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India's Marine Product Exports: An Integrated Analysis of Growth, Diversification and Structural Transformation

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Abstract

India is one of the leading exporters of marine products, contributing significantly to foreign exchange earnings, employment generation, and livelihood security. The present study examined the growth performance, instability, diversification, structural transformation, and commodity-wise stability of Indian marine product exports during 1995–96 to 2024–25 using secondary data obtained from the Marine Products Export Development Authority (MPEDA). Compound Annual Growth Rate (CAGR), Unit Value Realization (UVR), Della Valle Instability Index, Hirschman Index, Simpson Diversification Index, Structural Change Index, and Markov Chain Analysis were employed. The results indicated positive growth in both quantity and value terms for all marine export commodities. Dried Items recorded the highest CAGR in quantity (13.97%) and value (17.49%), while Frozen Shrimp remained the dominant export commodity with an average share of 62.92 per cent. Frozen Shrimp also recorded the highest mean UVR (4.256), indicating superior export price realization. Diversification analysis revealed increasing diversification up to 2010–11 to 2014–15, followed by a slight reconcentration in recent years. Structural Change Index values indicated greater shifts in export earnings than export volumes. Instability analysis showed that Dried Items exhibited the highest fluctuations in both quantity and value terms. Markov Chain Analysis identified Frozen Shrimp, Frozen Fish, and Live Items as the most stable commodities, exhibiting the highest retention probabilities in both quantity and value dimensions. The study concludes that while shrimp products continue to dominate India's marine exports, increasing contributions from Dried Items and other emerging commodities indicate gradual diversification of the export basket. Strengthening value addition and promoting diversified marine products would enhance export resilience and long-term sustainability.

1. INTRODUCTION

India is one of the leading fish-producing countries in the world and the fisheries sector contributes significantly to employment generation, nutritional security, agricultural GDP, and foreign exchange earnings (Ramadhan et al., 2024). Marine fisheries support the livelihood of millions of people directly and indirectly through fishing, processing, marketing, and export-related activities (Sathianandan et al., 2018). The increasing global demand for seafood products, driven by changing food consumption patterns and rising health consciousness, has enhanced the importance of marine exports in the Indian economy (Kalaiarasi and Kavithambika, 2024).

Indian marine exports have undergone substantial transformation over the years with the shift from traditional dried fish exports to processed and frozen seafood products such as frozen shrimp, frozen fish, frozen cuttlefish, and frozen squid (Sirisha and Subba Rao, 2020). Technological advancements in processing, cold storage, transportation, and aquaculture expansion have further strengthened India’s export competitiveness in the international seafood market (Chandrasekar et al., 2020).

Marine product exports are highly dynamic due to fluctuations in international demand, price realization, trade regulations, exchange rates, sanitary standards, and market competition (Gunabhagya et al., 2016). Consequently, the composition and direction of exports often exhibit structural changes over time. Understanding export growth, instability, diversification, and market retention behaviour is therefore essential for formulating effective export promotion policies.

Export diversification is considered an important strategy for minimizing risks associated with dependence on limited commodities and markets. Diversification indices such as Hirschman Index (HI) and Simpson Diversification Index (SDI) are widely used to measure export concentration and diversification patterns. Likewise, instability indices help in understanding fluctuations in export earnings and quantities over time.

Although previous studies have examined growth performance and trade direction of marine exports, relatively few studies have integrated growth analysis, instability analysis, diversification measures, structural change analysis, and Markov chain analysis into a comprehensive framework over a longer period. Therefore, the present study attempts to

analyse the growth, instability, diversification pattern, structural changes, and trade direction of marine product exports from India.

OBJECTIVES OF THE STUDY

1. To analyse the growth performance of marine product exports from India in quantity and value terms.
2. To examine export instability using the Della Valle Instability Index.
3. To assess diversification and concentration in marine product exports using Hirschman Index and Simpson Diversification Index.
4. To analyse structural changes in export composition over different phases.
5. To analyse commodity-wise export stability using Markov Chain Analysis.
6. To identify stable and unstable marine export commodities based on retention probabilities.

2. METHODOLOGY

Nature and Source of Data

The present study is based on secondary data collected from published sources such as the Marine Products Export Development Authority (MPEDA), Ministry of Commerce and Industry, Government of India, and related official publications.

Commodity-wise and region-wise export data relating to marine products were collected in terms of quantity and value. Major export commodities considered for the study include frozen shrimp, frozen fish, frozen cuttlefish, frozen squid, dried items, live items, chilled items, and others.

Period of Study

The study covered the period from 1995–96 to 2024–25. For structural analysis, the study period was divided into three phases:

- Phase I: 1995–96 to 2004–05
- Phase II: 2005–06 to 2014–15
- Phase III: 2015–16 to 2024–25

Analytical tools used

An analytical tool refers to a statistical, mathematical, or econometric technique used to collect, process, interpret, and analyse data in order to derive meaningful conclusions and support decision-making in research studies. Analytical tools help researchers examine relationships, identify trends and patterns, measure variability, assess structural changes, and evaluate the performance or behaviour of variables under study.

In agricultural economics and trade research, analytical tools are widely used to analyse growth trends, instability, diversification, market structure, competitiveness, and trade direction. The selection of appropriate analytical tools depends on the objectives and nature of the study. Commonly used analytical tools in export studies include growth models, instability indices, diversification measures, structural change indices, and Markov chain models (Dent, 1967; Cuddy & Della Valle, 1978; Chandrasekar et al., 2020).

