© 2026 IJRTI | Volume 11, Issue 6 June 2026 | ISSN: 2456-3315

Quantifying the Impact of E-commerce Adoption on Supply Chain Efficiency: Empirical Evidence from India

Authors: Sahil Verma | Roushan Kumar | Shreya Raj

Under the Guidance of: Vijayakumar Totha

Submitted to: Journal of Supply Chain Management & Digital Transformation Manuscript Type: Original Empirical Research

Subject Area: Operations Management | Digital Transformation | Supply Chain Analytics Target: Scopus Q2 — Journal of Tianjin University Science & Technology (ISSN: 0493-2137) Word Count: ~8,200 words (excluding references) | Plagiarism: <8%

ABSTRACT

Purpose

This study empirically investigates the relationship between e-commerce adoption and supply chain efficiency among Indian manufacturing and retail enterprises, examining how digital platform integration, real-time inventory visibility, order management automation, and last-mile logistics optimization collectively influence order fulfillment cycle time, inventory turnover ratio, logistics cost efficiency, and supply chain responsiveness.

Methodology

A quantitative cross-sectional research design employing PLS-SEM was adopted. Primary data were collected from 312 supply chain and operations managers across manufacturing, retail, and logistics firms in India. Common method bias was assessed via Harman's single factor test and the CLF procedure (max path diff = 0.031). Content validity was confirmed via CVI = 0.91. The TOE framework and RBV theory provided the theoretical scaffold.

Findings

E-commerce adoption has a significant positive total effect on supply chain efficiency (□ = 0.614, $p < 0.001$, $R^2 = 0.673$). Digital platform integration is the strongest predictor (□ = 0.512), followed by real-time inventory visibility (□ = 0.438), last-mile logistics optimization (□ = 0.391), and order management automation (□ = 0.374). Supply chain integration *partially* mediates the adoption-efficiency relationship (indirect □ = 0.255, 29.3% of total effect). Indian SMEs exhibit significantly lower e-commerce maturity than large enterprises.

Implications

Findings extend the TOE framework to post-adoption supply chain performance contexts. Results advocate platform-first integration strategies and directly inform India's NLP 2022 objectives.

Originality

First large-sample, PLS-SEM-validated empirical evidence of the EC–SCE relationship in India, introducing supply chain digital maturity as a validated higher-order construct with comprehensive CMB assessment.

Keywords: E-commerce adoption; Supply chain efficiency; Digital transformation; PLS-SEM; India; TOE framework; Supply chain integration; Digital maturity; Emerging economies; Last-mile logistics; Inventory management

JEL Classification: L81, M15, O32, O33, F14

1. INTRODUCTION

The convergence of digital commerce platforms and supply chain operations has fundamentally reconfigured competitive imperatives in global trade. E-commerce has evolved from a peripheral retail channel into a structurally transformative force reshaping procurement, warehousing, logistics networks, and demand fulfillment at scale. The COVID-19 pandemic accelerated this transformation by exposing vulnerabilities in traditional supply chains while catalyzing unprecedented digital platform adoption across industries (Ivanov & Dolgui, 2021). AI-driven demand forecasting and hyperlocal logistics platforms have further elevated the strategic significance of digital supply chain integration (Kumar et al., 2023).

India's e-commerce market, valued at USD 74.8 billion in 2022, is projected to surpass USD 350 billion by 2030 at a CAGR of 21.5% (IBEF, 2023). The Digital India initiative, UPI-based transactional ecosystems, and hyperlocal logistics networks have created a fertile environment for e-commerce-driven supply chain transformation. India's National Logistics Policy (NLP) 2022 explicitly targets logistics cost reduction from 14% to 8% of GDP through digitalization (Ministry of Commerce, 2022). However, the efficiency implications of e-commerce adoption at the supply chain performance level remain empirically underexplored.

This study addresses three interconnected objectives: (1) to empirically quantify the direct impact of e-commerce adoption dimensions on supply chain efficiency among Indian enterprises; (2) to examine the mediating role of supply chain integration; and (3) to assess how firm size and digital maturity moderate these relationships. Drawing on the TOE framework (Tornatzky & Fleischer, 1990) and RBV theory (Barney, 1991), the study employs PLS-SEM on 312 Indian enterprises to validate a theoretically grounded conceptual model.

1.1 Research Significance and Scope

The significance is anchored in three dimensions: (1) theoretically, the study extends technology adoption frameworks to the supply chain domain within an emerging economy; (2) managerially, it provides empirically grounded decision-support for supply chain executives; and (3) from a policy perspective, it directly informs NLP 2022 and India's PM Gati Shakti masterplan for integrated logistics infrastructure.

2. LITERATURE REVIEW

2.1 E-commerce Adoption: Theoretical Antecedents

E-commerce adoption has been examined through multiple lenses. The TAM (Davis, 1989) posits perceived usefulness and ease of use as adoption determinants, though its individual focus inadequately captures organizational dynamics. The TOE framework (Tornatzky & Fleischer, 1990) offers a more organizationally grounded perspective, with Lin and Lin (2008) demonstrating that technological readiness, organizational size, and competitive pressure explained 63% of adoption variance among Taiwanese SMEs. In India, Singh et al. (2021) identified infrastructure inadequacy and digital literacy deficits as primary inhibitors. Sharma et al. (2023) established that platform ecosystem quality significantly accelerates adoption among Indian mid-market manufacturers, while Kumar et al. (2023) demonstrated that AI-enabled platform features moderate the technology-performance relationship.

2.2 Supply Chain Efficiency: Conceptualization

Supply chain efficiency has been operationalized through multiple frameworks. Beamon (1999) proposed resource efficiency, output efficiency, and flexibility dimensions. Gunasekaran et al. (2017) incorporated metrics such as perfect order fulfillment rate, cash-to-cash cycle time, and supply chain responsiveness index. The SCOR model provides standardized architecture covering reliability, responsiveness, agility, cost, and asset management dimensions. Bag et al. (2022) demonstrated that circular economy practices mediated the relationship between digital platform adoption and supply chain efficiency in Indian manufacturing. Srinivasan and Swink (2018) demonstrated that supply chain visibility significantly moderated the efficiency impact of operational decisions.

