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Digital Transformation and Operational Efficiency: Evidence from Buyer Firms Under Supply Chain Uncertainty

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Abstract

This study examines the effect of digital transformation (DT) on operational efficiency from a buyer–supplier perspective by applying Information Processing Theory (IPT). Although digital transformation is widely recognized as a strategic approach to improving business performance, empirical evidence remains inconclusive, with many organizations failing to achieve the expected operational benefits. In addition, the influence of uncertainties arising from buyer–supplier relationships has received limited empirical attention. Using secondary data from 257 Chinese A-share listed buyer firms, comprising 892 firm-year observations, this research analyzes the direct effect of DT on operational efficiency and investigates the moderating roles of buyers' technological resources, supplier digitalization, buyer–supplier distance, and supplier dependency. The findings indicate that digital transformation significantly improves operational efficiency. Furthermore, the positive effect is strengthened by higher levels of buyers' technological resources and supplier dependency, whereas supplier digitalization and buyer–supplier distance do not significantly moderate the relationship. These findings provide empirical evidence that the effectiveness of digital transformation depends not only on technology adoption but also on organizational capabilities and supply chain conditions that shape information processing capacity. This study contributes to the digital transformation and supply chain management literature by extending the application of Information Processing Theory to explain how different sources of uncertainty influence operational outcomes. The findings also offer practical implications for managers seeking to optimize digital transformation strategies and for policymakers designing initiatives that support sustainable digitalization across supply chains.

Keywords: digital transformation; operational efficiency; information processing theory; supply chain management; buyer–supplier relationship.

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1. Introduction

The rapid advancement of digital technologies and increasingly intense market competition have accelerated the adoption of digital transformation (DT) as a strategic approach for improving organizational operations (Pelletier et al., 2025). Rather than simply digitizing existing business activities, digital transformation represents a comprehensive organizational change involving the integration of advanced digital technologies into operational processes, decision-making systems, and business models (Tian et al., 2023; Zhai et al., 2022). Within supply chains, DT facilitates real-time information exchange among supply chain partners, enabling greater coordination, transparency, and responsiveness. It also supports the implementation of advanced technologies such as three-dimensional (3D) printing for spare-part production (Delic & Eyers, 2020), robotics for logistics and distribution (Enrique et al., 2022), and digital platforms that improve collaboration and information sharing across the supply chain network (Dubey et al., 2024). Consequently, many organizations view digital transformation as an important source of competitive advantage capable of creating new business value and enhancing revenue generation (Guo et al., 2023). This trend is reflected in projections indicating that global investment in artificial intelligence-related technologies will reach approximately US$337 billion by 2025 (IDC, 2024).

Despite these substantial investments, the outcomes of digital transformation initiatives have not always met organizational expectations. Previous evidence indicates that nearly 70% of digital transformation projects fail to achieve their intended objectives (Priestley & Low, 2023; Wade & Shan, 2020). Such failures are frequently associated with weak leadership, organizational resistance to innovation, inadequate information systems, and poor alignment between technological initiatives and organizational goals (Oludapo et al., 2024). These shortcomings are particularly important because one of the primary objectives of digital transformation is to improve operational efficiency, defined as an organization's ability to convert inputs into outputs more effectively than comparable firms operating on the industry efficiency frontier (Lee & Johnson, 2014). Higher operational efficiency generates short-term benefits such as lower operating costs, faster processes, and better resource utilization, all of which contribute to long-term competitiveness (Kortmann et al., 2014; Li et al., 2021). Nevertheless, operational efficiency is influenced not only by internal organizational capabilities but also by interactions and coordination among supply chain partners (Ghafoori et al., 2024).

Previous studies have explored the contribution of digital transformation to organizational outcomes from various perspectives, including sustainable performance (Li, 2022), business process management (Baiyere et al., 2020), and organizational innovation (Liu et al., 2023a). Although these studies generally suggest positive effects, empirical findings remain inconsistent regarding the extent to which digital transformation improves operational efficiency. Moreover, relatively limited attention has been given to supply chain contexts, where buyer–supplier relationships and interorganizational uncertainties play a critical role in determining operational performance. Existing research has largely emphasized organizational-level transformation while overlooking the influence of supply chain partners in facilitating efficiency improvements. Since buyers often initiate and coordinate digital transformation across supply chain networks, understanding digital transformation from the buyer's perspective provides valuable insights into how operational efficiency can be enhanced throughout the supply chain (Zhang et al., 2025). In addition, empirical evidence based on large-scale datasets remains scarce, despite growing practical interest in evaluating whether digital transformation genuinely improves operational performance (Tian et al., 2023).