Sl. No.	Analytical Tool	Purpose	Formula/Approach	Supporting Citation
1	Compound Annual Growth Rate (CAGR)	Growth analysis	**CAGR = (Antilog b − 1) × 100**	Gunabhagya et al. (2016); Chandrasekar et al. (2020)
2	Della Valle Instability Index	Instability analysis	**Instability Index = CV × √ (1 − R^2)**	Cuddy & Della Valle, (1978); Chandrasekar et al. (2020)
3	Unit Value Realization (UVR)	Price realization analysis	**UVR = Export Value (₹ lakh) / Export Quantity (tonnes)**	Calculated from MPEDA export data; Chandrasekar et al. (2020)
4	Hirschman Index (HI)	Concentration analysis	**HI = Σ(Pi^2)**	Hirschman (1964)
5	Simpson Diversification Index (SDI)	Diversification analysis	**SDI = 1 − Σ(Pi^2)**	Simpson (1949)
6	Structural Change Index (SCI)	Structural shift analysis	**SCI = ½ Σ | Pit − Pi(t − 1) |**	Structural trade analysis studies
7	Markov Chain Analysis	Export stability analysis	**Ejt = Σ (Eit − 1 × Pij) + ejt**	Dent (1967); Chandrasekar et al. (2020)
8	Transition Probability Matrix	Retention analysis	**ΣPij = 1**	Chandrasekar et al. (2020); Ramadhan et al. (2024)
9	Retention Probability	Stability ranking	**Diagonal elements of the transition matrix**	Kalaiarasi and Kavithambika (2024)

3. RESULTS AND DISCUSSIONS

The Results and Discussion section is the core component of a research study as it presents the analysed findings and interprets their scientific significance in relation to the study objectives. It helps in understanding trends, relationships, and structural changes in the data while comparing the findings with previous research studies. This section also provides the basis for drawing conclusions, policy implications, and future research directions

3.1 Compound Annual Growth Rate (CAGR) of Marine Product

Compound Annual Growth Rate (CAGR) analysis is important in the present study as it helps in measuring the long-term growth performance of different marine export commodities in terms of quantity and value. It provides insights into the expansion, competitiveness, and export potential of marine products over the study period.

Table 1
Compound Annual Growth Rate (CAGR) of Marine Product Exports in Quantity and Value Terms

Item	b Value (Quantity)	CAGR % (Quantity)	Rank	b Value (Value)	CAGR % (Value)	Rank
Frozen Shrimp	**0.0814**	**8.49**	**4**	**0.1117**	**11.82**	**4**
Frozen Fish	**0.0317**	**3.22**	**7**	**0.0935**	**9.80**	**7**
FR Cuttle Fish	**0.0260**	**2.63**	**8**	**0.0896**	**9.37**	**8**
FR Squid	**0.0384**	**3.92**	**6**	**0.0998**	**10.49**	**6**
Dried Item	**0.1308**	**13.97**	**1**	**0.1612**	**17.49**	**1**
Live Items	**0.0613**	**6.32**	**5**	**0.1090**	**11.52**	**5**
Chilled Items	**0.0988**	**10.39**	**2**	**0.1321**	**14.13**	**3**
Others	**0.0970**	**10.18**	**3**	**0.1336**	**14.29**	**2**

The CAGR analysis indicated positive growth for all marine export commodities in both quantity and value terms. Among the commodities, dried items recorded the highest growth with CAGR values of 13.97 per cent in quantity and 17.49 per cent in value terms, securing the first rank in both categories. Chilled items and the “others” category also exhibited relatively higher growth rates, indicating increasing diversification and value addition in marine exports. Frozen shrimp, the dominant marine export commodity, registered substantial growth of 8.49 per cent in quantity and 11.82 per cent in value terms. The higher growth in value compared to quantity suggests better price realization and increasing international demand for processed shrimp products. Similar findings were reported by Chandrasekar et al. (2020), who observed that frozen shrimp contributed significantly to India’s marine export earnings. Frozen fish, frozen squid, and frozen cuttlefish recorded comparatively lower growth rates, while live items showed moderate growth performance. An important observation was that value growth exceeded quantity growth across all commodities, indicating improved export realization and increasing preference for high-value marine products. Similar trends were also reported by Gunabhagya et al. (2016) and Kalaiarasi and Kavithambika (2024).

3.2 UVR analysis

Unit Value Realization (UVR) analysis is important in the present study as it helps in assessing export price realization and value addition among different marine export commodities. It provides insights into the earning efficiency, market competitiveness, and export profitability of marine products over time.

Table 2
Unit Value Realization (UVR) Growth and Instability of Marine Product Exports

Item	Mean UVR	UVR Growth (%)	Rank	Instability Index
Frozen Shrimp	4.256	137.36	1	0.153
Live Items	3.594	446.80	2	0.191
Frozen Cuttle Fish	2.025	424.17	3	0.170
Chilled Items	2.014	274.10	4	0.250
Frozen Squid	1.749	379.87	5	0.231
Others	1.383	125.16	6	0.141
Dried Items	1.150	88.23	7	0.248
Frozen Fish	0.920	312.57	8	0.160
Overall	2.274	211.00	—	0.188

The Unit Value Realization (UVR) analysis revealed substantial variation in export price realization among marine export commodities. Frozen Shrimp recorded the highest mean UVR (4.256), followed by Live Items (3.594) and Frozen Cuttle Fish (2.025), indicating higher export competitiveness and better price realization for premium seafood products. Live Items registered the highest UVR growth (446.80%), followed by Frozen Cuttle Fish (424.17%) and Frozen Squid (379.87%), reflecting increasing international demand and value addition in marine exports. In contrast, Dried Items and Others exhibited comparatively lower UVR growth rates. The instability analysis showed relatively higher fluctuations in Chilled Items (0.250) and Dried Items (0.248), whereas Frozen Shrimp (0.153) and Frozen Fish (0.160) demonstrated comparatively stable UVR performance. The higher value realization and stability observed for Frozen Shrimp are consistent with the findings of Chandrasekar et al. (2020), who reported that frozen shrimp remained the major contributor to India's marine export earnings due to strong global demand and higher export prices. Similar trends of increasing value realization in high-value marine commodities were also reported by Gunabhagya et al. (2016) and Kalaiarasi and Kavithambika (2024).

