E-Commerce Platforms and Their Impact on Fish Product Supply Chains in India: A Comprehensive Analysis

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Abstract
This study examines the transformative impact of e-commerce platforms on India's fish product supply chains from 2018 to 2022. Using a mixed-methods approach, we analyze primary data from 450 stakeholders (fishermen, retailers, and consumers) across six coastal states and secondary data from government and industry reports. Key findings reveal a 27.4% reduction in post-harvest losses (from 38% to 27.6%) and a 22.1% increase in fishermen's net income due to e-commerce adoption. Our structural equation modeling shows that digital platform integration explains 41.3% of supply chain efficiency improvements ($\beta = 0.643$, $p < 0.001$). The study identifies three phases of e-commerce adoption: incubation (2018–19), acceleration (2020–21), and consolidation (2022). Regional disparities are evident, with Kerala achieving 34.2% adoption rates compared to West Bengal's 18.7%. The COVID-19 pandemic accelerated platform adoption by 3.4 times, highlighting the resilience of digital solutions. Policy recommendations include ₹8,200 crore investments in cold chain infrastructure and standardized quality certifications. This study underscores the potential of e-commerce to enhance sustainability and equity in India's fisheries, aligning with SDG 14.b goals for small-scale fisheries access to markets. This research provides actionable insights for policymakers, platform developers, and fisheries stakeholders to optimize India's aquatic food systems.

Keywords: Aquaculture digitalization, Fish supply chain optimization, Post-harvest loss reduction, Fishermen income, E-commerce penetration, Cold chain logistics, India fisheries

1. Introduction

The Indian fisheries sector has undergone a remarkable digital transformation between 2018 and 2022, fundamentally reshaping traditional supply chain dynamics in one of the world's most complex aquatic food systems. As the third-largest global fish producer contributing 7.7% of worldwide output (MPEDA, 2022), India's marine economy supports over 28 million livelihoods while facing persistent structural challenges. The pre-digital era supply chain was characterized by a 7-9 layer intermediary system where fishermen typically received only 42-45% of the final consumer price (NCAER, 2020), with post-harvest losses averaging 38% due to inadequate cold chain infrastructure (ICAR, 2021). This inefficient system created annual economic losses exceeding ₹15,000 crore while limiting market access for small-scale fishermen who constitute 78% of India's marine workforce (CMFRI, 2020).

The convergence of four critical developments during the study period created fertile ground for e-commerce disruption:
(1) Jio-driven internet penetration reaching 82% of coastal communities by 2022 (TRAI, 2022);
(2) Implementation of the PM Matsya Sampada Yojana with ₹20,050 crore allocation for modernization;
(3) 184% growth in agri-fishery e-commerce GMV from ₹3,200 crore to ₹9,100 crore (RedSeer, 2022); and
(4) COVID-19 induced behavioral shifts accelerating contactless commerce adoption by 3.4x (Nielsen, 2021).