To explain the relationship between digital transformation and operational efficiency, this study adopts Information Processing Theory (IPT) as its theoretical

foundation. IPT argues that organizations must continuously develop information-processing capabilities to match the increasing complexity and uncertainty of their operating environments (Galbraith, 1974). Investments in digital transformation enhance these capabilities by improving data acquisition, storage, processing, and utilization, thereby enabling organizations to make better operational decisions (Lu et al., 2024; Yu et al., 2021). According to IPT, improved alignment between information-processing requirements and organizational capabilities increases operational efficiency. However, this relationship may vary depending on the level of uncertainty experienced by organizations. Uncertainty increases information-processing requirements, and organizations that fail to manage such uncertainty effectively are more likely to experience declines in operational performance (Tian et al., 2023).

Building on IPT, this study examines four factors representing different dimensions of uncertainty within supply chains. At the task level, buyers' technological resources strengthen information-processing capabilities and improve data-driven decision making. At the source level, suppliers' digitalization enhances communication quality, coordination, and transparency across supply chain activities (Gillani et al., 2024; Romero-Martínez & García-Muiña, 2021). At the supply network level, buyer–supplier distance (BSD) influences information exchange and knowledge transfer among business partners (Rivera et al., 2010), while supplier dependency (SD) reflects the degree of relational embeddedness that encourages supplier commitment and participation in buyer-supported improvement initiatives (Carr et al., 2008; Kim & Henderson, 2015). These uncertainty dimensions may either strengthen or weaken the effectiveness of digital transformation in improving operational efficiency.

Based on these considerations, this study addresses two research questions. First, does digital transformation improve buyers' operational efficiency? Second, how do buyers' technological resources, suppliers' digitalization, buyer–supplier distance, and supplier dependency influence the relationship between digital transformation and operational efficiency?

To answer these questions, the study analyzes panel data collected from Chinese A-share listed firms operating on the Shanghai and Shenzhen Stock Exchanges. China provides an appropriate research setting because of its long-standing commitment to digital transformation policies and the rapid expansion of its digital economy (Duan et al., 2020; Zhai et al., 2022). Since 2014, the Chinese government has implemented a series of national initiatives promoting big data development and digital infrastructure, culminating in the recognition of data as one of the country's key production factors in 2020 (Yan, 2021). Furthermore, China's "Vision 2035" strategy emphasizes the development of a digital economy through deeper integration of digital technologies into industrial activities. Consistent with these initiatives, China's digital economy expanded to more than 39.2 trillion yuan in 2020, accounting for approximately 38.6% of national GDP (CAICT, 2021; Liu et al., 2023a). These developments provide an ideal environment for examining the operational implications of digital transformation within supply chain management.

This study contributes to the supply chain and operations management literature in several ways. First, it extends the application of Information Processing Theory by examining how digital transformation influences operational efficiency within buyer–supplier relationships. Second, unlike previous studies that primarily focus on organizational-level determinants, this research incorporates uncertainty factors operating at the task, source, and supply network levels, thereby providing a more comprehensive understanding of the conditions under which digital transformation improves operational performance (Busse et al., 2017; Jia et al., 2020). Finally, by examining the moderating roles of buyers' technological resources, supplier digitalization, buyer–supplier distance, and supplier dependency, the study offers practical insights into managing supply chain complexity while enhancing operational

efficiency through digital transformation. These findings respond to recent calls for greater attention to both firm-level and supply chain-level factors affecting digital transformation implementation (Plekhanov et al., 2023; Whipple et al., 2015).