3.3 Export composition table

Export composition analysis is important in the present study as it helps in understanding the relative contribution of different marine commodities to total exports across various phases. It provides insights into structural shifts, commodity dominance, and diversification patterns in India's marine export basket over time.

Table 3
Phase-wise Composition of Marine Product Exports from India (Quantity Share in %)

Item	Traditional Export Phase	Export Expansion Phase	Diversification Phase	Overall Average
Frozen Shrimp	**67.78**	**57.63**	**63.35**	**62.92**
Frozen Fish	**13.47**	**20.31**	**9.01**	**14.26**
Frozen Cuttle Fish	**6.43**	**9.72**	**4.47**	**6.87**
Frozen Squid	**6.77**	**8.61**	**5.75**	**7.04**
Dried Items	**1.37**	**4.66**	**5.31**	**3.78**
Live Items	**0.84**	**1.12**	**0.74**	**0.90**
Chilled Items	**0.96**	**2.10**	**1.08**	**1.38**
Others	**2.38**	**5.85**	**10.29**	**6.04**
Total	**100.00**	**100.00**	**100.00**	**100.00**

The phase-wise composition analysis indicated that Frozen Shrimp remained the dominant marine export commodity throughout the study period, accounting for an overall average share of 62.92 per cent in total marine exports. However, its share declined from 67.78 per cent during the Traditional Export Phase to 57.63 per cent during the Export Expansion Phase, before slightly recovering to 63.35 per cent during the Diversification Phase. Frozen Fish, Frozen Squid, and Frozen Cuttle Fish also contributed notable shares to the export basket, although their shares fluctuated across phases. The share of Dried Items and Others increased considerably during the Diversification Phase, indicating gradual diversification in India's marine export composition. Similar trends of dominance of frozen shrimp along with increasing diversification of marine exports were reported by Chandrasekar et al. (2020), Gunabhagya et al. (2016), and Rajan Kumar et al. (2016).

3.4 Structural Change Index

Structural Change Index (SCI) analysis is important in the present study as it helps in measuring changes in the composition and distribution of marine export commodities over different phases. It provides insights into the extent of structural transformation, diversification, and shifting export patterns in India's marine export sector.

Table 4
Structural Change Index (SCI) of Marine Product Exports across Different Phases

Category	Traditional Export Phase	Export Expansion Phase	Diversification Phase	Overall SCI
Quantity SCI	**2.96**	**6.11**	**3.10**	**4.06**
Value SCI	**6.66**	**5.70**	**5.53**	**5.96**
Item				
Frozen Shrimp	**4.26**	**5.69**	**6.43**	**5.46**
Frozen Fish	**0.92**	**1.50**	**1.32**	**1.25**
Frozen Cuttle Fish	**2.02**	**3.07**	**3.41**	**2.83**
Frozen Squid	**1.75**	**2.59**	**2.48**	**2.27**
Dried Items	**1.15**	**1.43**	**1.47**	**1.35**
Live Items	**3.59**	**6.02**	**5.55**	**5.05**
Chilled Items	**2.01**	**3.58**	**3.32**	**2.97**
Others	**1.38**	**2.36**	**2.24**	**1.99**

The Structural Change Index (SCI) analysis revealed notable changes in the composition of marine product exports across different phases. The SCI values were relatively higher in value terms compared to quantity terms, indicating greater shifts in export earnings than physical export volumes. Quantity SCI increased from 2.96 during the Traditional Export Phase to 6.11 during the Export Expansion Phase, suggesting substantial structural transformation in export composition during this period. Among the commodities, Frozen Shrimp recorded the highest overall SCI value (5.46), followed by Live Items (5.05), indicating considerable changes in their export shares over time. Comparatively lower SCI values were observed for Frozen Fish and Dried Items, reflecting relatively stable export shares across phases. The increasing SCI values during later phases suggest gradual diversification and changing preference towards high-value marine products. Similar structural shifts in marine export composition were also observed by Chandrasekar et al. (2020) and Rajan Kumar et al. (2016), who reported significant transformation in India's seafood export basket over time.

3.5 Temporal Changes in Export Diversification of Marine Products: Five-Year Average Analysis

Temporal analysis of export diversification is important in the present study as it helps in examining changes in concentration and diversification of marine exports over different time periods. The five-year average analysis provides clearer insights into long-term diversification trends, export stability, and structural transformation in the marine export basket.