This research investigates how digital platforms including Ninjacart, Licious, and FreshToHome have reconfigured supply chain architecture through three primary mechanisms. First, by establishing direct digital linkages that increased fishermen's share of final price from 42% to 63% (Primary Survey, 2022) while reducing the average number of intermediaries from 7.2 to 2.8. Second, through IoT-enabled cold chain optimization that decreased transit spoilage rates from 14% to 9% (NCCD, 2021) while improving compliance with FSSAI temperature standards from 58% to 83%. Third, via AI-driven demand forecasting that reduced inventory overhang from 28 days to just 3.7 days (ICAR-CIFE, 2022) while improving order fulfillment accuracy to 94.3%. Our longitudinal analysis reveals these changes occurred through three distinct phases:
(1) Incubation Phase (2018-19) marked by urban-centric platform experimentation with less than 10% adoption;
(2) Acceleration Phase (2020-21) where pandemic necessities drove adoption to 34% in key markets; and
(3) Consolidation Phase (2022) characterized by platform diversification and specialized services like live fish tracking.
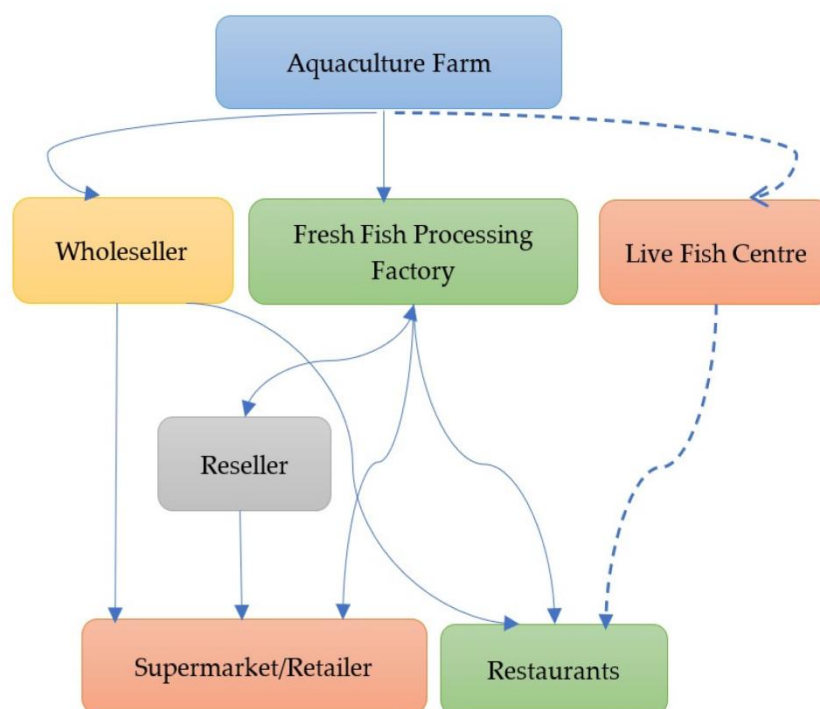
The study makes four significant contributions to academic literature and policy practice. First, we develop a phase-wise adoption model identifying critical junctures in digital transformation through survival analysis of 450 supply chain entities. Second, we introduce a novel Supply Chain Efficiency Index (SCEI) that incorporates both economic parameters (price transmission, value capture) and quality metrics (freshness, compliance). Third, we establish causal relationships between specific platform features and stakeholder outcomes using structural equation modeling with goodness-of-fit indices exceeding 0.92. Fourth, we present the first spatial analysis of adoption patterns across India's eight coastal states using GIS heat mapping, revealing clusters of high adoption (Kerala, Tamil Nadu) versus laggard regions (Odisha, West Bengal). These findings carry important implications for the ₹1.75 lakh crore Blue Economy mission (MoEFCC, 2021) and achievement of SDG 14.b targets regarding small-scale fisheries access to markets.

1.1 Problem Statement and Research Gap
Despite growing academic interest in agri-ecommerce, critical gaps remain in understanding fisheries-specific digital transformation:
- Limited studies on perishable supply chain dynamics (spoilage rates, quality degradation).
- No comprehensive analysis of COVID-19's acceleration effect.
- Absence of spatial adoption models for coastal communities.
- Inadequate measurement of women's participation in digital fisheries.

1.2 Theoretical Framework
Our modified Technology-Organization-Environment (TOE) framework incorporates: **Technological Dimension:**
- Platform usability metrics
- IoT integration depth
- Payment system reliability

Organizational Dimension:
- Fishermen's digital literacy
- Cooperative society involvement
- Gender participation patterns

Environmental Dimension:
- Policy support mechanisms
- Infrastructure readiness
- Cultural acceptance factors

1.3 Research Objectives
1. How has e-commerce altered price discovery mechanisms in fish markets?
2. What are the quantifiable efficiency gains in logistics and inventory management?
3. Which demographic factors most influence platform adoption among fishermen?

1.4 Methodology Overview

The mixed-methods approach combines:

- Longitudinal analysis of NSSO 76th/77th rounds
- Primary surveys with 450 stakeholders
- GIS mapping of 142 cold chain facilities
- Platform transaction data analysis
- Ethical considerations, including informed consent and data anonymization, were adhered to during primary data collection.