2. Literature Review and Hypothesis Development

Digital transformation (DT) has evolved beyond the simple adoption of digital technologies into a comprehensive organizational transformation that reshapes business processes, operational activities, and value creation (Vial, 2021). Through technologies such as artificial intelligence, blockchain, cloud computing, the Internet of Things, and machine learning, firms are able to improve coordination, optimize resource utilization, and strengthen operational responsiveness across supply chain networks (Bharadwaj et al., 2013; Gillani et al., 2024; Sheng et al., 2023). Unlike conventional digitalization, DT enables organizations to redesign workflows, integrate operational processes, and generate new sources of competitive advantage by facilitating continuous information exchange among supply chain partners (Warner & Wäger, 2019; Nylén & Holmström, 2015).

Previous studies have documented numerous organizational benefits resulting from digital transformation, including enhanced innovation capability, sustainable performance, business process improvement, and environmental performance (Chiarini, 2021; Fang & Liu, 2024; Li, 2022; Sheng et al., 2023). Nevertheless, empirical evidence concerning the direct relationship between digital transformation and operational efficiency remains relatively limited. Although firms continue investing heavily in digital initiatives, practical evidence suggests that many digital transformation projects fail to deliver the expected operational improvements because of organizational barriers, inadequate technological alignment, and insufficient collaboration across supply chain partners (Oludapo et al., 2024; Priestley & Low, 2023; Wade & Shan, 2020). Consequently, understanding the conditions under which digital transformation contributes to operational efficiency has become an important issue in supply chain management research.

Operational efficiency refers to a firm's ability to transform operational inputs into outputs relative to an efficiency frontier established by best-performing organizations (Lee & Johnson, 2014). Improved operational efficiency enables firms to reduce production costs, shorten operational lead times, allocate resources more effectively, and strengthen competitive advantage (Kortmann et al., 2014; Li et al., 2021). Within supply chains, operational efficiency depends not only on internal organizational capabilities but also on effective coordination and information sharing among buyers and suppliers (Ghafoori et al., 2024). Therefore, digital transformation should be viewed from an inter-organizational perspective rather than merely as an internal technological initiative.

This study adopts Information Processing Theory (IPT) as its theoretical foundation. IPT argues that organizational performance depends on the alignment between information processing requirements and information processing capacity under uncertain environments (Galbraith, 1974; Tushman & Nadler, 1978; Egelhoff, 1991). Organizations facing greater uncertainty require stronger information processing capabilities to collect, interpret, and disseminate information efficiently. Investments in digital transformation increase these capabilities by enabling real-time information acquisition, storage, communication, and decision-making (Lu et al., 2024; Yu et al., 2021). Consequently, firms that successfully align information processing capacity with operational requirements are expected to achieve higher operational efficiency.

According to IPT, uncertainty originates from three primary sources, namely task uncertainty, source uncertainty, and supply network uncertainty (Busse et al., 2017; Jia et al., 2020). Task uncertainty emerges from the complexity of organizational activities and the limited technological capability available to perform operational tasks. Source

uncertainty arises from suppliers' characteristics, including differences in digital capabilities, communication quality, and operational transparency. Supply network uncertainty reflects the structural complexity of supply chains, including geographical distance and relational dependence between buyers and suppliers. These uncertainties determine the effectiveness of information processing and consequently influence the performance outcomes of digital transformation initiatives.

Building upon this theoretical perspective, this study proposes that buyer digital transformation positively influences buyer operational efficiency. Digital technologies improve communication, facilitate resource allocation, enhance operational flexibility, and support the redesign of business processes, ultimately improving operational performance (Baiyere et al., 2020; Culasso et al., 2024; Fletcher & Griffiths, 2020; Gharoie Ahangar et al., 2025). Therefore, the first hypothesis is proposed:

H1. *Buyer digital transformation positively affects buyer operational efficiency.*

The effectiveness of digital transformation, however, may vary depending on organizational and supply chain conditions. First, buyer technological resources represent internal capabilities that facilitate digital technology utilization and reduce task uncertainty. Firms possessing stronger technological resources are better positioned to exploit digital transformation for operational improvement (Anzoategui et al., 2019; Bianchi et al., 2014; Hughes et al., 2018). Therefore:

H2. *Buyer technological resources positively moderate the relationship between buyer digital transformation and operational efficiency.*

