitiveness if current conditions remain unchanged.

Beyond 2028, the model projects a continued deterioration, with losses potentially exceeding USD 300 Thousand by 2035.

Although negative trade values in forecasting models often reflect theoretical projections rather than actual economic outcomes, the trend clearly signals serious structural challenges within the citrus export ecosystem.

Forecast Data - Interpretation

The linear trend projection indicates a continuous decline in export values from 2025 onward. The model produces negative values after 2028. In real trade statistics, export values cannot be negative; therefore, these projections should not be interpreted as actual losses. Instead, they reflect a limitation of the linear trend model when extended far beyond the historical data range.

The negative values therefore represent the continuation of the declining trend under the model assumptions rather than real economic outcomes.

Forecasting Data- Scope & Limitation

The forecasting analysis is based on export data covering the period 2014–2024. Although this dataset captures recent export dynamics, the relatively short time span may limit the statistical reliability of long-term projections up to 2035. Future studies could improve forecast accuracy by incorporating a longer historical dataset covering earlier years of citrus peel exports.

8. Key Determinants of Export Decline

8.1 Post-Harvest Losses Post-harvest inefficiencies constitute a primary structural constraint on India's citrus export potential. Losses ranging between 8.3% and 30.7% substantially diminish the availability of export-grade produce. Deficiencies in storage infrastructure, inadequate ventilation during transit, substandard handling practices, and the absence of a robust cold-chain network collectively exacerbate these losses, undermining both quality and volume in international markets.

8.2 Climatic Variability Citrus cultivation is acutely vulnerable to climatic fluctuations. Variability in temperature, rainfall, and humidity heightens the incidence of fruit splitting, pest infestation, and physiological disorders, thereby compromising peel integrity and reducing its suitability for

export. Climatic volatility thus represents a systemic risk to both productivity and quality assurance.

8.3 Domestic Consumption Pressure

Approximately 75% of India's citrus output is absorbed by domestic markets, leaving only a marginal surplus for international trade. Strong internal demand—intensified during public health crises such as the COVID-19 pandemic—further constrains exportable volumes, reinforcing the structural imbalance between production capacity and global market participation.

8.4 Rising Global Freight Costs

Geopolitical disruptions in maritime trade have precipitated sharp increases in container freight rates, now 2.5–3 times higher than historical levels. Extended transit durations and elevated shipping costs erode profitability margins for perishable commodities such as citrus peel, diminishing India's competitiveness in global supply chains.

8.5 Pest and Disease Management Challenges

Insect pests and pathogenic diseases continue to impair citrus productivity and degrade fruit quality. Compliance with stringent international phytosanitary protocols imposes additional regulatory and financial burdens on producers and exporters, further constraining India's ability to expand its footprint in global citrus peel markets.

9. Limitations of the Study

The study relies primarily on secondary trade data and linear forecasting models, which assume the continuation of existing trends. However, future export performance may be influenced by:

- Policy reforms
- Technological innovations
- Improvements in supply chain infrastructure

- Expansion of value-added citrus processing industries

These factors could potentially alter the projected outcomes.

10. Conclusion

The analysis underscores that India's citrus peel export sector is undergoing a structural contraction, marked by persistent negative growth, heightened volatility, and intensifying global competitive pressures. Despite the country's robust production base, export performance remains systematically constrained by post-harvest inefficiencies, climatic vulnerabilities, logistical disruptions, regulatory frictions, and the absorptive pull of strong domestic demand.

Reversing this trajectory necessitates a coordinated policy and industry response, with emphasis on:

- Establishing modern, resilient cold-chain infrastructure
- Expanding investment in value-added citrus processing and derivative industries
- Strengthening integrated pest management and quality assurance systems
- Enhancing export logistics, trade facilitation, and market access mechanisms

A strategic framework that fuses agricultural innovation, supply-chain modernization, and export-promotion policies is imperative. Such an integrated approach has the potential to reposition citrus peel from a low-value agricultural residue into a high-value industrial commodity, thereby transforming India's citrus by-product sector into a globally competitive export domain.

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