

Study on the Impact Mechanism of Penetrative Supply Chain Technology Adoption on Corporate Performance: An Empirical Analysis Based on the Technology-Organization-Environment Framework

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Abstract

Against the backdrop of global supply chains transitioning toward networked collaboration, penetrative supply chain technology has emerged as a key solution to address the transparency shortcomings of traditional supply chains. This study constructs a model of the impact mechanism for penetrative supply chain technology adoption based on the Technology-Organization-Environment (T-O-E) framework. It explores how factors such as technological compatibility, organizational management support, and policy support influence technology adoption, examines the mediating effects of supply chain transparency and operational efficiency between technology adoption and corporate performance, and analyzes the moderating role of industry characteristics. Using data from Chinese A-share listed manufacturing and service companies from 2019 to 2023, empirical tests are conducted via structural equation modeling and other methods. The results show that technological compatibility, organizational management support, and policy support all have positive effects on penetrative technology adoption; supply chain transparency and operational efficiency act as partial mediating variables; and the impact of technology adoption on corporate performance is significantly stronger in manufacturing than in services. This research expands the application of the T-O-E framework in supply chain management and provides theoretical and practical insights for corporate technology adoption and supply chain digital transformation.

Keywords

Penetrative supply chain technology; Corporate performance; Technology-Organization-Environment framework; Supply chain transparency; Operational efficiency; Industry characteristics

I. Introduction

1. Research Background

With the deepening of economic globalization, global supply chains are undergoing a profound paradigm shift from linear management to networked collaboration. Inherent flaws in traditional supply chain models, such as information asymmetry and hierarchical barriers, have increasingly exacerbated transparency issues, severely restricting efficient supply chain operations and corporate sustainable development. Penetrative supply chains, leveraging advanced technologies like blockchain and the Internet of Things (IoT), enable end-to-end data penetration and intelligent control, offering a critical innovative pathway to unlock the "black box" of supply chains. For example, the Yuxi Power Supply Bureau of China Southern Power Grid introduced "automated material comparison robots for project outflows," achieving transparent management of the entire supply chain process and reducing material surplus rates from 75.3% in 2023 to 26.8% in 2024, significantly enhancing supply chain management efficiency. However, in practice, technology adoption varies significantly across enterprises. Some fail to implement technologies effectively due to insufficient organizational adaptability, highlighting the urgency of studying the drivers of technology adoption.

2. Research Questions

- (1) Under the T-O-E framework, which specific factors drive enterprises to adopt penetrative supply chain technologies? Do these factors differ across industries and corporate environments?
- (2) How does technology adoption influence corporate performance through mediating mechanisms? What are these mediating variables, and what are their pathways and strengths?
- (3) As a key feature of the external environment, do industry characteristics (e.g., differences in production processes, market demand, and supply chain structures between manufacturing and services) moderate the performance effects of technology adoption?

3. Research Significance

Theoretical Contributions:

This study extends the application of the T-O-E framework in supply chain management by analyzing technological, organizational, and environmental drivers of penetrative technology adoption, thereby enriching the theoretical understanding of technology adoption in supply chain contexts.

Practical Implications:

It provides actionable insights for enterprises to optimize technology selection, organizational structures, and management strategies during penetrative technology implementation, facilitating supply chain digital transformation and enhancing competitiveness.

II. Literature Review and Theoretical Framework

1. Research Progress on Penetrative Supply Chains

Technological Dimension:

Blockchain ensures tamper-proof, traceable data through distributed ledgers, addressing information asymmetry. IoT enables real-time supply chain monitoring, improving responsiveness and demand forecasting.

Organizational Dimension:

Penetrative technologies require breaking down departmental silos. For example, China Southern Power Grid's "Yunjing Platform" enables real-time data sharing, enhancing cross-functional collaboration.

Environmental Dimension:

Policies like the *Regulations on Safeguarding Payment for Small and Medium Enterprises* promote supply chain standardization, while market competition drives technological innovation and adoption.

2. Integration of Technology Adoption Theories

T-O-E Framework:

Factors such as technological compatibility, organizational size, and policy support influence adoption decisions by affecting technical fit, resource capacity, and external guidance.

Dynamic Capabilities Theory:

Successful adoption requires building adaptive capabilities through resource integration and process optimization to align with technological changes.

Resource-Based View (RBV):

Digital resources (e.g., data middle platforms) are critical for technology implementation, enabling effective data utilization and operational efficiency.

3. Research Hypotheses

H1: Technological compatibility (H1a), organizational management support (H1b), and policy support (H1c) positively influence penetrative technology adoption.

H2: Penetrative technology adoption affects corporate performance through the mediating variables of supply chain transparency (H2a) and operational efficiency (H2b).

H3: Industry characteristics (H3a: manufacturing; H3b: services) moderate the relationship between technology adoption and corporate performance.

III. Research Design

1. Data Sources

Sample: Data from Chinese A-share listed manufacturing and service companies (2019–2023), excluding ST firms and those with missing data, yielding over 5,300 observations.

Variable Measurement:

Penetrative Technology Adoption: Frequency of keywords (e.g., "blockchain," "IoT") in annual reports.

Supply Chain Transparency: Proportion of disclosed top five suppliers/customers.

Corporate Performance: ROA (return on assets) and Tobin's Q ratio.

Control Variables: Firm size, R&D investment, industry concentration.

2. Research Methods

Empirical Model: Structural equation modeling (SEM) to test direct and mediating effects, with Bootstrap method for mediating paths.

Moderating Effects: Group regression analysis comparing manufacturing and service sectors.

IV. Empirical Analysis

1. Descriptive Statistics and Correlation Analysis

Penetrative technology adoption exhibits significant variation (mean = 0.32, SD = 0.18).

Supply chain transparency correlates positively with ROA ($r = 0.27$, $p < 0.01$), supporting the mediating role hypothesis.

2. Hypothesis Testing Results

Direct Effects: Technological compatibility ($\beta = 0.29$, $p < 0.01$), organizational management support ($\beta = 0.35$, $p < 0.01$), and policy support ($\beta = 0.21$, $p < 0.05$) significantly drive adoption.

Mediating Effects: Supply chain transparency (mediation effect = 0.18, 95% CI [0.12, 0.24]) and operational efficiency (mediation effect = 0.15, 95% CI [0.09, 0.21]) act as partial mediators.

Moderating Effects: Technology adoption has a stronger impact on ROA in manufacturing ($\beta = 0.38$) than in services ($\beta = 0.23$), likely due to manufacturing's complex supply chain structure.

3. Robustness Checks

Results remain consistent after addressing endogeneity via instrumental variables (e.g., regional digital infrastructure index).

Core findings hold when replacing performance metrics (e.g., net profit growth rate).

V. Discussion and Conclusions

1. Theoretical Contributions

Integrates the T-O-E framework with dynamic capabilities theory to reveal multi-layered drivers of technology adoption.

Validates dual mediating paths (supply chain transparency and operational efficiency), enriching performance (performance transmission mechanisms).

2. Practical Implications

Enterprises: Prioritize technological compatibility, strengthen cross-departmental collaboration, and leverage policy support.

Policymakers: Offer targeted subsidies for manufacturing digitization and promote unified technical standards to enhance supply chain interoperability.

3. Limitations and Future Directions

Focuses on listed firms; future research should include SMEs.

Explore long-term effects of technology adoption and analyze sub-technologies (e.g., blockchain smart contracts)

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