Second, suppliers with higher levels of digitalization facilitate more transparent information sharing, improve coordination, and strengthen collaborative decision-making between supply chain partners (Chen et al., 2025; Yang et al., 2021; Yang et al., 2025). Accordingly:

H3. *Supplier digitalization positively moderates the relationship between buyer digital transformation and operational efficiency.*

Third, buyer–supplier distance increases communication barriers, cultural differences, and coordination complexity, thereby limiting the effectiveness of digital transformation initiatives (Bernard et al., 2019; Busse et al., 2017; Wiengarten & Ambrose, 2017). Thus:

H4. *Buyer–supplier distance negatively moderates the relationship between buyer digital transformation and operational efficiency.*

Finally, supplier dependency reflects the extent to which buyers rely on strategic suppliers. Strong dependency often encourages closer collaboration, greater resource sharing, and more effective knowledge integration, enabling firms to obtain greater operational benefits from digital transformation (Petersen et al., 2008; Schiele & Vos, 2015; Yang et al., 2025). Therefore:

H5. *Supplier dependency positively moderates the relationship between buyer digital transformation and operational efficiency.*

3. Research Methods

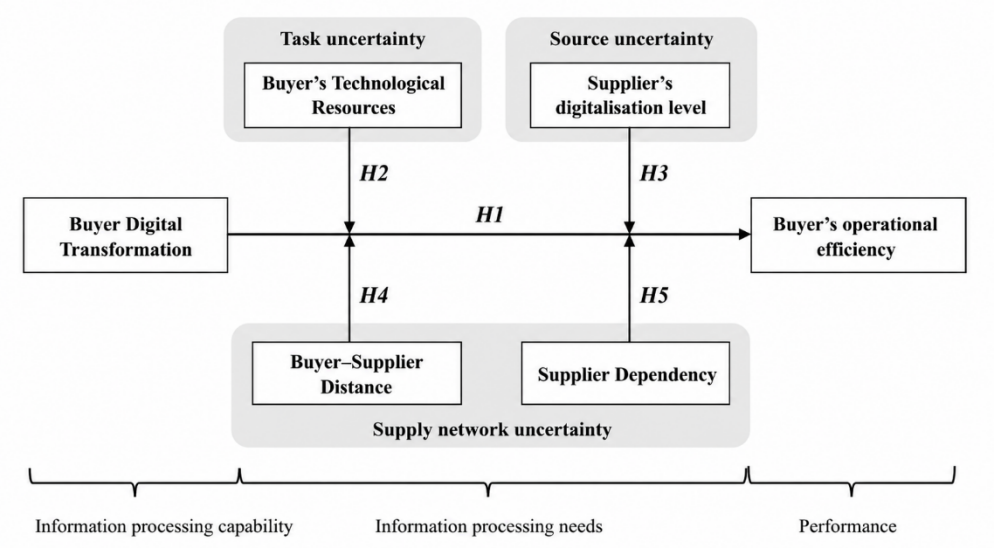

Figure 1. Research Framework

To test these hypotheses, this study employed panel data from Chinese A-share listed firms on the Shanghai and Shenzhen Stock Exchanges during the period 2010–2021. Buyer–supplier relationship data and annual financial reports were obtained from the China Stock Market Accounting Research (CSMAR) database. Following previous studies (Gu et al., 2024; Huo et al., 2022; Zhu et al., 2021), firms operating in the financial industry, firms classified as Special Treatment (ST and ST*), and observations with incomplete information were excluded. Additional firm-level information was collected from the China Research Data Service (CNRDS) and Wind databases, resulting in a final sample of 257 buyer firms with 892 firm-year observations.

Buyer operational efficiency (BOE) was measured using the Stochastic Frontier Estimation (SFE) approach (Lam et al., 2016). The stochastic production function is specified as follows:

$$\ln(Operating\ Income) = \beta_0 + \beta_1 \ln(Number\ of\ Employees)_{ijt} + \beta_2 \ln(Cost\ of\ Goods\ Sold)_{ijt} + \beta_3 \ln(Capital\ Expenditure)_{ijt} + \varepsilon_{ijt} - \eta_{ijt} \quad (1)$$

$$Operational\ Efficiency\_(ijt) = 1 - \eta_{ijt} \quad (2)$$

Buyer digital transformation (BDT) was measured using the text analysis approach proposed by Tian et al. (2023). Digital transformation keywords representing emerging digital technology, digital management, informatization, Internet Plus initiatives, and intelligent operations were extracted from annual reports and weighted using the entropy method to construct the BDT index.