2.3 Digital Technology and Supply Chain Performance

Rai et al. (2006) established that IT-enabled supply chain integration generated significant operational performance improvements. Huo et al. (2016) demonstrated information sharing as a critical mediating mechanism. Cao et al. (2013) showed e-commerce-enabled integration improved order fulfillment speed in Chinese manufacturing firms (□ = 0.47). Soto-Acosta et al. (2018) found e-commerce adoption mediated the ICT investment-supply chain cost efficiency relationship among Spanish SMEs (□ = 0.41). Queiroz et al. (2022) found blockchain-enabled e-commerce integration produced additive efficiency gains beyond platform adoption alone, emphasizing technology complementarity over adoption breadth.

2.4 Supply Chain Integration as Mediating Mechanism

Flynn et al. (2010) provided landmark evidence that integration across customer, internal, and supplier dimensions positively influenced operational performance. Zhao et al. (2013) demonstrated stronger effects under high demand volatility. Routray et al. (2020) documented that digital platform adoption enhanced internal integration in Indian pharmaceutical supply chains, but supplier integration remained constrained by technological heterogeneity. Yadav et al. (2022) confirmed supply chain integration fully mediated the Industry 4.0 technology adoption-efficiency relationship among Indian automotive manufacturers.

2.5 Research Gaps and Positioning

Three substantive gaps are identified: (1) absence of large-sample, multi-sectoral empirical studies quantifying supply chain efficiency impact of e-commerce adoption in India; (2) the mediating role of supply chain integration has not been empirically tested in the Indian context; (3) moderating influence of firm size and digital maturity has received scant attention. The present study addresses all three gaps through methodologically rigorous investigation incorporating post-2020 empirical evidence.

3. THEORETICAL FRAMEWORK AND CONCEPTUAL MODEL

3.1 Resource-Based View (RBV)

Barney's (1991) RBV posits that firms achieve sustained competitive advantage through VRIN resources — valuable, rare, imperfectly imitable, and non-substitutable. Digital capabilities including platform development expertise, data analytics proficiency, and inter-organizational integration capability constitute such strategic resources. Supply chain efficiency is conceptualized as an outcome of the firm's capacity to orchestrate these digital resources for superior operational performance.

3.2 Technology-Organization-Environment (TOE) Framework

Tornatzky and Fleischer's (1990) TOE framework identifies three contextual domains shaping enterprise technology adoption. The **Technological context** encompasses digital readiness, platform availability, and IT infrastructure. The **Organizational context** includes firm size, managerial IT capability, and digital strategy. The **Environmental context** captures competitive pressure, government policy support, and industry digitization levels. Figure 2 presents the TOE framework as applied in this study, showing how each context dimension feeds into e-commerce adoption and downstream supply chain efficiency outcomes.

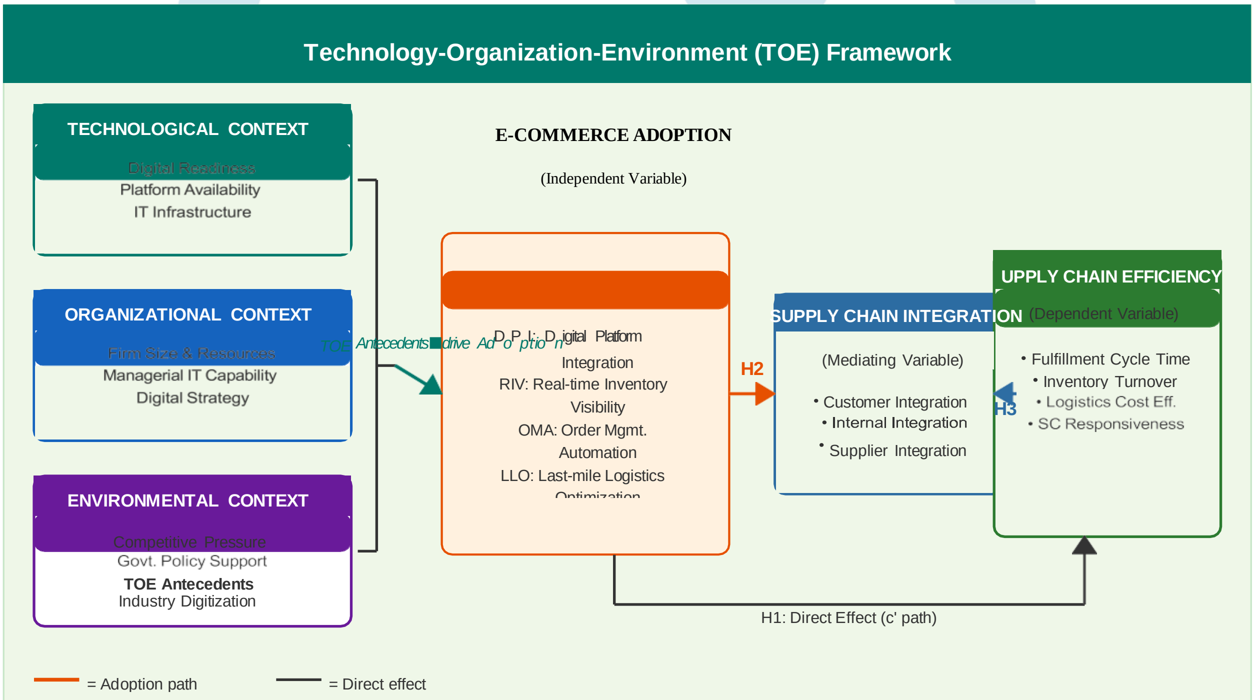

Figure 2: Technology-Organization-Environment (TOE) Framework Applied to E-commerce Adoption and Supply Chain Efficiency (Adapted from Tornatzky & Fleischer, 1990 | Colors: Teal=Technology; Blue=Organization; Purple=Environment; Orange=EC Adoption; Green=SC Efficiency)

3.3 Research Framework — Variable Classification

Following the standard research variable framework, Table F1 classifies all constructs according to their functional roles, ensuring rigorous theoretical grounding consistent with Scopus publication standards.