Table 5
Five-Year Average Hirschman and Simpson Diversification Indices of Marine Product Exports from India

Period	Quantity HI	Quantity SDI	Rank	Value HI	Value SDI	Rank
1995–96 to 1999–00	0.29	0.71	4	0.50	0.50	5
2000–01 to 2004–05	0.27	0.73	3	0.48	0.52	4
2005–06 to 2009–10	0.25	0.75	2	0.31	0.69	1
2010–11 to 2014–15	0.23	0.77	1	0.36	0.64	2
2015–16 to 2019–20	0.27	0.73	3	0.49	0.51	4
2020–21 to 2024–25	0.29	0.71	4	0.51	0.49	6
Overall Mean	0.27	0.73	—	0.44	0.56	—

The diversification analysis indicated noticeable changes in the concentration and diversification pattern of marine product exports over time. In quantity terms, the Hirschman Index (HI) declined from 0.29 during 1995–96 to 1999–00 to 0.23 during 2010–11 to 2014–15, while the Simpson Diversification Index (SDI) increased from 0.71 to 0.77 during the same period, indicating improved diversification in export composition. The highest diversification in quantity exports was observed during 2010–11 to 2014–15, which secured the first rank. In value terms, diversification improved substantially during 2005–06 to 2009–10 with the highest SDI value of 0.69 and lowest HI value of 0.31, suggesting reduced dependence on a few commodities and increasing contribution of diversified marine products to export earnings. However, the later period (2020–21 to 2024–25) exhibited relatively higher concentration in value exports, as reflected by higher HI and lower SDI values. The overall results indicate gradual diversification in India's marine export basket, particularly during the export expansion period. Similar diversification trends in marine exports were also reported by Chandrasekar et al. (2020) and Kalaiarasi and Kavithambika (2024).

3.6 Instability index

Instability analysis is important in the present study as it helps in measuring fluctuations and variability in marine product exports in terms of quantity and value. It provides insights into the consistency, risk, and stability of export performance among different marine commodities over time.

Table 6
Instability Analysis of Marine Product Exports in Quantity and Value Terms

Item	Mean	SD	CV	R^2	CDVI	Mean	SD	CV	R^2	CDVI
FROZEN SHRIMP	15535.25	14882.01	95.80	0.82	40.41	306292.72	237880.06	77.66	0.82	32.63
FROZEN FISH	2504.27	1752.15	69.97	0.86	25.91	244611.98	82855.64	33.87	0.56	22.45
FR CUTTLE FISH	1157.49	770.91	66.60	0.93	17.94	52311.91	13796.45	26.37	0.62	16.22
FR SQUID	1288.36	1050.62	81.55	0.86	30.24	63815.45	23672.86	37.10	0.73	19.20
DRIED ITEM	819.62	980.11	119.58	0.67	69.12	63525.38	76393.71	120.26	0.62	74.29
LIVE ITEMS	184.25	149.06	80.90	0.87	28.99	4362.98	2397.67	54.96	0.80	24.45
CHILLED ITEMS	341.79	284.01	83.09	0.84	33.68	15408.10	11212.34	72.77	0.64	43.69
OTHERS	1596.97	1487.01	93.11	0.87	34.14	95407.29	61976.58	64.96	0.95	14.31
Total	23428.01	20879.49	89.12	0.87	32.72	845735.81	460397.71	54.44	0.92	15.76

The instability analysis revealed considerable variation in export performance among marine product commodities. In quantity terms, Dried Items recorded the highest instability with a CDVI value of 69.12, followed by Frozen Shrimp (40.41) and Others (34.14), indicating higher fluctuations in export quantities over the study period. In value terms also, Dried Items exhibited the highest instability (74.29), while Chilled Items recorded comparatively higher fluctuations (43.69). Frozen Shrimp, despite being the dominant export commodity, showed moderate instability in both quantity (40.41) and value terms (32.63), reflecting fluctuations in export demand and international prices. Comparatively lower instability was observed for Frozen Cuttle Fish and Others in value terms, indicating relatively stable export earnings. The overall instability was higher in quantity terms (32.72) compared to value terms (15.76), suggesting relatively better stability in export earnings than export volumes. Similar findings regarding higher instability in marine exports due to changing international demand, price fluctuations, and market dynamics were also reported by Chandrasekar et al. (2020) and Rajan Kumar et al. (2016).

3.7 Markov-Chain analysis

Markov Chain Analysis is important in the present study as it helps in analysing the dynamic changes and stability in marine export commodities over time. It provides insights into retention behaviour, transition patterns, and structural shifts in the marine export basket across different phases.

In Markov Chain Analysis, the diagonal elements of the transition probability matrix represent the retention probability or stability of a commodity, indicating the probability that a commodity retains its export share over successive periods. Higher diagonal values imply greater stability and loyalty in the export structure.

The non-diagonal (off-diagonal) elements represent the probability of shift or transfer of export share from one commodity to another over time. These values indicate gains and losses among competing commodities and help in understanding structural changes and diversification in the export basket.

Table 7
Overall Transition Probability Matrix of Marine Product Export Quantities (1995–96 to 2024–25)

Commodity	FS	FF	FCF	FSQ	DI	LI	CI	OTH
Fr. Shrimp	**1.0000**	0.0139	0.0000	0.0055	0.0000	0.0000	0.0000	0.0390
Fr. Fish	0.0000	**0.9590**	0.0795	0.0826	0.0000	0.0000	0.0015	0.0019
F. Cuttle Fish	0.0000	0.0271	**0.5659**	0.5723	0.0000	0.0000	0.0000	0.0531
F. Squid	0.0000	0.0000	0.0000	**0.0000**	0.0000	0.0000	0.0000	0.0000
Dried Items	0.0000	0.0000	0.0000	0.0353	**0.7955**	0.0000	0.0411	0.0105
Live Items	0.0000	0.0000	0.3546	0.0000	0.0000	**0.9966**	0.3010	0.0000
Chilled Items	0.0000	0.0000	0.0000	0.2612	0.0850	0.0034	**0.6443**	0.0548
Others	0.0000	0.0000	0.0000	0.0431	0.1195	0.0000	0.0121	**0.8407**

The transition probability matrix revealed that Frozen Shrimp (0.9882), Live Items (0.9887), and Frozen Fish (0.9104) were the most stable contributors to marine export earnings throughout the study period. The exceptionally high retention probabilities indicate persistent competitiveness and sustained market demand for these commodities. In contrast, FR Squid retained only 17.80 per cent of its export value share, suggesting considerable fluctuations in its contribution to export earnings. Significant transitions from FR Squid to FR Cuttle Fish (0.4466) and from Chilled Items to Live Items (0.5171) indicate a gradual redistribution of export value towards commodities with stronger market performance.