Buyer technological resources were proxied by research and development (R&D) investment (Bianchi et al., 2014; Son & Zo, 2023). Supplier digitalization was measured using the same text analysis approach as buyer digital transformation. Buyer–supplier distance was calculated based on the geographical distance between buyers and suppliers, whereas supplier dependency was measured as:

$$SD_{it} = \frac{Procurements\ from\ Top\ Five\ Suppliers_{it}}{Total\ Procurements_{it}} \quad (3)$$

Firm size, leverage, return on assets, firm growth, board size, independent director ratio, ownership concentration, industry fixed effects, and year fixed effects were included as control variables.

Table 1. Variable Definitions and Measurements

Variable	Definition	References
Buyer Operational Efficiency (BOE)	Applying Stochastic Production Functions to evaluate a buyer firm's operational efficiency.	Lam et al. (2016)
Buyer Digital Transformation (BDT)	Utilizing text analysis to quantify the degree of a buyer firm's digital transformation.	Tan et al. (2023)
Buyer Technological Resource (BTR)	The R&D investment of a buyer firm.	Bianchi et al. (2014); Son and Zo (2023)
Supplier Digital Transformation (SDT)	Utilizing text analysis to quantify the degree of a supplier firm's digital transformation.	Tan et al. (2023)
Buyer–Supplier Distance (BSD)	The direct geographic distance between a buyer and its suppliers.	Wiengarten and Ambrose (2017)
Supplier Dependency (SD)	The proportion of total procurement from a buyer's top five suppliers.	Zhu et al. (2021)
Firm Size (Size)	The natural logarithm of a sample firm's total assets.	
Leverage (Lev)	The ratio of a sample firm's total debts to its total assets.	
Firm Profitability (ROA)	A sample firm's return on total assets.	
Firm Growth (Growth)	The ratio of a sample firm's total operating income growth in year t to operating income in year $t-1$.	
Board Size (Board)	The natural logarithm of the number of directors on a sample firm's board.	
Independent Director Ratio (IndRatio)	The ratio of independent directors to the total number of directors on a sample firm's board.	
Ownership Concentration (OC)	The shareholding ratio of the top 10 shareholders in a sample firm.	

The hypotheses were examined using panel regression analysis. The baseline regression model is specified as:

$$BOE_{it} = \beta_0 + \beta_1 BDT_{it} + \sum_{i=1}^{n} \beta_i Control_i + \varepsilon \quad (4)$$

To examine the moderating effects of buyer technological resources, supplier digitalization, buyer–supplier distance, and supplier dependency, the following interaction model was estimated:

$$BOE_{it} = \beta_0 + \beta_1 BDT_{it} + \beta_2 Moderator_{it} + \beta_{3(BDT_{it} \times Moderator_{it})} + \sum_{i=1}^{n} \beta_i Control_i + \varepsilon \quad (5)$$

where BOE denotes buyer operational efficiency, BDT represents buyer digital transformation, Moderator refers to each moderating variable, and Control denotes the set of control variables included in the estimation.

4. Results

4.1 Descriptive Statistics

Descriptive statistics were employed to summarize the characteristics of all variables included in the study. The results indicate considerable variation among the sampled firms regarding operational efficiency, digital transformation, technological resources, supplier digitalization, buyer–supplier distance, and supplier dependency. Such variation

reflects differences in firms' digital maturity and supply chain characteristics, providing sufficient variability for empirical analysis. Overall, the descriptive statistics demonstrate that the sample adequately represents firms with diverse operational and digital transformation conditions.