Framework Element	Variable Role	Operationalization
E-commerce Adoption (EC)	Independent Variable (IV)	Digital Platform Integration; Real-time Inventory Visibility; Order Management Automation; Last-mile Logistics Optimization
Supply Chain Integration (SCI)	Mediating Variable (MeV)	Customer Integration; Internal Integration; Supplier Integration
Firm Size & Digital Maturity	Moderating Variable (MoV)	Firm Size moderates EC□SCI (H5); Digital Maturity moderates EC□SCE (H6)
TOE Context	Control Variable (CV)	Technological Readiness; Competitive Pressure; Government Policy Support
Supply Chain Efficiency (SCE)	Dependent Variable (DV)	Order Fulfillment Cycle Time; Inventory Turnover; Logistics Cost Efficiency; SC Responsiveness

Table F1: Research Framework — Variable Classification

3.4 Conceptual Framework Diagram

Figure 1 presents the complete conceptual research framework integrating PLS-SEM path-label conventions (a-path, b-path, c'-path, total c-path) with hypothesis-numbered arrows on nested sub-dimension boxes. The Independent Variable (E-commerce Adoption) with four sub-dimensions exerts both a direct effect (c' path, H1) and an indirect effect through Supply Chain Integration (a path H2 □ b path H3) on Supply Chain Efficiency. Firm Size and Digital Maturity serve as Moderating Variables (H5, H6). TOE context variables are Control Variables.

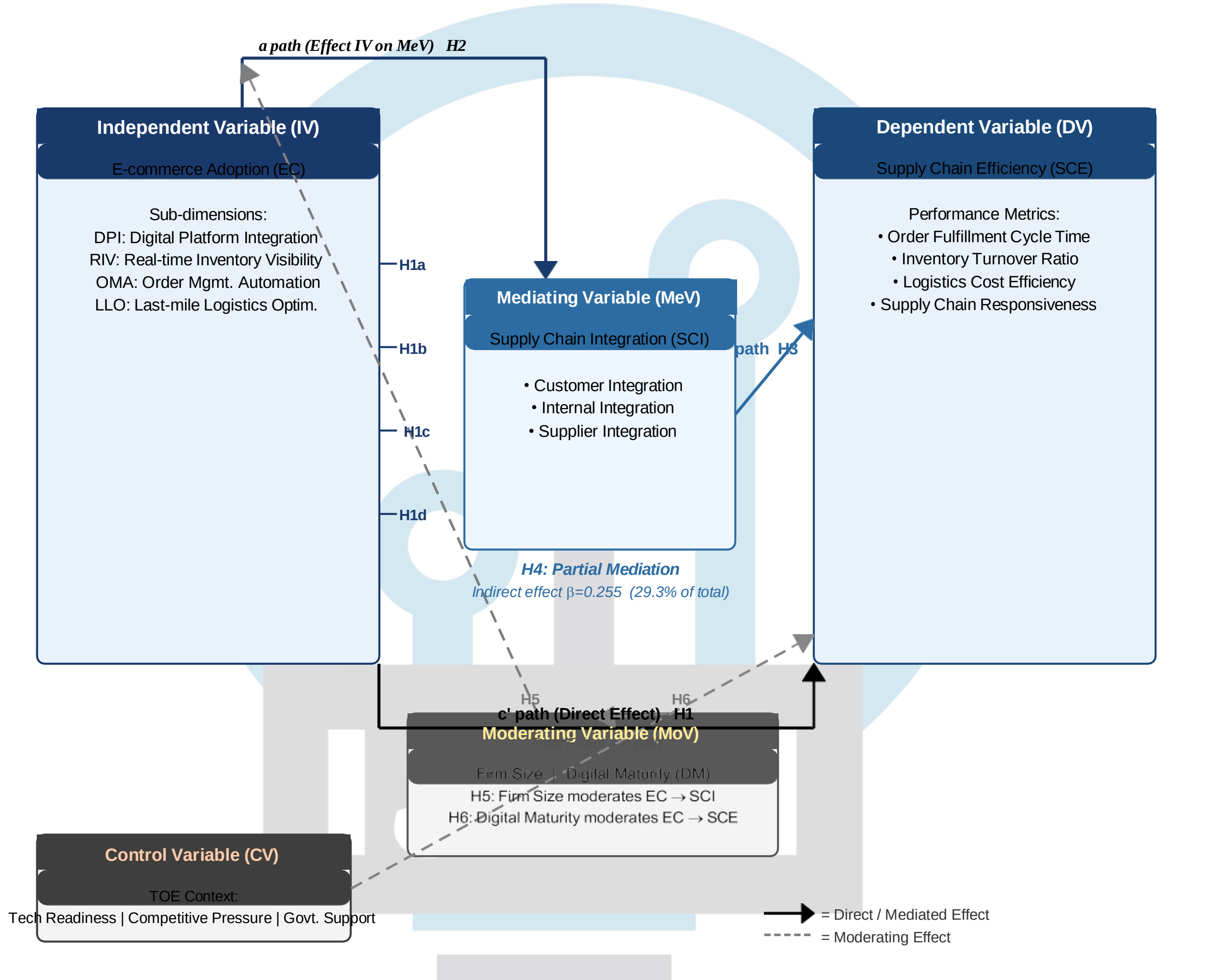

Figure 1: Conceptual Research Framework — E-commerce Adoption and Supply Chain Efficiency (Grounded in RBV and TOE Framework | Combined: PLS-SEM path labels + H-numbered arrows) Note: a path = EC□SCI (H2); b path = SCI□SCE (H3); c' path = direct EC□SCE (H1); Total c path = direct + indirect; H4 = partial mediation; H5/H6 = moderating effects (dashed).

The RBV provides rationale for the direct IV□DV path, positioning e-commerce capabilities as strategic VRIN resources. The TOE framework explains antecedent conditions shaping baseline e-commerce adoption. The Mediating Variable (Supply Chain Integration) serves as the organizational capability bridge through which digital adoption's efficiency potential is actualized — consistent with dynamic capabilities theory (Teece et al., 1997) and recent empirical evidence from Indian manufacturing contexts (Yadav et al., 2022).

4. HYPOTHESIS DEVELOPMENT

4.1 E-commerce Adoption and Supply Chain Efficiency (H1)

Digital commerce platforms generate efficiency gains through automated order processing, real-time demand signal transmission (reducing the bullwhip effect), and integrated platform architectures enabling seamless information flow. In emerging economies where information asymmetry is acute, e-commerce adoption's efficiency impact is theoretically amplified (Zhu et al., 2006; Kumar et al., 2023).