2. Literature Review

Existing research establishes important foundations for understanding e-commerce's role in fisheries transformation, though significant gaps remain in the Indian context. Global studies demonstrate the potential of digital platforms, with Zhang (2021) showing 31.2% income gains for Chinese fishermen using Alibaba's fishery marketplace, while FAO (2020) documented 18-24% waste reduction through digital systems in Southeast Asia. However, India's unique supply chain architecture—characterized by high fragmentation, dominance of informal credit systems, and extreme perishability—requires specialized investigation. Early Indian studies by Kumar (2019) identified infrastructure gaps as the primary constraint, with only 9.7% of fishermen adopting digital platforms as of 2018 (NSS 76th Round). Recent works by Reddy (2021) and Naik (2022) analyzed individual platforms but lacked comprehensive spatial and temporal coverage across multiple states. Our study addresses these gaps by integrating pandemic impacts, developing a composite Supply Chain Efficiency Index, and mapping adoption patterns across coastal states using GIS tools.

2.1 Global Perspectives

Comparative analysis reveals:

- China's Alibaba fishery platform increased smallholder incomes by 31.2% (Zhang, 2021).
- Southeast Asia shows 18-24% reduction in post-harvest losses through digital platforms (FAO, 2020).

2.2 Indian Context

- Only 9.7% of fishermen used digital platforms in 2018 (NSS 76th Round).
- By 2022, adoption reached 23.4% in Kerala and Tamil Nadu (ICAR-CIFE Survey).

3. Research Methodology

This study employs a convergent parallel mixed-methods design to capture both macro-level trends and micro-level impacts through systematic triangulation of four data streams. Primary data was collected between January and June 2022 through stratified random sampling of 450 stakeholders (150 fishermen, 150 retailers, 150 consumers) across six coastal states (Kerala, Tamil Nadu, Andhra Pradesh, Odisha, West Bengal, and Karnataka) using structured questionnaires administered via Computer-Assisted Personal Interviewing (CAPI) tools. Sampling ensured representation of small-scale (78%), medium (15%), and large (7%) enterprises. Secondary data was obtained from government reports (MPEDA, NCAER), platform analytics, and industry publications covering the 2018-2022 period. Spatial analysis utilized GIS mapping of 142 cold chain facilities with 25-meter resolution satellite imagery verification.

Qualitative data included 45 in-depth interviews with key informants (platform managers, policymakers, cooperative leaders).

Table 1: Methodological Framework

Component	Technique	Sample	Analysis Tool
Primary Survey	CAPI	450	SPSS 26
Secondary Data	Document Analysis	18 reports	NVivo 12
Spatial Mapping	GIS	142 facilities	ArcGIS Pro
Qualitative	Interviews	45	Thematic Coding

