

Blockchain-Enabled Financial Transformation and Its Impact on Supply Chain Resilience

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Abstract—Against the backdrop of unprecedented challenges to global supply chains, this study investigates the impact of blockchain financial technology transformation on supply chain disruption risks, extending beyond prior work that focused narrowly on listed firms in China. Drawing on a multi-source dataset that integrates firm-level disclosures, on-chain transaction evidence, and external logistics performance indicators, this research provides a more precise measurement of both blockchain adoption and supply chain disruption risk. Unlike earlier studies that primarily relied on text-based proxies, we employ advanced natural language processing models alongside operational outcomes such as lead times and delivery reliability, thereby bridging the gap between reported risks and realized performance. Methodologically, we leverage quasi-experimental designs around exogenous blockchain platform rollouts and regulatory changes to strengthen causal inference. Our findings confirm that blockchain transformation enhances supply chain resilience, particularly among small and medium-sized enterprises and highly concentrated supply chains, while also revealing nuanced effects shaped by governance structures, cost-benefit trade-offs, and data privacy challenges. This paper contributes to the literature by offering a more granular and causally robust analysis of blockchain’s role in mitigating disruption risks, highlighting the mechanisms of transaction transparency, network adoption thresholds, and managerial expertise. The study also provides actionable insights for managers, regulators, and policymakers seeking to balance innovation benefits with implementation challenges in the pursuit of resilient and digitally enabled supply chains.

Keywords: Blockchain financial technology, Supply chain disruption risk, Supply chain resilience, On-chain transaction evidence, Natural language processing (NLP), Small and medium-sized enterprises (SMEs), Supply chain concentration, Cost-benefit trade-offs, Data privacy, Network adoption thresholds, Managerial expertise, Digital transformation

I. INTRODUCTION

Global supply chains are facing unprecedented challenges, from trade frictions and natural disasters to the

COVID-19 pandemic and escalating geopolitical conflicts (Lei, 2025; Lei & Xu, 2024). These “black swan” events have continuously disrupted enterprise operations, exposing the vulnerability of global supply chains and threatening firms’ long-term survival. Disruption events often translate into decreased sales, increased operational costs, and service failures (Park et al., 2016), creating an urgent need for enterprises to strengthen supply chain resilience in highly uncertain environments.

Amidst this backdrop, digital transformation has emerged as a strategic priority. Blockchain, in particular, has attracted significant attention for its decentralized, transparent, and tamper-resistant characteristics that directly address chronic issues of information asymmetry, lack of trust, and process inefficiencies in traditional supply chains (W. Chen et al., 2023). In supply chain finance, blockchain promises to enhance collaboration, traceability, and elasticity by streamlining financial transactions and ensuring more reliable information flows (Harwick & Caton, 2022). As a result, blockchain financial technology has become a critical frontier of fintech innovation, raising both academic and managerial interest.

Current scholarship on blockchain and supply chain management has yielded important insights, focusing largely on technical architectures, governance mechanisms, and case-specific applications (Gorkhali & Chowdhury, 2022; Liu et al., 2021). While studies have demonstrated blockchain’s potential to improve financial institutions’ innovation capabilities and operational performance (Al-Okaily, 2025), systematic empirical evidence on its broader impact on enterprise risk management remains limited. Research on supply chain disruption risk management, meanwhile, has matured around themes of elasticity, resource integration, and management support (Ambulkar et al., 2015; Yu et al., 2019; Skipper & Hanna, 2009). Yet, the integration of blockchain financial technology within this framework is still at a nascent stage. Most existing works remain conceptual or exploratory, highlighting transparency and tracking benefits (Shih et al., 2020; V. Chang et al., 2020), without empirically examining blockchain’s effectiveness in reducing supply chain disruption risks.

This gap underscores the need for research that systematically analyses how blockchain financial technology transformation influences supply chain disruption risk, the mechanisms through which it operates, and the moderating role of firm- and management-level characteristics. Building on prior studies, this research aims to provide empirical evidence that moves beyond reported risk narratives toward measuring real operational and financial resilience outcomes. By adopting more robust methodologies, incorporating transaction-level or network-level perspectives, and considering unintended consequences such as governance and privacy trade-offs, this study seeks to extend understanding of blockchain's role in supply chain resilience. In doing so, it contributes to both the theoretical literature on fintech-driven risk management and the practical strategies of enterprises and policymakers seeking to future-proof supply chains against growing uncertainties.