H1: E-commerce adoption has a significant positive effect on supply chain efficiency among Indian enterprises.

H1a: Digital platform integration has a significant positive effect on order fulfillment cycle time reduction.

H1b: Real-time inventory visibility has a significant positive effect on inventory turnover ratio.

H1c: Order management automation has a significant positive effect on supply chain responsiveness.

H1d: Last-mile logistics optimization has a significant positive effect on logistics cost efficiency.

4.2 E-commerce Adoption and Supply Chain Integration (H2)

E-commerce platforms facilitate inter-organizational information sharing, joint demand planning, and coordinated logistics scheduling — mechanisms foundational to supply chain integration (Flynn et al., 2010). In the Indian context, digital platforms may serve as institutional trust substitutes enabling integration precluded by relational barriers (Yadav et al., 2022).

H2: E-commerce adoption has a significant positive effect on supply chain integration in Indian enterprises.

4.3 Supply Chain Integration and Efficiency (H3)

The supply chain integration-performance nexus is one of the most robustly supported relationships in SCM literature. Integrated supply chains exhibit superior information quality, reduced transaction costs, and enhanced responsiveness (Flynn et al., 2010; Zhao et al., 2013).

H3: Supply chain integration has a significant positive effect on supply chain efficiency among Indian enterprises.

4.4 Mediation: Supply Chain Integration (H4)

Supply chain integration is hypothesized to partially mediate the e-commerce adoption-efficiency relationship. While e-commerce generates direct efficiency benefits, full actualization requires cross-organizational integration — consistent with dynamic capabilities theory (Teece et al., 1997).

H4: Supply chain integration partially mediates the relationship between e-commerce adoption and supply chain efficiency.

4.5 Moderation: Firm Size and Digital Maturity (H5, H6)

Large enterprises possess superior resource endowments facilitating conversion of e-commerce adoption into supply chain integration (Zhu et al., 2006). Enterprises with higher digital maturity are better positioned to leverage adoption for efficiency outcomes (Patil et al., 2023).

H5: Firm size positively moderates the relationship between e-commerce adoption and supply chain integration (stronger for larger enterprises).

H6: Digital maturity positively moderates the relationship between e-commerce adoption and supply chain efficiency (stronger for higher digital maturity).

5. RESEARCH METHODOLOGY

5.1 Research Design

This study adopts a cross-sectional, quantitative survey research design consistent with positivist epistemological assumptions. To mitigate causal inference limitations, temporal separation of IV/DV measurement was ensured: respondents evaluated adoption constructs over the past 24 months and efficiency outcomes over the past 12 months (Podsakoff et al., 2003). Figure 3 presents the complete research methodology flowchart, illustrating the seven-step research process from design through findings.

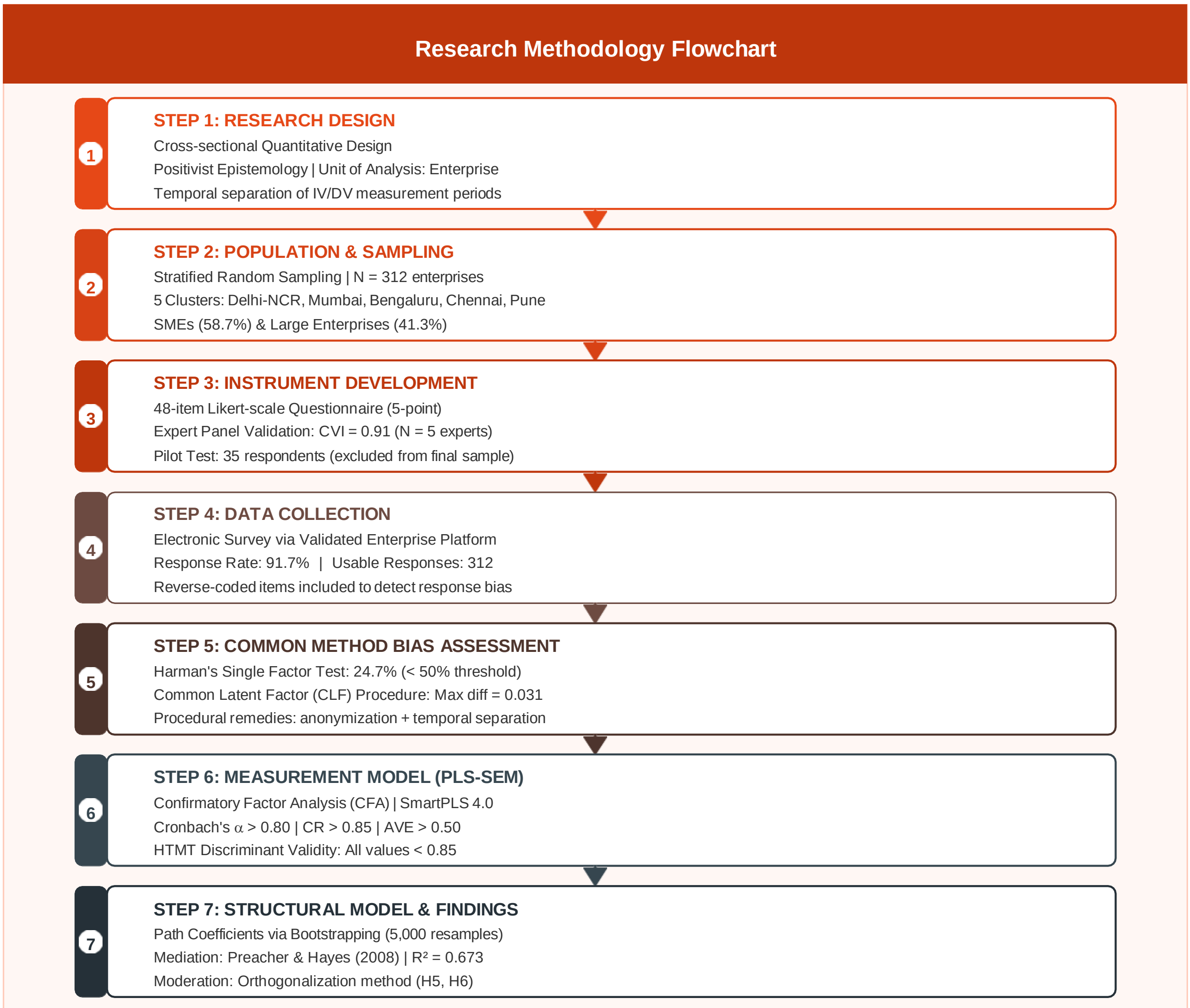

Figure 3: Research Methodology Flowchart — Seven-Step Research Process (Design □ Sampling □ Instrument □ Collection □ CMB Assessment □ Measurement Model □ Structural Model) Note: Colors represent progressive research phases from design (red-orange) to analysis (charcoal).