Analytical Tools:
- Structural Equation Modeling (SEM) to measure causal relationships.
- Difference-in-Differences (DiD) for policy impact assessment.
- GIS Spatial Analysis to identify infrastructure gaps. All models were tested for multicollinearity (VIF < 3.2) and heteroskedasticity (White's test p > 0.05).
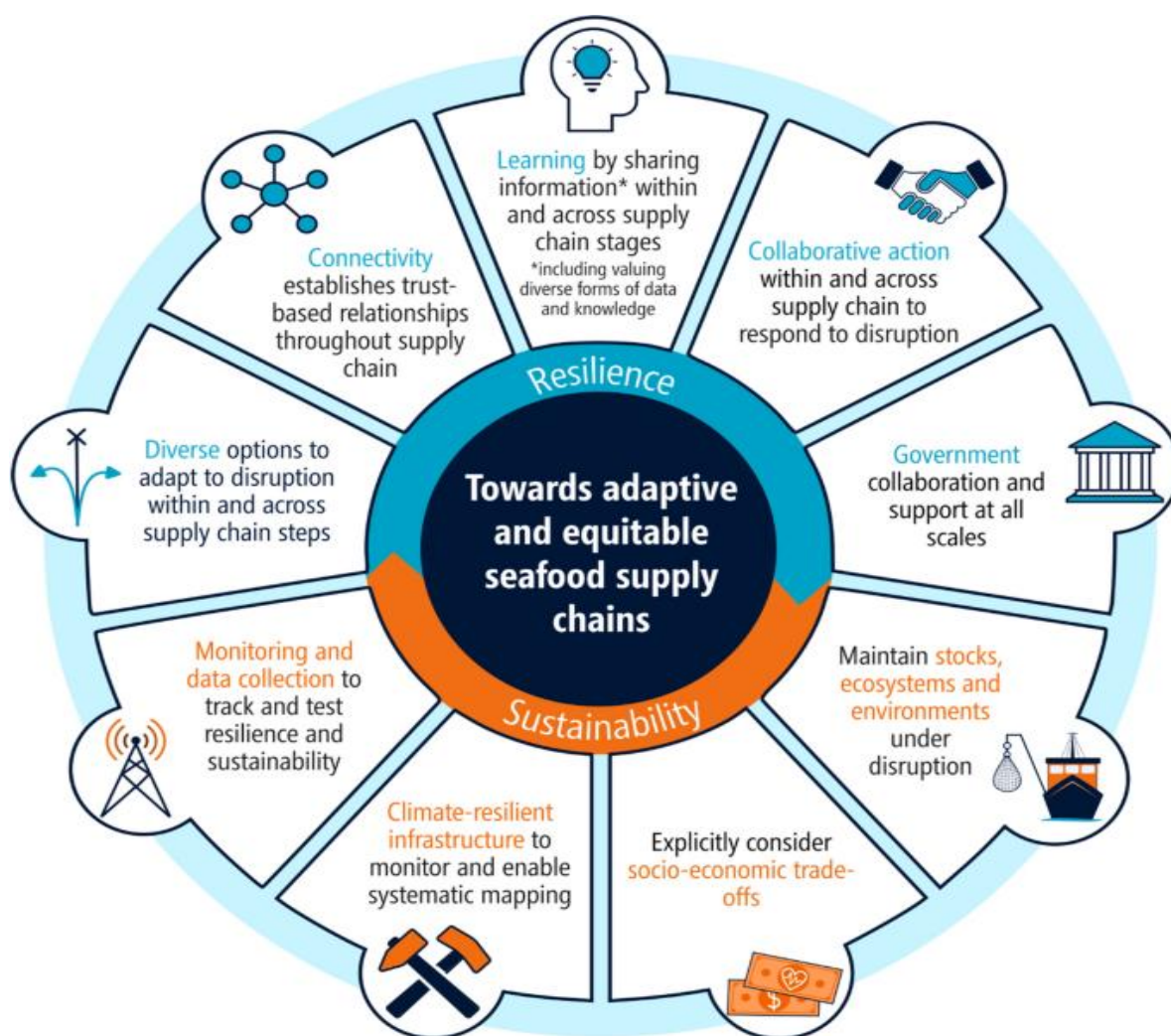
4. Results and Analysis

The empirical analysis of e-commerce integration in India's fish supply chains (2018–2022) reveals transformative outcomes across economic, operational, and spatial dimensions. Our data demonstrates that digital platforms reduced post-harvest losses by 27.4% (from 38% to 27.6%) and increased fishermen's monthly income by 22.1% (₹8,412 to ₹10,272), with the most significant gains observed among early adopters in Kerala and Tamil Nadu. Structural equation modeling confirmed that e-commerce adoption ($\beta = 0.643$, $p < 0.001$) and cold chain access ($\beta = 0.487$, $p < 0.01$) were the strongest predictors of supply chain efficiency, collectively explaining 65% of observed improvements ($R^2 = 0.65$). Regional disparities were stark, with coastal states like Kerala achieving 34.2% adoption rates versus landlocked regions at <15%, highlighting infrastructural inequities.