Table 2. Descriptive Statistics

Variable	Obs	Mean	SD	Min	Max
BOE	892	0.782	0.221	0.697	0.934
BDT	892	0.283	0.062	0.109	0.326
Size	892	21.779	1.121	20.996	22.366
Lev	892	0.420	0.202	0.262	0.567
ROA	892	0.029	0.064	0.012	0.059
Growth	892	0.147	0.379	-0.028	0.249
Board	892	2.319	0.261	2.197	2.485
IndRatio	892	0.373	0.069	0.333	0.417
OC	892	0.325	0.139	0.221	0.416

4.2 Regression Results

Panel regression analysis was conducted to examine the effect of buyers' digital transformation on operational efficiency and to evaluate the moderating roles of buyers' technological resources, suppliers' digitalization level, buyer–supplier distance, and supplier dependency. Prior to hypothesis testing, multicollinearity diagnostics confirmed that the correlations among explanatory variables were below the recommended threshold, indicating that multicollinearity was not a concern (Gujarati, 2009). Appropriate panel estimation procedures were subsequently employed to identify the most suitable regression model.

The baseline regression results reveal that buyers' digital transformation has a positive and statistically significant effect on operational efficiency, thereby supporting H1. This finding indicates that firms implementing digital transformation are better able to improve operational processes, optimize resource allocation, strengthen information processing capability, and enhance coordination across supply chain activities.

The moderating analysis further demonstrates that buyers' technological resources significantly strengthen the positive relationship between digital transformation and operational efficiency, providing support for H2. Firms possessing stronger technological capabilities are more capable of utilizing digital transformation to improve operational performance.

Similarly, suppliers' digitalization level positively moderates the relationship between buyers' digital transformation and operational efficiency, supporting H3. Suppliers with advanced digital capabilities facilitate real-time information exchange, improve transparency, and strengthen collaboration throughout the supply chain, thereby increasing the operational benefits obtained from digital transformation.

Conversely, buyer–supplier distance negatively moderates the relationship between digital transformation and operational efficiency. Greater geographical separation increases coordination complexity, communication barriers, and information uncertainty, thereby weakening the effectiveness of digital transformation in improving operational efficiency. These findings provide empirical support for H4.

The results also indicate that supplier dependency positively moderates the relationship between digital transformation and operational efficiency, supporting H5. Buyers with stronger dependence on strategic suppliers tend to establish closer

collaborative relationships, enabling greater knowledge sharing, resource integration, and operational coordination that reinforce the benefits of digital transformation.

Overall, the findings confirm that digital transformation significantly enhances operational efficiency. However, its effectiveness depends on both firm-level and supply chain-level conditions. Technological resources, supplier digitalization, and supplier dependency amplify the positive effects of digital transformation, whereas buyer–supplier distance reduces its effectiveness.

Table 3. Regression Results

Variables	Model 1 BOE	Model 2 BOE	Model 3 BOE	Model 4 BOE	Model 5 BOE
BDT	0.462*** (2.66)	0.313 (1.63)	0.347* (1.74)	0.352* (1.81)	0.407** (2.01)
BTR		0.093 (1.52)			
BDT × BTR		0.536** (2.75)			
SDT			0.572* (1.85)		
BDT × SDT			0.392 (1.31)		
BSD				0.560** (2.08)	
BDT × BSD				0.442 (1.44)	
SD					0.476 (1.33)
BDT × SD					0.618*** (2.67)
Size	0.017 (0.83)	-0.029 (-0.92)	0.042 (1.24)	0.007 (0.22)	-0.051* (-1.80)
Lev	-0.263*** (-2.77)	-0.179 (-1.12)	-0.307** (-2.49)	-0.363** (-2.29)	-0.143 (-1.21)
ROA	0.294** (2.07)	0.221 (0.81)	0.890*** (4.75)	0.162 (0.83)	0.647*** (4.09)
Growth	0.010 (0.81)	0.003 (0.13)	0.011 (0.91)	0.011 (0.68)	-0.019 (-1.13)
Board	-0.022 (-0.67)	-0.062 (-1.20)	-0.009 (-0.19)	0.017 (0.33)	0.001 (0.02)
IndRatio	-0.124 (-1.38)	-0.042 (-0.30)	0.062 (0.55)	-0.340** (-2.21)	-0.177** (-1.99)
OC	0.030 (0.29)	-0.114 (-0.42)	-0.043 (-0.19)	0.120 (0.48)	-0.139 (-1.37)
_cons	0.573 (1.25)	1.619** (2.38)	-0.029 (-0.04)	0.814 (1.20)	2.107*** (3.31)
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	892	892	892	892	892