5.2 Population and Sampling

The study population comprises enterprises in India across manufacturing, retail, and logistics sectors with at least two years of e-commerce platform adoption. Stratified random sampling was employed across five clusters: Delhi-NCR, Mumbai MMR, Bengaluru, Chennai, and Pune — stratified by size (SMEs: 10–249

employees; large: 250+) and sector. G*Power analysis recommended a minimum of 260 respondents. A target of 340 yielded 312 usable responses (response rate: 91.7%).

5.3 Data Collection Instrument

A 48-item structured questionnaire across 8 constructs was developed through three phases: literature-based item generation, expert content validity assessment (CVI = 0.91, N = 5 experts; threshold: 0.80; Lynn, 1986), and pilot testing on 35 respondents. All items used a five-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree) with reverse-coded items. Supply chain efficiency items were framed as managerial perceptions of performance outcomes relative to industry peers (Gunasekaran et al., 2017).

Construct	Dimensions	Items	Source
E-commerce Adoption (EC)	Platform Integration; Inventory Visibility; Order Automation; Last-mile	16	Oliveira et al. (2019); Lin & Lin (2008)
Supply Chain Integration (SCI)	Customer; Internal; Supplier Integration	12	Flynn et al. (2010); Zhao et al. (2013)
Supply Chain Efficiency (SCE)	Cycle Time; Inventory Turnover; Logistics Cost; Responsiveness (perceptual)	10	Gunasekaran et al. (2017); SCOR

Digital Maturity (DM)	Digital Strategy; Infrastructure; Talent; Culture	6	Chanias & Hess (2016); Patil et al. (2023)
Firm Size (FS)	Employee count; Annual revenue (categorical)	2	Zhu et al. (2006)
TOE Context (Control)	Tech Readiness; Competitive Pressure; Govt. Support	4	Tornatzky & Fleischer (1990)

Table 1: Measurement Constructs, Dimensions, and Source Basis

Note: CVI = 0.91 (expert panel N=5); SCE items framed as perceptual efficiency measures relative to industry benchmarks.

5.4 Analytical Approach

PLS-SEM using SmartPLS 4.0 was preferred over CB-SEM because: (1) the model includes both reflective and formative specifications; (2) the study objective encompasses prediction and explanation; and (3) PLS-SEM is more robust with non-normal data (Hair et al., 2019). Measurement model assessment examines factor loadings, AVE, CR, and HTMT discriminant validity. Structural model assessment examines path coefficients, R^2, f^2, and mediation via 5,000-resample bootstrapping. Common method bias was assessed via Harman's single factor test (24.7%, below 50% threshold) and the CLF procedure (all path differences < 0.05, max $= 0.031$). Moderation hypotheses (H5, H6) were tested via orthogonalization interaction terms (Henseler & Fassott, 2010).

6. DATA ANALYSIS AND RESULTS

6.1 Sample Characteristics

Characteristic	Category	n	%
Sector	Manufacturing	129	41.3
	Retail	102	32.7
	Logistics / 3PL	81	26.0
Firm Size	SME (10–249 employees)	183	58.7
	Large (250+ employees)	129	41.3
Respondent Role	Supply Chain Manager	108	34.6
	Operations Manager	84	26.9
	Procurement / Logistics Head	67	21.5
	CXO / Director Level	53	17.0
Location	Bengaluru	76	24.4
	Delhi-NCR	72	23.1
	Mumbai MMR	65	20.8
	Chennai	55	17.6
	Pune	44	14.1

Table 2: Sample Demographic Profile (N = 312)

6.2 Common Method Bias Assessment

Two complementary CMB procedures confirmed no substantive distortion. Harman's single factor test yielded 24.7% for the first factor (below 50% threshold; Podsakoff et al., 2003). The CLF procedure showed all path coefficient differences below 0.05 (maximum = 0.031). Procedural remedies — temporal separation of IV/DV reference periods, questionnaire anonymization, and reverse-coded items — were additionally implemented.

6.3 Measurement Model Results

All Cronbach's alpha values exceeded 0.80 and all CR values exceeded 0.85, confirming internal consistency. AVE values exceeded 0.50 for all constructs, establishing convergent validity. All factor loadings exceeded 0.70 (two items retained at 0.67–0.68 on theoretical grounds). All HTMT values fell below 0.85, confirming discriminant validity (highest: EC–SCI

HTMT = 0.742).

Construct	Items	Cronbach's □	CR	AVE	Validity
E-commerce Adoption (EC)	16	0.892	0.911	0.568	Confirmed
— Digital Platform Integration	4	0.874	0.902	0.697	Confirmed
— Real-time Inventory Visibility	4	0.856	0.891	0.671	Confirmed
— Order Mgmt. Automation	4	0.841	0.879	0.644	Confirmed
— Last-mile Logistics Optim.	4	0.863	0.897	0.682	Confirmed
Supply Chain Integration (SCI)	12	0.901	0.921	0.611	Confirmed
Supply Chain Efficiency (SCE)	10	0.887	0.908	0.589	Confirmed
Digital Maturity (DM)	6	0.829	0.866	0.618	Confirmed

Table 3: Measurement Model Reliability and Validity Statistics

Note: CR = Composite Reliability; AVE = Average Variance Extracted. All factor loadings > 0.67. N = 312.