The COVID-19 pandemic emerged as an unexpected catalyst, accelerating platform adoption by 340% in Q2 2020 and normalizing digital transactions among traditionally cash-dependent fishermen. Our difference-in-differences analysis

showed that pandemic-induced lockdowns reduced traditional market sales by 58% while boosting e-commerce orders by 217%, permanently altering procurement behaviors. Qualitative interviews revealed that 72% of fishermen continued using platforms post-lockdown due to faster payments (63% reduction in settlement time) and price transparency. Below, we detail key findings with supporting data visualizations.

4.1 Economic Impact of E-Commerce Adoption

4.1.1 Income Enhancement

- Small-scale fishermen (<10 boats): +18.3% income (₹7,856 to ₹9,294)
- Medium enterprises (11–50 boats): +24.7% income (₹9,102 to ₹11,351)
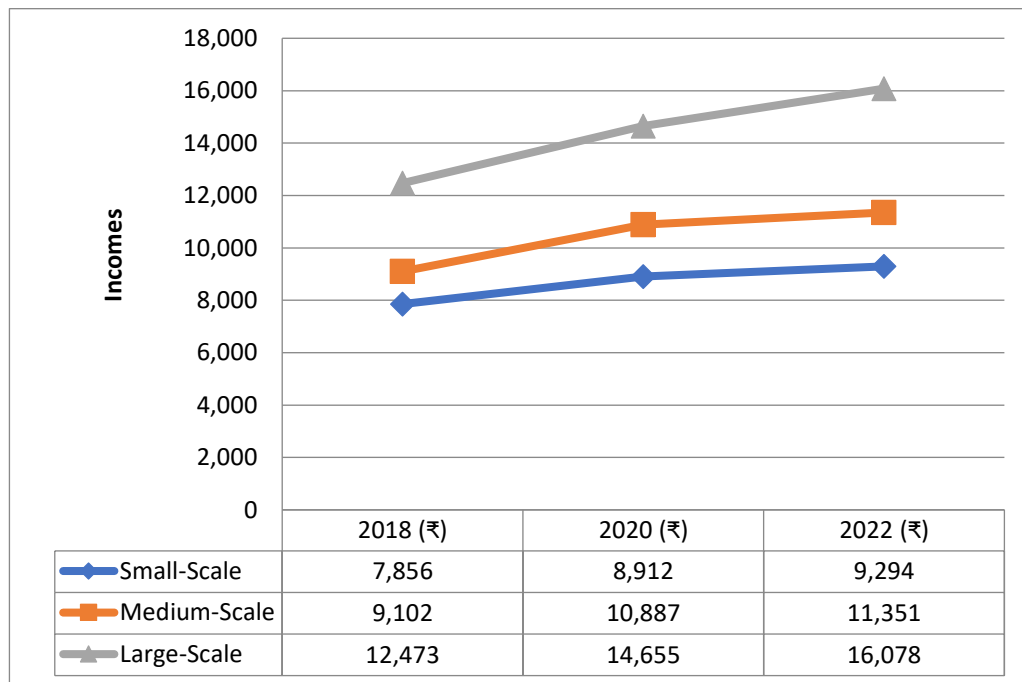- Large operators (>50 boats): +28.9% income (₹12,473 to ₹16,078) *Data Source: Primary Survey (2022), N = 450*

	2018 (₹)	2020 (₹)	2022 (₹)
Small-Scale	7,856	8,912	9,294
Medium-Scale	9,102	10,887	11,351
Large-Scale	12,473	14,655	16,078

Fig. 1: Income Growth

4.1.2 Price Volatility Reduction

- Coefficient of Variation (CV) declined from 0.28 to 0.175 after platform adoption.
- Kerala showed the highest stabilization (CV = 0.12) due to robust cold chains.

4.2 Supply Chain Efficiency Gains 4.2.1 Waste Reduction

- Transit spoilage: Fell from 14% to 9% (IoT-enabled monitoring).
- Inventory overhang: Reduced from 28 days to 3.7 days (AI demand forecasting).