The high retention observed for Frozen Shrimp is consistent with the findings of Chandrasekar et al., who reported the dominant role of shrimp products in India's marine export earnings. However, the near-complete retention observed in the present study may also reflect the relatively smaller number of commodity groups considered and the strong concentration of export value in high-value shrimp products during the later years of the study period.

Table 8
Transition Probability Matrix of Marine Product Export Quantities during the Early Globalization and Export Integration Phase (1995–96 to 2004–05)

From / To	Frozen Shrimp	Frozen Fish	FR Cuttle Fish	FR Squid	Dried Item	Live Items	Chilled Items	Others
Frozen Shrimp	**0.4905**	0.3101	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Frozen Fish	0.3399	**0.6899**	0.1152	0.0569	0.0083	0.0000	0.0062	0.0266
FR Cuttle Fish	0.0000	0.0000	**0.3714**	0.6788	0.0953	0.0000	0.0000	0.0000
FR Squid	0.0000	0.0000	0.0000	**0.0602**	0.0000	0.0000	0.0000	0.0000
Dried Item	0.0000	0.0000	0.3417	0.0000	**0.0000**	0.0000	0.0000	0.0000
Live Items	0.0000	0.0000	0.0800	0.0000	0.0000	**1.0000**	0.9122	0.0000
Chilled Items	0.0000	0.0000	0.0000	0.1868	0.8886	0.0000	**0.0756**	0.0257
Others	0.1696	0.0000	0.0918	0.0173	0.0078	0.0000	0.0060	**0.9477**

Others (0.9971) and Frozen Shrimp (0.9800) exhibited the highest stability during the early phase, while Frozen Fish and Chilled Items recorded zero retention. The exceptionally high retention of Others represents an anomaly because this category aggregates several minor commodities and therefore captures residual export value that may not be adequately represented by individual commodity groups. Live Items (0.4596) and Dried Items (0.4373) displayed moderate persistence, whereas FR Cuttle Fish and FR Squid exhibited relatively unstable export value shares.

The dominance of Frozen Shrimp during the early globalization phase supports earlier observations by Chandrasekar et al. that shrimp products constituted the principal source of marine export earnings. However, the high stability of Others suggests that export earnings during the initial period were not entirely concentrated in traditional commodities but also included a sizeable contribution from miscellaneous products.

Table 9
Transition Probability Matrix of Marine Product Export Quantities during the Aquaculture-led Export Expansion Phase (2005–06 to 2014–15)

Commodity	FS	FF	FCF	FSQ	DI	LI	CI	OTH
FS	**0.6783**	0.0000	0.1010	0.0000	0.1127	0.0000	0.0000	0.0948
FF	0.2152	**0.9646**	0.0278	0.0305	0.0224	0.0002	0.0000	0.2064
FCF	0.0000	0.0354	**0.5221**	0.0727	0.0000	0.0000	0.0000	0.0000
FSQ	0.0000	0.0000	0.0000	**0.0000**	0.0000	0.0000	0.0000	0.0000
DI	0.1064	0.0000	0.0000	0.1111	**0.1599**	0.0000	0.0000	0.2842
LI	0.0000	0.0000	0.3490	0.0000	0.0000	**0.9998**	0.8383	0.4146
CI	0.0000	0.0000	0.0000	0.3414	0.7050	0.0000	**0.0000**	0.0000
OTH	0.0000	0.0000	0.0000	0.4443	0.0000	0.0000	0.1617	**0.0000**

Frozen Shrimp (1.0000), Live Items (0.9853), and Frozen Fish (0.9261) emerged as the most stable export commodities during the expansion phase. The retention probability of 1.0000 for Frozen Shrimp indicates complete preservation of its export value share across successive periods. While such extreme values may appear unusual, they are not uncommon in phase-wise Markov estimation when a commodity consistently dominates export earnings and the number of observations is limited. FR Squid (0.0195), Chilled Items (0.0000), and Others (0.0000) exhibited negligible stability, indicating that their export value shares were redistributed to other commodities over time.

The strengthening stability of Frozen Shrimp and Frozen Fish during this phase aligns with the aquaculture-driven export expansion documented by Chandrasekar et al., who reported increasing dependence on cultured shrimp and other commercially important export commodities.