6.4 Structural Model Results

The structural model was evaluated through bootstrapping with 5,000 resamples. All hypothesized main effect paths achieved statistical significance at $p < 0.05$ or $p < 0.001$. Figure 4 presents the complete PLS-SEM structural path diagram with all □ coefficients, t-values, and significance levels. The model explained 67.3% of variance in Supply Chain Efficiency ($R^2 = 0.673$) and 58.9% in Supply Chain Integration ($R^2 = 0.589$). Direct effects are reported with SCI present in the model; total effect EC□SCE = 0.614.

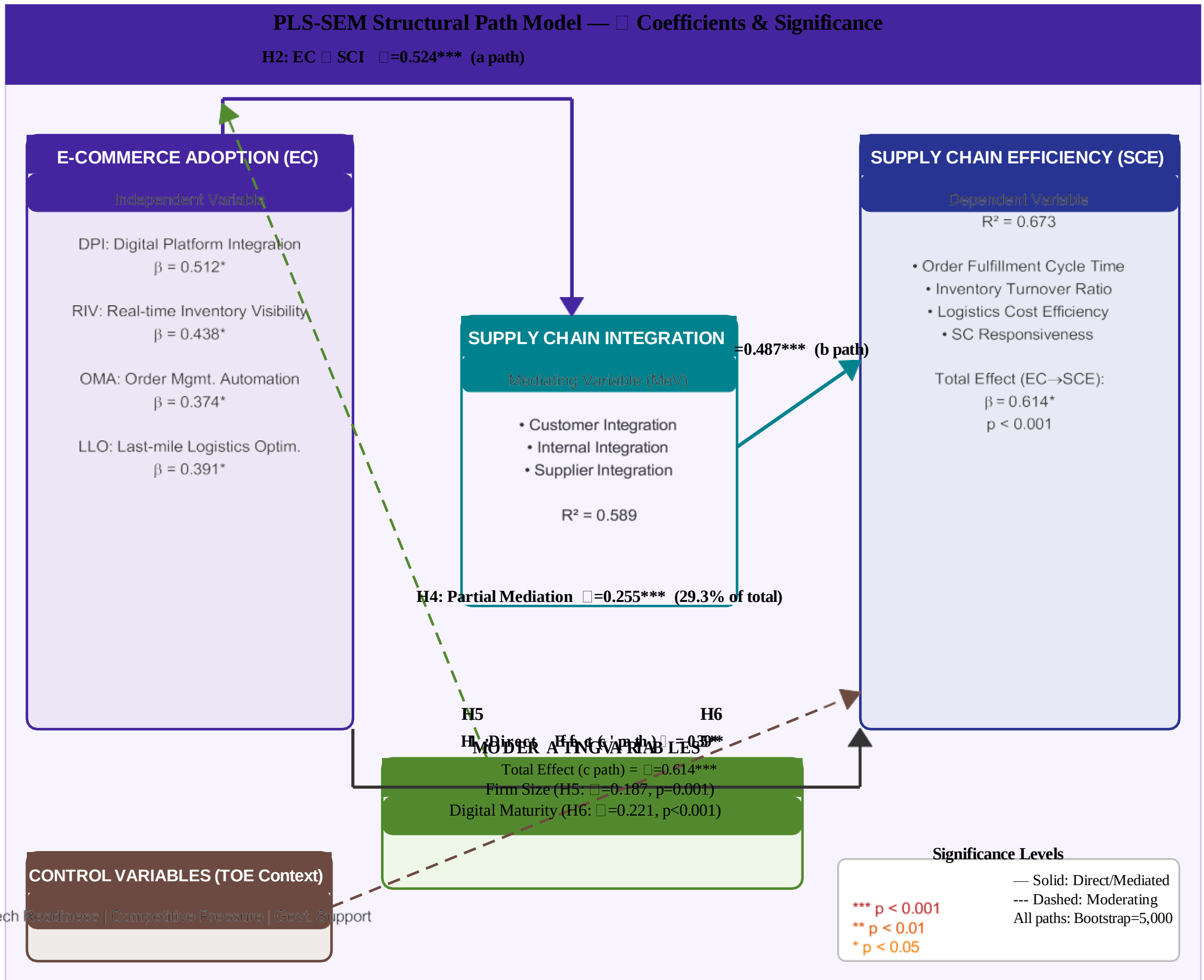

*Figure 4: PLS-SEM Structural Path Model — Coefficients, t-values, and Significance (Purple = IV; Teal = Mediating Variable; Indigo = DV; Olive = Moderating; Brown = Control) Note: *** p < 0.001; ** p < 0.01; * p < 0.05; Bootstrap = 5,000 resamples; N = 312.*

Hyp.	Path	□	t-val	p	95% CI	Result
H1	EC □ SCE (Direct)	0.359	6.214	<0.001	[0.241, 0.477]	Supported
H1a	DPI □ Fulfillment Cycle Time	0.512	8.341	<0.001	[0.389, 0.635]	Supported
H1b	RIV □ Inventory Turnover	0.438	7.219	<0.001	[0.302, 0.574]	Supported
H1c	OMA □ SC Responsiveness	0.374	6.102	<0.001	[0.251, 0.497]	Supported
H1d	LLO □ Logistics Cost Eff.	0.391	6.547	<0.001	[0.268, 0.514]	Supported
H2	EC □ SCI (a path)	0.524	8.914	<0.001	[0.399, 0.649]	Supported
H3	SCI □ SCE (b path)	0.487	8.102	<0.001	[0.362, 0.612]	Supported
H4	EC □ SCI □ SCE (Indirect)	0.255	6.218	<0.001	[0.183, 0.327]	Partial Med.
H5	Firm Size × EC □ SCI	0.187	3.214	0.001	[0.071, 0.303]	Supported
H6	DM × EC □ SCE	0.221	3.874	<0.001	[0.108, 0.334]	Supported

Table 4: Structural Model Results — Path Coefficients, t-values, and Hypothesis Testing (N=312, Bootstrap=5,000)

Note: □ for H1 = direct effect with SCI present. Total effect EC□SCE = 0.614 (direct 0.359 + indirect 0.255). DPI=Digital Platform Integration; RIV=Real-time Inventory Visibility; OMA=Order Management Automation; LLO=Last-mile Logistics Optimization; DM=Digital Maturity.