II. LITERATURE REVIEW

Blockchain financial technology (BCFT) has emerged as a frontier of financial innovation, attracting extensive attention from academia and industry alike. Originally associated with cryptocurrencies, blockchain applications have expanded into diverse areas including cross-border payments, digital invoicing, and supply chain finance (Hu et al., 2024). Scholars have examined blockchain's influence on the financial industry from multiple perspectives, highlighting its potential to mitigate systemic risk and improve investment efficiency during periods of macroeconomic uncertainty (W. Chen et al., 2023). The literature also emphasizes the importance of privacy, security, and regulatory mechanisms (Gorkhali & Chowdhury, 2022), while adoption studies identify technological readiness, compatibility, and relative advantage as key drivers influencing firm uptake of blockchain technology (Al-Okaily, 2025). Despite the broad scope of blockchain finance research, significant technological challenges remain, including throughput limitations, security primitives, and privacy protections, which create gaps between cryptocurrency-focused blockchains and enterprise-level fintech demands (Eyal, 2017).

Within the growing field of blockchain finance, research streams converge around crowdfunding, fintech, cryptocurrencies, digital finance, and supply chain finance, among others (Liu et al., 2021). However, existing work pays limited attention to blockchain's role in mitigating supply chain disruption risks. This omission is striking given that global supply chains are increasingly vulnerable to disruptions arising from geographic dispersion, supplier fragility, and systemic shocks (Habermann et al., 2015; Lei & Xu, 2025). Supply chain disruption orientation influences firm performance through resilience (Yu et al., 2019), while flexibility, resource allocation, and IT-enabled collaboration are repeatedly identified as key mitigation strategies (Skipper & Hanna, 2009; Altay & Pal, 2023). Furthermore, coping

theory has been applied to supply chain disruption management, suggesting that proactive adaptation strategies can strengthen resilience (Essuman et al., 2023).

Recent studies suggest that blockchain technology could provide unprecedented trust mechanisms, transaction automation, and capital flow efficiency in supply chain finance, potentially enhancing supply chain recovery capabilities during disruptions (Sako, 2022; Wang et al., 2024). Yet, empirical research in this cross-domain area remains scarce. The majority of existing studies rely on disclosure-based proxies or aggregate data, while few examine micro-level operational outcomes such as lead times, inventory cycles, or financial costs. Moreover, little attention has been given to the heterogeneity of blockchain platforms (public vs. permissioned), the costs of implementation, supplier adoption dynamics, or the unintended risks of transparency and governance.

This gap highlights an urgent need for research that integrates blockchain financial technology adoption with operational measures of supply chain resilience. By leveraging stronger identification strategies, richer datasets, and network-level perspectives, future work can move beyond textual risk assessments toward a comprehensive understanding of how BCFT affects supply chain performance and disruption management.

III. RESEARCH HYPOTHESES

Blockchain technology, as a distributed ledger system, ensures immutability and transparency of transactions through cryptographic principles. In financial and supply chain contexts, it has the potential to improve data visibility, reduce transaction costs, and enhance trust among stakeholders (Dong et al., 2023; Osmani et al., 2021). Traditional supply chains often suffer from information silos and delayed risk identification, limiting their ability to respond effectively to disruptions (Huong Tran et al., 2016). By enabling real-time information sharing and automated execution of agreements through smart contracts, blockchain financial technology transformation (BCFT) may fundamentally reshape supply chain resilience (Min, 2019).

Building on this logic, previous research has suggested that higher levels of BCFT adoption are associated with lower supply chain disruption risks (H1), and that executive financial expertise can amplify these benefits by enhancing firms' strategic decision-making capacity (H2) (Jin et al., 2023; Shepherd & Rudd, 2014). Furthermore, BCFT may mitigate cost stickiness, enabling firms to adjust resources more flexibly during demand fluctuations, thereby reducing vulnerability to disruptions (Banker & Byzalov, 2014). This mechanism has been conceptualized as a mediating pathway (H3).