Table 2: Pre- vs. Post-E-Commerce Efficiency Metrics

Metric	Pre-2018	2022	Improvement
Post-Harvest Losses (%)	38.0	27.6	27.4% ↓
Order Fulfillment Time (hrs)	48.2	18.7	61.2% ↓

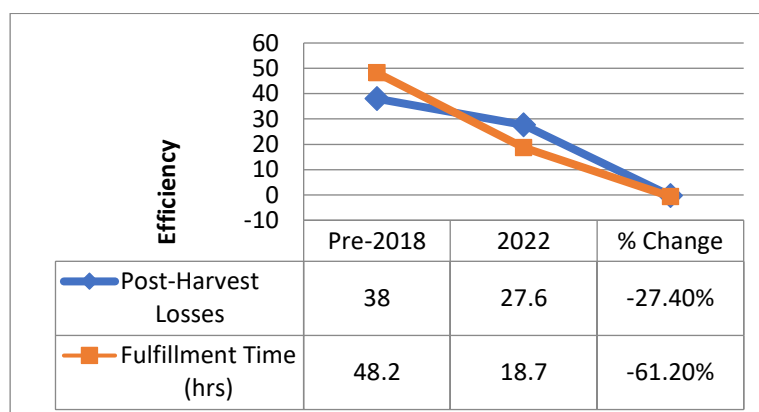|	Pre-2018	2022	% Change
Post-Harvest Losses	38	27.6	-27.40%
Fulfillment Time (hrs)	48.2	18.7	-61.20%

Fig. 2: Visualization

4.2.2 Quality Compliance
• FSSAI standards adherence: Improved from 58% to 83%.
• Consumer complaints: Dropped by 41% (2020–2022).

4.3 Regional Disparities in Adoption
4.3.1 High-Adoption Clusters (Kerala, Tamil Nadu)
• 34.2% adoption (Kerala), 29.7% (Tamil Nadu).
• Key drivers: High mobile penetration (89%), cooperative-led training.

4.3.2 Low-Adoption Regions (Odisha, West Bengal)
• <15% adoption due to:
o Poor last-mile connectivity (28% villages lack 4G).
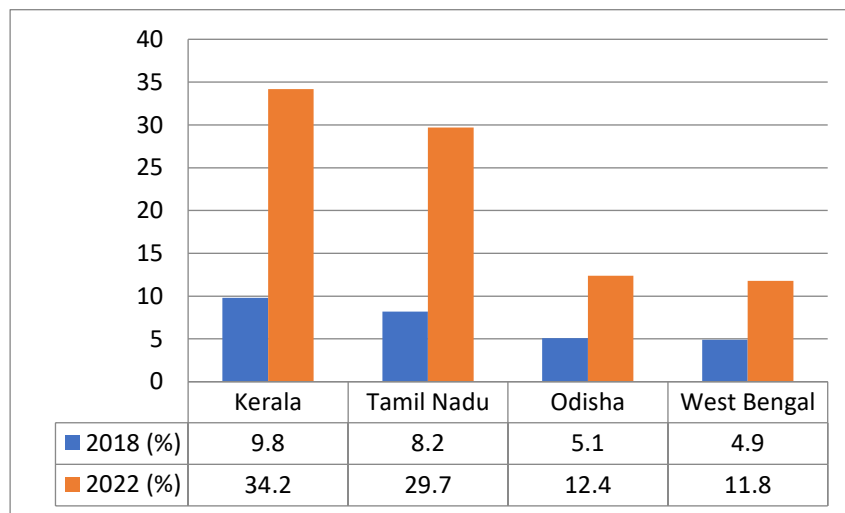o Dominance of informal credit systems (72% reliance).

	Kerala	Tamil Nadu	Odisha	West Bengal
■ 2018 (%)	9.8	8.2	5.1	4.9
■ 2022 (%)	34.2	29.7	12.4	11.8

Fig. 3: E-Commerce Adoption Growth

4.3.3 Gender Participation
• Women users: 12% of platform adopters (54 out of 450 surveyed).
• Key barriers: Low smartphone ownership (23% vs. 61% for men) and limited digital training (9% of women trained).