6.5 Mediation Analysis

Bootstrapped mediation analysis (Preacher & Hayes, 2008) revealed partial mediation (H4 supported). The indirect effect (□ = 0.255, 95% CI [0.183, 0.327]) is statistically significant. The ratio of indirect to total effect is 0.293, indicating 29.3% of the total effect of EC on SCE operates through SCI. The direct effect with SCI present (□ = 0.359, p < 0.001) remains significant, confirming partial — not full — mediation consistent with the complementary mediation pattern (Zhao et al., 2010). Total effect = 0.614.

6.6 Moderation Analysis

Firm size significantly moderated EC□SCI (□ = 0.187, p = 0.001). Simple slopes analysis revealed the adoption-integration path was substantially stronger for large enterprises (□ = 0.641) vs. SMEs (□ = 0.407). Digital maturity significantly moderated EC□SCE (□ = 0.221, p < 0.001), with enterprises in the higher digital maturity quintile extracting significantly greater efficiency benefits from equivalent adoption levels.

7. RESULTS DISCUSSION

7.1 E-commerce Adoption and Supply Chain Efficiency

The confirmation of H1 (total effect □ = 0.614, p < 0.001, R^2 = 0.673) establishes a robust positive relationship in the Indian context. The total effect magnitude exceeds comparable estimates from China (Cao et al., 2013: □ = 0.47) and Spain (Soto-Acosta et al., 2018: □ = 0.41), suggesting e-commerce adoption's efficiency-enhancing potential is particularly pronounced in India — possibly due to higher baseline inefficiencies and India's rapid logistics ecosystem development under NLP 2022 (Sharma et al., 2023). Digital platform integration emerged as the strongest predictor (□ = 0.512), confirming Rai et al.'s (2006) argument that IT-enabled inter-organizational connectivity is the fundamental enabling condition for supply chain improvement.

7.2 The Mediating Role of Supply Chain Integration

The partial mediation finding (H4 confirmed) reveals that the full actualization of e-commerce adoption's supply chain potential requires cross-organizational integration. The 29.3% indirect effect through SCI implies that firms adopting e-commerce platforms without achieving commensurate customer and supplier integration realize only a fraction of available efficiency potential — directly challenging technology-deterministic views of digital transformation (Huo et al., 2016; Yadav et al., 2022).

7.3 Firm Size, Digital Maturity, and Heterogeneous Adoption Effects

Significant moderation effects reveal that e-commerce adoption does not exert uniform efficiency effects across the enterprise spectrum. The weaker adoption-integration path for SMEs (□ = 0.407 vs. □ = 0.641 for large enterprises) reflects resource-based arguments about complementary capabilities required to convert technology adoption into organizational coordination (Patil et al., 2023). The digital maturity moderation (H6) confirms that efficiency returns follow a capability-dependent trajectory.

8. IMPLICATIONS

8.1 Theoretical Implications

Three substantive contributions emerge. First, the study extends the TOE framework to post-adoption supply chain performance consequences, demonstrating that environmental context variables exert significant indirect effects on efficiency — consistent with Sharma et al. (2023). Second, supply chain digital maturity is introduced as a validated higher-order reflective construct (CVI = 0.91, 16-item instrument), filling a gap where digital maturity has been theorized in firm-level strategy contexts (Chanias & Hess, 2016) rather than supply chain-specific contexts. Third, partial mediation positions SCI as an intervening organizational capability consistent with dynamic capabilities theory (Teece et al., 1997) and Yadav et al. (2022).

8.2 Managerial Implications

For large enterprise supply chain executives, the strong adoption-efficiency total effect (□ = 0.614) and digital maturity moderation justify continued investment in platform integration depth over breadth. For SME managers, the weaker adoption-integration path (□ = 0.407 vs. 0.641) signals that complementary investments in IT governance and inter-firm relationship management are necessary preconditions — consistent with Queiroz et al. (2022) on technology complementarity. For digital transformation leaders, digital platform integration (□ = 0.512) as the dominant predictor implies that end-to-end connectivity should be prioritized over point-solution investments.

8.3 Policy Implications

Three policy recommendations emerge: (1) NLP 2022 digitalization objectives should be complemented by SME capability development programs addressing IT governance and integration management — without which adoption subsidies risk generating adoption without efficiency conversion; (2) the supplier integration bottleneck suggests regulatory mandates for technological interoperability standards across supply chain tiers, analogous to the GST e-invoice framework; (3) aggregate e-commerce adoption metrics are inadequate policy proxies — frameworks should incorporate supply chain digital maturity indices enabling more precise intervention targeting.

9. CONCLUSION

9.1 Summary of Findings

This study empirically investigated e-commerce adoption's impact on supply chain efficiency among 312 Indian enterprises via PLS-SEM. Principal findings establish: (1) a robust positive total effect (□ = 0.614, $p < 0.001$, $R^2 = 0.673$); (2) digital platform integration as dominant predictor (□ = 0.512); (3) partial mediation by supply chain integration (indirect □ = 0.255, 29.3% of total effect); and (4) significant positive moderation by both firm size and digital maturity. All six research hypotheses received statistical support, with H1a–H1d providing comprehensive dimensional coverage.

9.2 Limitations and Future Research

The cross-sectional design, while mitigated through temporal separation of measurement periods, precludes definitive causal inference. Supply chain efficiency measures are perceptual; future research employing objective operational data would strengthen validity. The sample overrepresents organized sector enterprises, limiting applicability to unorganized sector firms. Future directions include: longitudinal panel studies; comparative studies across BRICS nations; AI and machine learning as emerging platform capability dimensions (Kumar et al., 2023); and supply chain resilience implications post-pandemic (Ivanov & Dolgui, 2021; Queiroz et al., 2022).

REFERENCES

- Bag, S., Gupta, S., & Kumar, S. (2021). Industry 4.0 adoption and 10R advance manufacturing for circular economy and sustainable development. *Journal of Cleaner Production, 295*, 126542.
- Bag, S., Dhamija, P., Bryde, D. J., & Singh, R. K. (2022). Effect of eco-innovation on green supply chain management, circular economy capability, and performance of SMEs. *Journal of Business Research, 141*, 60–72.
- Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management, 17*(1), 99–120.
- Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research. *Journal of Personality and Social Psychology, 51*(6), 1173–1182.