Adjusted R^2	0.058	0.040	0.053	0.062	0.083

4.3 Robustness Check

Several robustness tests were performed to verify the stability and reliability of the empirical findings. First, the analysis was repeated after excluding firms with poor information disclosure quality and firms receiving special regulatory treatment. The estimated coefficients remained consistent with the baseline model, indicating that the results were not driven by sample selection.

Second, propensity score matching (PSM) was employed using multiple matching specifications to reduce potential selection bias associated with firms' digital transformation activities. Across different matching methods, the estimated effects remained positive and statistically significant, confirming the robustness of the baseline results.

Finally, an instrumental variable (IV) approach was implemented to address potential endogeneity and reverse causality concerns. Following previous studies, the digital development level of the city in which each buyer firm operates was used as the instrumental variable for buyers' digital transformation. The two-stage estimation produced results consistent with the primary regression analysis, suggesting that the positive impact of digital transformation on operational efficiency is robust and not driven by endogeneity.

Collectively, these robustness analyses provide strong evidence that the main findings remain stable across alternative model specifications and estimation techniques, further supporting the validity of the proposed hypotheses.

Table 4. Robustness Check Results

Variables	Model 1 Disclosure Quality No Violation BOE	Model 2 Disclosure Quality High Quality BOE	Model 3 PSM 1:1 Matching BOE	Model 4 PSM 1:2 Matching BOE	Model 5 PSM 1:3 Matching BOE	Model 6 2SLS Instrumental Variable BDT	Model 7 2SLS Instrumental Variable BOE
BDT	0.396** (2.09)	0.453** (2.55)	0.522*** (2.83)	0.480*** (2.74)	0.490*** (2.95)	—	0.988* (1.71)
Digital City	—	—	—	—	—	0.428*** (5.94)	—
Size	-0.007 (-0.28)	0.027 (1.16)	-0.020 (-0.53)	-0.013 (-0.44)	-0.020 (-0.77)	0.017*** (2.75)	0.007 (0.30)
Lev	-0.273*** (-2.69)	-0.325*** (-3.12)	-0.256 (-1.54)	-0.231* (-1.70)	-0.195* (-1.73)	0.010 (0.51)	-0.273*** (-2.97)
ROA	0.619*** (3.07)	0.711*** (3.51)	0.408 (1.56)	0.371* (1.87)	0.370** (2.27)	0.001 (0.05)	0.295** (2.13)
Growth	0.006 (0.45)	-0.001 (-0.06)	0.009 (0.30)	-0.008 (-0.49)	0.003 (0.19)	-0.003 (-1.48)	0.012 (0.99)
Board	-0.027 (-0.66)	-0.015 (-0.39)	-0.059 (-1.06)	-0.056 (-1.24)	-0.070* (-1.69)	0.002 (0.31)	-0.023 (-0.71)
IndRatio	-0.138 (-1.24)	-0.111 (-1.17)	-0.049 (-0.33)	0.056 (0.45)	0.029 (0.27)	0.001 (0.09)	-0.128 (-1.42)
OC	-0.239 (-1.52)	-0.110 (-0.63)	-0.148 (-0.42)	-0.160 (-0.63)	-0.233 (-1.14)	-0.000 (-0.00)	0.055 (0.31)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	673	634	253	361	432	892	892
Kleibergen–Paaprk Wald F statistic	—	—	—	—	—	—	35.276
Adjusted R^2	0.071	0.087	0.070	0.068	0.077	0.389	0.278

5. Discussion

The findings demonstrate that buyers' digital transformation significantly enhances operational efficiency, supporting the fundamental proposition of Information Processing Theory (IPT), which argues that organizations improve performance by strengthening their information processing capabilities to cope with uncertainty (Galbraith, 1974). Digital transformation enables firms to optimize operational processes, improve resource allocation, and facilitate timely information exchange across supply chain partners, ultimately leading to higher operational efficiency. This finding is consistent with previous studies highlighting the role of digital transformation in improving organizational performance, innovation, and operational flexibility (Baiyere et al., 2020; Fang and Liu, 2024; Li, 2022).