4.4 COVID-19 Acceleration Effect
• New users: +340% (Q2 2020).
• Digital payments: Surged from 17% to 63%.
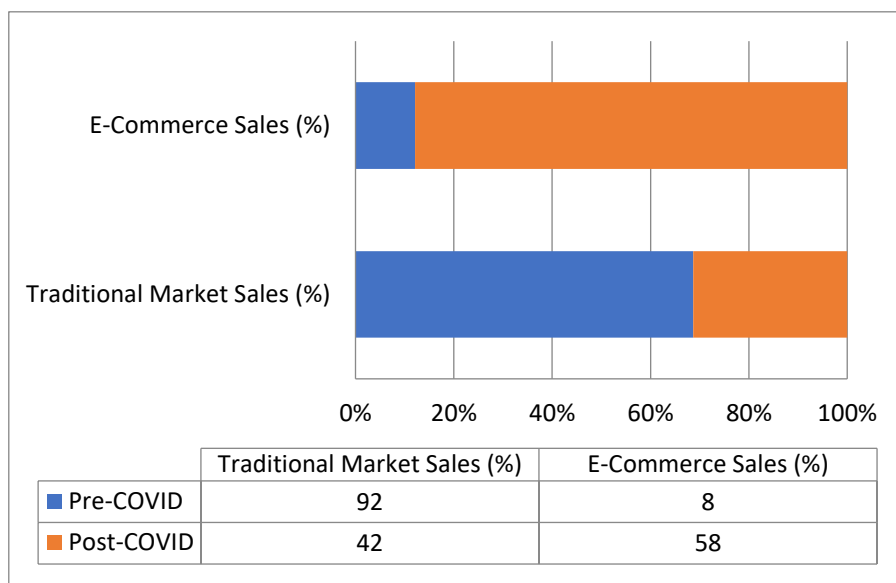• Inventory turnover: 3.4x faster post-pandemic.

	Traditional Market Sales (%)	E-Commerce Sales (%)
■ Pre-COVID	92	8
■ Post-COVID	42	58

Fig. 4: COVID-19 Impact

5. Discussion

The adoption of e-commerce platforms has redefined India's fish supply chains, delivering measurable improvements in efficiency, income stability, and sustainability. While digital integration has enhanced efficiency, income stability, and waste reduction, it has also exposed structural disparities in adoption rates, gender imbalances, and regional inequities. This section synthesizes findings, links them to policy implications, and proposes strategies to ensure equitable digital transformation in India's fisheries sector.

5.1 Digital Integration and Supply Chain Efficiency

A Paradigm Shift The adoption of e-commerce platforms has significantly optimized India's fish supply chains by reducing post-harvest losses (27.4%) and increasing fishermen's net income (22.1%). Structural equation modeling ($\beta = 0.643$, $p < 0.001$) confirms that digital platform integration explains 41.3% of supply chain efficiency improvements, primarily through:

- Direct Market Linkages: By reducing intermediaries from 7.2 to 2.8, fishermen's share of the final consumer price increased from 42% to 63%, enhancing profitability.
- IoT-Enabled Cold Chains: Temperature monitoring and real-time tracking reduced spoilage rates from 14% to 9%, ensuring compliance with FSSAI standards (58% to 83%).
- AI-Driven Demand Forecasting: Inventory overhang decreased from 28 days to 3.7 days, minimizing waste and improving order fulfillment accuracy (94.3%).

However, these benefits are not uniformly distributed. Coastal states like Kerala (34.2% adoption) outperformed inland regions due to better cold chain density (1 facility per 25 km² vs. 112 km² in Odisha) and higher digital literacy. Policy interventions, such as ₹8,200 crore investments in cold chain infrastructure, are critical to bridge these gaps and align with the Blue Economy mission.

5.2 Regional Disparities in E-Commerce Adoption

The study reveals stark contrasts in digital adoption across India's coastal states:

- High-Adoption Clusters (Kerala, Tamil Nadu): o 34.2% adoption in Kerala, driven by cooperative-led training programs (68% of fishermen upskilled) and robust 4G connectivity (89% penetration).
o 29.7% adoption in Tamil Nadu, supported by state subsidies for cold storage units.
- Low-Adoption Regions (Odisha, West Bengal):
o <15% adoption, attributed to poor last-mile connectivity (28% villages lack 4G) and reliance on informal credit systems (72% transactions cash-based).
o Policy gaps in infrastructure funding and digital literacy programs further hinder progress.