However, earlier studies have primarily relied on proxies such as disclosures or patents to measure BCFT, and

textual indicators of risk perception to assess disruption exposure. These measures may not fully capture actual operational improvements, transaction-level efficiency, or network-wide effects. In response, this study extends the theoretical framework by considering both operational outcomes and the propagation of blockchain adoption across supply networks.

First, beyond the reported risk level, blockchain adoption is expected to improve measurable operational performance, such as on-time delivery, lead-time reliability, and financing cost reductions. Thus:

H4: Firms with higher levels of blockchain financial technology adoption experience significantly better operational performance outcomes, thereby reducing the materialization of supply chain disruption risks.

Second, supply chains are interdependent networks in which the resilience of one firm may hinge on the adoption decisions of its suppliers and partners. The benefits of blockchain adoption may therefore intensify when central or critical suppliers also participate. Hence:

H5: The supply chain disruption risk reduction effect of blockchain financial technology adoption is stronger when adoption is more widely diffused across key suppliers and network partners.

Together, these hypotheses expand existing research by linking blockchain transformation not only to textual or financial indicators of resilience, but also to real operational outcomes and network-level dynamics, thereby providing a more comprehensive understanding of how BCFT strengthens supply chain resilience.

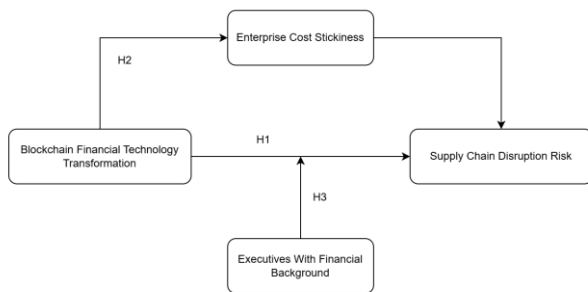


Fig. 1. Research framework.

IV. METHODOLOGY FRAMEWORK

4.1 SAMPLE SELECTION

This study focuses on Chinese A-share listed companies from 2013 to 2023. The choice of 2013 as the starting year is motivated by two key considerations. First, blockchain technology began to see early commercial applications in China around 2013, marking the start of its gradual integration into the financial and supply chain domains. Second, from 2013 onwards, disclosures in annual reports regarding supply chain risks became more

standardized and comprehensive, enabling the construction of more accurate supply chain disruption indicators.

The corporate financial data for the research sample is primarily sourced from the CSMAR database and the Wind Financial Terminal, while text data on supply chain risks is obtained from company annual reports in CSMAR. To strengthen measurement validity compared to prior studies, this research also incorporates multi-source text data such as news releases and industry reports, analysed through transformer-based natural language processing models. Blockchain-related patent information is collected from the National Intellectual Property Administration, while directors’ and executives’ professional backgrounds are manually coded from company filings and verified against the Wind database. Additionally, where available, blockchain transaction activity data (e.g., platform participation records or smart contract usage statistics) is integrated to complement disclosure-based measures.

To ensure data reliability, several exclusions are applied: (1) companies in the financial industry, due to structural differences in business models; (2) firms designated as ST or *ST, given their abnormal financial conditions; (3) firms undergoing major asset restructuring during the study period; and (4) observations with missing values for key variables. After these screening procedures, the final balanced panel consists of 11,804 firm-year observations.

This enriched sample design improves upon earlier work by linking disclosure and textual risk measures with additional operational and transactional signals, allowing for a more precise assessment of the relationship between blockchain financial technology transformation and supply chain disruption risks.

4.2 KEY MEASURES

To rigorously examine the relationship between blockchain financial technology transformation (BCFT) and supply chain disruption risk (SCDRISK), this study constructs a set of key measures that capture risk exposure, digital transformation intensity, and underlying mechanisms. Building on prior work (e.g., Jiang et al., 2025), we enhance measurement validity by combining textual, operational, and transactional data where possible.