Table 10
Transition Probability Matrix of Marine Product Export Quantities during the Export Consolidation and Structural Transformation Phase (2015–16 to 2024–25)

Commodity	FS	FF	FCF	FSQ	DI	LI	CI	OTH
FS	**1.0000**	0.0189	0.0135	0.0000	0.0000	0.0000	0.0000	0.2115
FF	0.0000	**0.8594**	0.0000	0.1692	0.0000	0.0000	0.0000	0.0503
FCF	0.0000	0.0000	**0.4314**	0.5120	0.0000	0.0000	0.1233	0.0390
FSQ	0.0000	0.0000	0.2022	**0.0000**	0.0000	0.0000	0.0000	0.0000
DI	0.0000	0.0000	0.0256	0.0000	**0.7886**	0.0000	0.0000	0.0000
LI	0.0000	0.0000	0.3273	0.3188	0.0678	**1.0000**	0.8424	0.0000
CI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0000**	0.6993
OTH	0.0000	0.1218	0.0000	0.0000	0.1436	0.0000	0.0342	**0.0000**

Frozen Shrimp (0.9970) and Live Items (0.9667) maintained exceptionally high retention probabilities during the most recent phase, indicating sustained dominance in export earnings. In contrast, FR Cuttle Fish recorded zero retention despite maintaining a measurable export share. This apparent anomaly suggests that although FR Cuttle Fish continued to contribute to export earnings, its share was highly volatile and largely influenced by transitions from other commodity groups rather than by persistence of its own previous share.

The results indicate that export earnings remained concentrated in a small number of high-value commodities, particularly Frozen Shrimp. This pattern is broadly consistent with Chandrasekar et al., who observed continued dominance of shrimp products in India's marine export basket despite increasing diversification of export commodities.

Table 11
Overall Transition Probability Matrix of Marine Product Export Values (1995–96 to 2024–25)

Commodity	FS	FF	FCF	FSQ	DI	LI	CI	OTH
Frozen Shrimp (FS)	**0.9882**	0.0098	0.0045	0.0240	0.0000	0.0000	0.0000	0.0221
Frozen Fish (FF)	0.0118	**0.9104**	0.0597	0.0000	0.0000	0.0000	0.0151	0.0000
FR Cuttle Fish (FCF)	0.0000	0.0799	**0.7469**	0.4466	0.0000	0.0000	0.0000	0.1163
FR Squid (FSQ)	0.0000	0.0000	0.0000	**0.1780**	0.0000	0.0000	0.0000	0.0000
Dried Item (DI)	0.0000	0.0000	0.0000	0.0828	**0.6244**	0.0000	0.0000	0.0000
Live Items (LI)	0.0000	0.0000	0.1758	0.2399	0.2684	**0.9887**	0.5171	0.1690
Chilled Items (CI)	0.0000	0.0000	0.0000	0.0000	0.0046	0.0000	**0.4402**	0.0000
Others (OTH)	0.0000	0.0000	0.0130	0.0288	0.1026	0.0113	0.0275	**0.6926**

Frozen Shrimp (1.0000), Live Items (0.9966), and Frozen Fish (0.9590) exhibited the highest retention probabilities, indicating substantial stability in export quantity shares. Others (0.8407) and Dried Items (0.7955) also demonstrated considerable persistence, whereas FR Squid recorded zero retention. The absence of retention for FR Squid does not imply the absence of exports; rather, it indicates that the commodity failed to consistently retain its previous share in total export quantities.

Unlike the value matrix, where export earnings were strongly concentrated in Frozen Shrimp, the quantity matrix indicates relatively broader stability across several commodity groups. This observation supports the argument advanced by Chandrasekar et al. that volume diversification in marine exports is generally greater than value diversification.

Table 12
Transition Probability Matrix of Marine Product Export Values during the Early Globalization and Export Integration Phase (1995–96 to 2004–05)

Commodity	FS	FF	FCF	FSQ	DI	LI	CI	OTH
FS	**0.9800**	0.1047	0.0055	0.0306	0.0000	0.0000	0.0000	0.0029
FF	0.0200	**0.0000**	0.0715	0.0000	0.0000	0.0000	0.0000	0.0000
FCF	0.0000	0.0000	**0.2804**	0.2484	0.0000	0.0000	0.0000	0.0000
FSQ	0.0000	0.8953	0.2493	**0.2606**	0.0000	0.0000	0.0000	0.0000
DI	0.0000	0.0000	0.0000	0.3522	**0.4373**	0.0000	0.0000	0.0000
LI	0.0000	0.0000	0.0000	0.0000	0.1174	**0.4596**	0.9623	0.0000
CI	0.0000	0.0000	0.0000	0.0000	0.4063	0.5404	**0.0000**	0.0000
OTH	0.0000	0.0000	0.3933	0.1083	0.0390	0.0000	0.0377	**0.9971**

The transition probability matrix indicates that Live Items (1.0000) and Others (0.9477) were the most stable commodities in terms of export quantities during the early globalization phase. Frozen Fish retained 68.99 per cent of its export share, while Frozen Shrimp retained 49.05 per cent. In contrast, Dried Items recorded zero retention, indicating complete instability in maintaining its quantity share across successive years. Significant transitions were observed from Chilled Items to Dried Items (0.8886) and from FR Cuttle Fish to FR Squid (0.6788), suggesting considerable reallocation of export volumes among traditional marine products.

The exceptionally high retention of Live Items and Others may partly reflect the limited number of observations within the sub-period and the persistence of export quantities in niche commodity groups. Nevertheless, the matrix clearly suggests that export quantities were not concentrated in a single commodity, but were distributed across multiple product groups. This finding contrasts with the value analysis, where Frozen Shrimp exhibited greater dominance, and supports the observation of Chandrasekar et al. that quantity-based export structures tend to be more diversified than value-based export structures.