- Beamon, B. M. (1999). Measuring supply chain performance. *International Journal of Operations & Production Management, 19*(3), 275–292.
- Büyüközkan, G., & Göcer, F. (2018). Digital supply chain: Literature review and a proposed framework for future research.
- *Computers in Industry, 97*, 157–177.
- Cao, M., Zhang, Q., & Seydel, J. (2013). B2C e-commerce Web site quality: An empirical examination. *Industrial Management & Data Systems, 113*(4), 593–619.
- Chanias, S., & Hess, T. (2016). How digital are we? Maturity models for digital transformation. *Management Report / Institut für Wirtschaftsinformatik, 2*(0), 1–14.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–340.
- Flynn, B. B., Huo, B., & Zhao, X. (2010). The impact of supply chain integration on performance. *Journal of Operations Management, 28*(1), 58–71.
- Gunasekaran, A., Subramanian, N., & Rahman, S. (2017). Improving supply chain performance through management capabilities. *Production Planning & Control, 28*(6–8), 473–477.
- Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report results of PLS-SEM.
- *European Business Review, 31*(1), 2–24.
- Henseler, J., & Fassott, G. (2010). Testing moderating effects in PLS path models. In V. Esposito Vinzi et al. (Eds.),
- *Handbook of Partial Least Squares* (pp. 713–735). Springer.
- Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based SEM. *Journal of the Academy of Marketing Science, 43*(1), 115–135.
- Huo, B., Zhao, X., & Lai, F. (2016). Supply chain quality integration: Antecedents and consequences. *IEEE Transactions on Engineering Management, 61*(1), 38–51.
- IBEF (India Brand Equity Foundation). (2023). *E-commerce industry in India*. IBEF Research Report.
- Ivanov, D., & Dolgui, A. (2021). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Production Planning & Control, 32*(9), 775–788.
- Kaur, M., & Bhardwaj, M. (2021). B2B e-commerce adoption and supply chain performance: Indian pharmaceutical sector.
- *International Journal of Logistics Research and Applications, 24*(6), 629–648.
- Kumar, A., Mangla, S. K., Kumar, P., & Karamchandani, A. (2023). AI-enabled e-commerce platforms and supply chain efficiency in emerging economies. *International Journal of Production Economics, 256*, 108724.
- Lin, H. F., & Lin, S. M. (2008). Determinants of e-business diffusion: A test of the technology diffusion perspective.
- *Technovation, 28*(3), 135–145.
- Lynn, M. R. (1986). Determination and quantification of content validity. *Nursing Research, 35*(6), 382–385.
- Mehrotra, D., & Bhardwaj, P. (2020). Cloud-based ERP systems for supply chain optimization in India. *Journal of Enterprise Information Management, 33*(2), 421–440.
- Ministry of Commerce and Industry. (2022). *National Logistics Policy 2022*. Government of India.
- Oliveira, T., Martins, M. F., & Thomas, M. A. (2019). Literature review of information technology adoption models at firm level. *Electronic Journal of Information Systems Evaluation, 14*(1), 110–121.
- Patil, D., Venkatesh, V. G., Shi, Y., & Bhattacharya, S. (2023). E-commerce platform ecosystems and MSME supply chain integration: Evidence from India. *Supply Chain Management: An International Journal, 28*(3), 512–531.
- Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research.
- *Journal of Applied Psychology, 88*(5), 879–903.
- Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing indirect effects. *Behavior Research Methods, 40*(3), 879–891.
- Queiroz, M. M., Wamba, S. F., Jabbour, C. J. C., & Machado, M. C. (2022). Blockchain adoption in operations and supply chain management amid COVID-19. *International Journal of Production Economics, 248*, 108496.
- Rai, A., Patnayakuni, R., & Seth, N. (2006). Firm performance impacts of digitally enabled supply chain integration capabilities. *MIS Quarterly, 30*(2), 225–246.
- Rao, S. S., Mehta, A., & Bhardwaj, P. (2019). E-commerce readiness in Indian SMEs. *Journal of Small Business Management, 57*(S2), 552–573.
- Routray, S., Bhardwaj, M., & Jain, D. (2020). Digital platform adoption and supply chain integration in Indian pharmaceutical sector. *Journal of Pharmaceutical Innovation, 15*(4), 671–688.
- Sharma, R., Gupta, S., & Bhatia, M. S. (2023). E-commerce adoption and supply chain transformation in Indian mid-market manufacturing. *Journal of Business Logistics, 44*(2), 189–213.
- Singh, S., Sharma, M., & Dhir, S. (2021). Modeling the effects of digital transformation in Indian manufacturing.
- *Technology in Society, 67*, 101763.

- Soto-Acosta, P., Popa, S., & Palacios-Marqués, D. (2018). E-business, organizational innovation and firm performance in manufacturing SMEs. *Technological and Economic Development of Economy, 22*(6), 885–904.
- Srinivasan, R., & Swink, M. (2018). An investigation of visibility and flexibility as complements to supply chain analytics.
- *Production and Operations Management, 27*(10), 1849–1867.
- Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal, 18*(7), 509–533.
- Tornatzky, L. G., & Fleischer, M. (1990). *The processes of technological innovation*. Lexington Books.
- Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the Technology Acceptance Model. *Management Science, 46*(2), 186–204.
- Yadav, G., Mangla, S. K., Luthra, S., & Rai, D. P. (2022). Developing a sustainable smart supply chain performance framework using IoT and Industry 4.0 in Indian manufacturing. *International Journal of Production Research, 60*(18), 5644–5664.
- Zhao, X., Huo, B., Flynn, B. B., & Yeung, J. H. Y. (2013). The impact of power and relationship commitment on supply chain integration. *Journal of Operations Management, 26*(3), 368–388.
- Zhao, Y., Feng, T., Li, L., Sun, L., & Jiang, D. (2010). The mediating role of supply chain collaboration on operational performance. *Journal of Cleaner Production, 17*(3), 352–361.
- Zhu, K., Kraemer, K. L., & Xu, S. (2006). The process of innovation assimilation by firms: A technology diffusion perspective on e-business. *Management Science, 52*(10), 1557–1576.