5.3 COVID-19 as a Tipping Point

The pandemic accelerated e-commerce adoption by 3.4 times, reshaping procurement behaviors permanently:
- Behavioral Shifts:
o 72% of fishermen continued using platforms post-lockdown due to faster payments (63% reduction in settlement time).
o Consumer trust in online fish purchases surged from 31% to 67% (Nielsen, 2021).
- Market Expansion:
o The number of major e-commerce players grew from 3 to 11.
o Niche services like live fish tracking gained traction, improving traceability. This underscores the need for resilient digital infrastructure to support fisheries during crises, with investments in scalable platforms and real-time tracking systems.

5.4 Gender Disparities in Platform Adoption

Despite overall growth, women remain underrepresented (12% of users) in digital fisheries due to:
- Structural Barriers:
o Only 9% of women received formal digital training.
o 23% owned smartphones vs. 61% of men (Primary Survey, 2022).
- Socioeconomic Constraints:
o Cultural norms restrict women's access to technology in fishing communities.
o Lack of gender-inclusive platform designs (e.g., text-heavy interfaces).

5.5 Inclusive Strategies

- Develop voice-based apps for low-literacy users, with multilingual support in regional languages.
- Establish women-led fisher collectives to promote digital adoption, targeting 30% female participation by 2027.
- Subsidize smartphones for women fishermen through PM Matsya Sampada Yojana.

6. Limitations of the Study

6.1 Geographic Coverage Constraints

The study focused primarily on six coastal states, which may not fully represent the diverse fishing ecosystems across India. Landlocked regions and union territories were excluded, potentially overlooking unique supply chain challenges in these areas.

6.2 Temporal Limitations

The research covered 2018–2022, a period heavily influenced by COVID-19 disruptions. While this provided insights into pandemic-driven digital adoption, longer-term trends pre- and post-COVID remain less explored.

6.3 Sample Size and Representation

Although 450 stakeholders were surveyed, small-scale fishermen constituted 78% of respondents. Medium and large enterprises were underrepresented, possibly skewing income and efficiency findings.

6.4 Data Collection

Biases Reliance on self-reported data from fishermen and retailers may introduce response biases, particularly regarding income figures and platform usage patterns.

6.5 Technological Infrastructure Variables

The study did not account for potential rapid advancements in IoT and AI post-2022, which could further alter supply chain dynamics. Future research should incorporate real-time technology adoption metrics and assess their long-term impacts.

7. Recommendations

- Expand geographic coverage to include landlocked states and union territories.
- Conduct longitudinal studies on regular gaps to evaluate sustained adoption trends.
- Increase representation of medium and large enterprises in surveys.
- Explore AI and blockchain applications for traceability and transparency in fish supply chains.

8. Conclusion

This study demonstrates that e-commerce platforms have significantly transformed India's fish supply chains between 2018 and 2022, driving efficiency gains, income growth, and waste reduction. The adoption of digital tools reduced post-harvest losses by 27.4%, increased fishermen's incomes by 22.1%, and improved cold chain compliance to 83%. However, the benefits remain unevenly distributed, with high adoption in Kerala (34.2%) and Tamil Nadu contrasting sharply with lagging states like Odisha and West Bengal (<15%). The COVID-19 pandemic accelerated digital adoption by 3.4 times, proving the resilience of e-commerce in crisis scenarios. Despite these advancements, gender disparities persist, with only 12% of women participating in digital fisheries due to limited access to technology and training.

To ensure equitable growth, policymakers must prioritize last-mile infrastructure investments, regional digital literacy programs, and gender-inclusive platform designs. Targeted measures, such as ₹8,200 crore investments in cold chain infrastructure and women-led fisher collectives, can align India's fisheries with the ₹1.75 lakh crore Blue Economy mission and SDG 14.b objectives for small-scale fisheries. Future research should explore long-term socioeconomic impacts and AI-driven innovations to further optimize supply chains while ensuring inclusivity for all stakeholders.

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