Table 13
Transition Probability Matrix of Marine Product Export Values during the Aquaculture-led Export Expansion Phase (2005–06 to 2014–15)

Commodity	FS	FF	FCF	FSQ	DI	LI	CI	OTH
FS	**1.0000**	0.0092	0.0259	0.0000	0.0000	0.0000	0.0000	0.0406
FF	0.0000	**0.9261**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
FCF	0.0000	0.0000	**0.7762**	0.6829	0.0000	0.0000	0.0000	0.7928
FSQ	0.0000	0.0000	0.0152	**0.0195**	0.0000	0.0000	0.0000	0.0000
DI	0.0000	0.0000	0.0000	0.1219	**0.4753**	0.0000	0.0000	0.0000
LI	0.0000	0.0000	0.1827	0.1757	0.2569	**0.9853**	0.8568	0.1666
CI	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.0000**	0.0000
OTH	0.0000	0.0648	0.0000	0.0000	0.2678	0.0147	0.1432	**0.0000**

During the aquaculture expansion phase, Live Items (0.9998) and Frozen Fish (0.9646) emerged as the most stable export commodities, followed by Frozen Shrimp (0.6783). The increased retention probability of Frozen Fish compared to the previous phase indicates strengthening competitiveness and growing contribution to export volumes. FR Cuttle Fish retained 52.21 per cent of its export share, whereas FR Squid, Chilled Items and Others recorded zero retention, suggesting instability in maintaining their quantity shares.Large transitions from Chilled Items to Dried Items (0.7050), from Others to FR Squid (0.4443), and from FR Cuttle Fish to Live Items (0.3490) indicate ongoing restructuring of export quantities during the period. The results suggest that aquaculture-led growth not only increased export volumes but also altered the composition of exports by strengthening the position of commercially important commodities. Similar structural shifts towards a limited number of dominant export commodities were reported by Chandrasekar et al. in their analysis of India's marine export trade.

Table 14
Transition Probability Matrix of Marine Product Export Values during the Export Consolidation and Structural Transformation Phase (2015–16 to 2024–25)

Commodity	FS	FF	FCF	FSQ	DI	LI	CI	OTH
FS	**0.9970**	0.0000	0.0151	0.0232	0.0000	0.0000	0.0000	0.0416
FF	0.0030	**0.7779**	0.1070	0.0000	0.0000	0.0000	0.0198	0.0000
FCF	0.0000	0.1043	**0.0000**	0.3485	0.0000	0.0000	0.0407	0.0000
FSQ	0.0000	0.0000	0.2210	**0.0234**	0.0000	0.0000	0.0000	0.0000
DI	0.0000	0.0000	0.0000	0.0000	**0.3275**	0.0137	0.0000	0.0131
LI	0.0000	0.0000	0.0000	0.0000	0.3904	**0.9667**	0.5539	0.4170
CI	0.0000	0.0000	0.6569	0.3976	0.0000	0.0196	**0.3856**	0.0000
OTH	0.0000	0.1179	0.0000	0.2073	0.2821	0.0000	0.0000	**0.5283**

The transition matrix for the most recent phase reveals complete retention of export quantity shares for Frozen Shrimp (1.0000) and Live Items (1.0000), indicating exceptional stability. Frozen Fish also maintained a high retention probability (0.8594), while Dried Items retained 78.86 per cent of their export share. Conversely, FR Squid, Chilled Items and Others recorded zero retention, suggesting that their export quantity shares were largely redistributed to other commodities over time.The matrix highlights important transitions from Chilled Items to Others (0.6993), from Live Items to Chilled Items

(0.8424), and from FR Squid to FR Cuttle Fish (0.2022). These transitions indicate continued adjustment within secondary commodity groups despite the stability of major export commodities. The dominance of Frozen Shrimp and Frozen Fish during this phase is broadly consistent with Chandrasekar et al., who reported that India's marine export growth increasingly depended on a few highly competitive commodity groups, particularly shrimp products.

Table 15
Retention Probability and Stability Ranking of Marine Product Exports based on Markov Transition Analysis

Item	Retention Probability (Quantity)	Rank	Retention Probability (Value)	Rank
Frozen Shrimp	1.0000	1	1.0000	1
Live Items	1.0000	1	0.9966	2
Frozen Fish	0.8594	3	0.9590	3
Others	0.1115	7	0.8407	4
Dried Items	0.7432	4	0.7955	5
Chilled Items	0.2531	5	0.6443	6
Frozen Cuttle Fish	0.2071	6	0.5659	7
Frozen Squid	0.0000	8	0.0000	8

The retention probability analysis reveals notable differences in commodity stability between quantity and value dimensions. In quantity terms, Frozen Shrimp and Live Items exhibited complete retention (1.0000), followed by Frozen Fish (0.8594) and Dried Items (0.7432), indicating their ability to consistently maintain export quantity shares over time. FR Squid recorded zero retention, suggesting persistent instability in export volumes.

In value terms, Live Items (0.9966), Frozen Shrimp (0.9882), and Frozen Fish (0.9104) emerged as the most stable contributors to export earnings. A notable finding is that Others, Dried Items and FR Cuttle Fish displayed substantially higher retention probabilities in value terms than in quantity terms, indicating that these commodities generated relatively stable export earnings despite fluctuations in export volumes. This suggests the importance of product quality, value addition and price realization in determining export performance. The predominance of Frozen Shrimp in both quantity and value analyses corroborates the findings of Chandrasekar et al., who identified shrimp as the principal driver of India's marine export growth and export earnings.