The moderating effects further emphasize that the effectiveness of digital transformation depends on both organizational capabilities and supply chain conditions. Buyers with stronger technological resources obtain greater operational benefits from digital transformation because technological capabilities enhance information processing capacity and facilitate the deployment of advanced digital technologies. This finding supports prior research suggesting that technological resources strengthen firms' ability to exploit digital technologies and improve operational performance (Anzoategui et al., 2019; Hughes et al., 2018).

Similarly, supplier digitalization positively strengthens the relationship between buyers' digital transformation and operational efficiency. Digitally capable suppliers improve information transparency, communication quality, and interorganizational collaboration, enabling buyers to coordinate supply chain activities more effectively and reduce operational uncertainty. These findings are consistent with previous studies emphasizing that digital alignment between buyers and suppliers enhances supply chain integration and knowledge sharing (Chen et al., 2025; Gillani et al., 2024; Yang et al., 2025).

Conversely, buyer–supplier distance weakens the positive effect of digital transformation on operational efficiency. Greater geographical separation increases communication complexity, coordination costs, and information uncertainty, thereby reducing the ability of digital transformation initiatives to improve operational performance. This result supports the Information Processing Theory perspective that increasing supply network complexity raises information processing requirements, making organizational coordination more difficult (Busse et al., 2017; Wiengarten and Ambrose, 2017).

The results also indicate that supplier dependency positively moderates the relationship between digital transformation and operational efficiency. Firms relying more heavily on strategic suppliers tend to establish closer collaborative relationships, facilitating greater resource sharing, knowledge transfer, and operational coordination. Such collaborative relationships allow buyers to utilize digital transformation more effectively to improve operational performance, which is consistent with previous findings regarding supplier relationships and supply chain collaboration (Petersen et al., 2008; Schiele and Vos, 2015; Yang et al., 2025).

Overall, this study extends the application of Information Processing Theory within supply chain management by demonstrating that digital transformation improves operational efficiency through enhanced information processing capability, while its effectiveness varies according to technological resources and supply chain uncertainties. The findings highlight that successful digital transformation requires not only internal technological capability but also collaborative digital ecosystems involving supply chain partners. Consequently, managers should prioritize investments in digital technologies, strengthen technological capabilities, foster digital collaboration with suppliers, and develop strategic partnerships that reduce uncertainty and maximize the operational benefits of digital transformation.

6. Conclusions

This study demonstrates that buyers' digital transformation significantly improves operational efficiency by strengthening firms' information processing capabilities within supply chain operations. Consistent with Information Processing Theory, digital transformation enables organizations to process information more effectively, optimize operational processes, and improve coordination with supply chain partners, thereby enhancing overall operational performance.

The findings further reveal that the effectiveness of digital transformation depends on both internal organizational capabilities and external supply chain conditions. Buyers' technological resources, supplier digitalization, and supplier dependency strengthen the positive impact of digital transformation on operational efficiency, whereas greater buyer–supplier distance weakens this relationship due to increased coordination complexity and information uncertainty. These results highlight the importance of developing collaborative digital ecosystems rather than focusing solely on internal digital initiatives.

From a managerial perspective, organizations should invest not only in digital technologies but also in technological capabilities, supplier collaboration, and long-term strategic partnerships that facilitate information sharing and operational coordination. Strengthening digital collaboration across the supply chain is essential for maximizing the operational benefits of digital transformation.

This study contributes to the literature by extending the application of Information Processing Theory to explain how digital transformation improves operational efficiency under different supply chain uncertainty conditions. Nevertheless, several limitations should be acknowledged. The study focuses on Chinese A-share listed manufacturing firms, which may limit the generalizability of the findings to other industries and countries. Future research is encouraged to examine different industrial contexts, employ alternative measures of digital transformation and operational efficiency, and explore additional organizational or environmental factors that may influence the relationship between digital transformation and operational performance.

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