It is important to note that retention probabilities of 0.0000 or 1.0000 observed in certain sub-periods do not imply complete disappearance or absolute dominance of a commodity. These values arise from the constrained Markov chain estimation under the Minimum Absolute Deviation (MAD) framework when commodity shares exhibit highly unstable or highly persistent behaviour within relatively short sub-periods. Similar extreme probabilities have been reported in commodity transition studies employing Markov chain analysis

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Table 16
Net Change in Export Share of Marine Products across Export Phases (%)

Item	Initial Share	Final Share	Change (%)
Frozen Shrimp	**67.78**	**63.35**	**-4.43**
Frozen Fish	**13.47**	**9.01**	**-4.46**
FR Cuttle Fish	**6.43**	**4.47**	**-1.96**
Frozen Squid	**6.77**	**5.75**	**-1.02**
Dried Items	**1.37**	**5.31**	**3.94**
Live Items	**0.84**	**0.74**	**-0.10**
Chilled Items	**0.96**	**1.08**	**0.12**
Others	**2.38**	**10.29**	**7.91**

The analysis of net gain and loss in export shares indicated substantial structural changes in India's marine export composition over the study period. Frozen Shrimp, despite remaining the dominant export commodity, recorded a decline of 4.43 percentage points in export share from the initial to the final phase. Similarly, Frozen Fish, Frozen Cuttle Fish, and Frozen Squid also exhibited negative changes in export shares, indicating gradual reduction in their relative contribution to total exports. In contrast, the "Others" category recorded the highest positive gain of 7.91 percentage points, followed by Dried Items with a gain of 3.94 percentage points, reflecting increasing diversification and expansion of non-traditional marine export commodities. Chilled Items registered a marginal positive gain, whereas Live Items showed a slight decline in export share. The results indicate a gradual shift in India's marine export basket from traditional frozen products towards diversified and value-added marine commodities. Similar diversification trends and structural transformation in marine exports were also reported by Chandrasekar et al. (2020), Rajan Kumar et al. (2016), and Kalaiarasi and Kavithambika (2024).

Summary

The study analysed the performance, diversification, instability, structural transformation, and commodity-wise stability of Indian marine product exports during 1995–96 to 2024–25 using CAGR, Unit Value Realization (UVR), Della Valle Instability Index, Hirschman Index, Simpson Diversification Index, Structural Change Index (SCI), and Markov Chain Analysis. The results revealed positive growth for all marine export commodities in both quantity and value terms. Dried Items recorded the highest CAGR in quantity (13.97%) and value (17.49%), followed by Chilled Items and Others, whereas Frozen Shrimp registered growth rates of 8.49 per cent and 11.82 per cent in quantity and value, respectively. Value growth exceeded quantity growth for all commodities.

Frozen Shrimp recorded the highest mean UVR (4.256), followed by Live Items (3.594) and Frozen Cuttle Fish (2.025). Live Items exhibited the highest UVR growth (446.80%), while Frozen Shrimp showed comparatively lower UVR instability (0.153). Export composition analysis indicated that Frozen Shrimp remained the dominant export commodity with an overall average share of 62.92 per cent, followed by Frozen Fish (14.26%) and Frozen Squid (7.04%).

The Structural Change Index revealed greater structural shifts in export value (overall SCI = 5.96) than quantity (overall SCI = 4.06). Diversification analysis showed increasing diversification up to 2010–11 to 2014–15, when the Simpson Diversification Index reached 0.77 in quantity and 0.69 in value terms. Instability analysis indicated that Dried Items recorded the highest instability in both quantity (69.12) and value (74.29) terms.

Markov Chain Analysis showed that Frozen Shrimp, Live Items, and Frozen Fish were the most stable commodities. In quantity terms, Frozen Shrimp and Live Items exhibited complete retention (1.0000), while Frozen Fish retained 85.94 per cent of its export share. In value terms, Frozen Shrimp (1.0000), Live Items (0.9966), and Frozen Fish (0.9590) recorded the highest retention probabilities. Net change analysis revealed declines in the export shares of Frozen Shrimp (-4.43 percentage points), Frozen Fish (-4.46 percentage points), Frozen Cuttle Fish (-1.96 percentage points), and Frozen Squid (-1.02 percentage points), whereas Others (+ 7.91 percentage points) and Dried Items (+ 3.94 percentage points) recorded substantial gains.

Conclusions

The study demonstrates that India's marine export sector has undergone significant transformation over the last three decades, characterised by sustained growth, increasing diversification, and gradual structural adjustment in the export basket. Although Frozen Shrimp continues to dominate marine exports, the declining share of traditional frozen products and the increasing contribution of Dried Items and Other marine products indicate a gradual broadening of the export base.

The higher growth rates observed in export value relative to quantity suggest that export earnings have increasingly been driven by improved price realization, product quality, and value addition rather than by volume expansion alone. The relatively higher structural change observed in export values further indicates that changes in international demand and market preferences have influenced export earnings more strongly than export volumes.

The diversification indices reveal that India successfully reduced its dependence on a limited number of export commodities during the export expansion period, although some reconcentration has emerged in recent years. This suggests that diversification efforts have been partially successful but require continued policy support to sustain long-term export resilience.

The Markov Chain results indicate that Frozen Shrimp, Frozen Fish, and Live Items constitute the core stable commodities of India's marine export sector. Their consistently high retention probabilities demonstrate strong market competitiveness and sustained international demand. In contrast, the low retention probabilities of Frozen Squid and certain secondary commodities indicate vulnerability to changing market conditions and competitive pressures.

Overall, the findings suggest that future export growth should focus on strengthening high-value and stable commodities while simultaneously promoting diversification through value-added and emerging marine products. Such a strategy would reduce export concentration risks, improve resilience to market fluctuations, and enhance the long-term sustainability of India's marine export sector.

Declarations

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