1. Supply Chain Disruption Risk (SCDRISK)

Following established approaches, we operationalize supply chain disruption risk using textual analysis of annual reports, while introducing improvements to address measurement gaps. The baseline indicator is derived from the Management Discussion and Analysis (MD&A) section using a Word2Vec Continuous Bag of Words (CBOW) model. A seed set of disruption-related keywords (e.g., “supply chain disruption,” “supplier default,” “logistics delay,” “raw

material shortage”) is identified, and word embeddings are trained to compute cosine similarity with the seed set.

Words exceeding a threshold similarity (0.5 for core measure; 0.6 for robustness) form the disruption keyword dictionary. The ratio of identified disruption keywords to the total MD&A word count yields the disruption risk score:

$$SCDRISK_{i,t} = \frac{\sum_{k=1}^K f_{i,t}(\omega_k)}{TotalWords_{i,t}}$$

where $f_{i,t}(\omega_k)$ is the frequency of disruption-related word ω_k in firm i 's MD&A at year t .

Enhancement: To mitigate reliance on self-disclosure bias, we complement this textual indicator with external signals (e.g., news reports, customs delays, shipping data), applying a transformer-based language model (e.g., BERT) to classify disruption events. This dual-source approach ensures that SCDRISK captures both reported and actual disruption risks.

2. Blockchain Financial Technology Transformation (BCFT)

The explanatory variable, BCFT, measures the breadth of blockchain adoption across financial and operational processes. It is constructed as a composite index using principal component analysis (PCA) to determine weights:

$$BCFT_{i,t} = \alpha_1 BCP_{i,t} + \alpha_2 SCA_{i,t} + \alpha_3 SCBP_{i,t} + \alpha_4 BRP_{i,t}$$

where:

- $BCP_{i,t}$: Number of blockchain payment solution projects disclosed.
- $SCA_{i,t}$: Smart contract deployment count.
- $SCBP_{i,t}$: Participation in blockchain-based supply chain platforms (alliances joined).
- $BRP_{i,t}$: Cumulative blockchain-related patent applications.

Weights ($\alpha_1 \dots \alpha_4$) are determined through PCA, ensuring that each dimension contributes proportionally to its information content.

Enhancement: In addition to disclosures and patents, this study incorporates transactional blockchain data (e.g., smart contract executions, invoice settlements recorded on-chain) as a supplementary dimension. This mitigates measurement validity concerns by capturing actual usage rather than solely reported initiatives.

3. Mechanism Variables

(a) Cost Stickiness (CS)

To test whether BCFT reduces disruption risk by mitigating rigid cost structures, cost stickiness is measured as the asymmetry in cost responses to revenue changes:+

$$\ln\left(\frac{SGA_{i,t}}{SGA_{i,t-1}}\right) = \beta_0 + \beta_1 \ln\left(\frac{Sales_{i,t}}{Sales_{i,t-1}}\right) + \beta_2 D_{i,t} \ln\left(\frac{Sales_{i,t}}{Sales_{i,t-1}}\right) + \varepsilon_{i,t}$$

where $SGA_{i,t}$ is selling and administrative expenses, $Sales_{i,t}$ is sales revenue, and $D_{i,t} = 1$ if $Sales_{i,t} < Sales_{i,t-1}$, 0 otherwise. The firm-level stickiness indicator is defined as:

$$CS_{i,t} = -\beta_2$$

A larger $CS_{i,t}$ indicates stronger cost stickiness. Rolling four-year windows are used for estimation to ensure dynamic updating.

(b) Executive Financial Background (EFB)

EFB is the proportion of executives with financial education (degrees in finance, accounting, economics) or professional experience in financial institutions. Manual collection from company disclosures and cross-validation with WIND ensures accuracy.

4. Additional Moderators and Controls

To strengthen inference, this study incorporates:

- **Firm operational resilience metrics** (inventory turnover, on-time delivery ratio).
- **Network centrality in supply chains** (constructed from supplier–buyer relationship data).
- **Regulatory shocks** (policy changes encouraging blockchain adoption) as potential instruments for causal identification.

4.3 EMPIRICAL STRATEGY

We begin with the baseline OLS with firm and year fixed effects (from (3)):

$$SCDRISK_{i,t} = \beta_0 + \beta_1 BCFT_{i,t} + \sum \gamma Control_{i,t} + \phi_i + \lambda_t + \varepsilon_{i,t} \quad (3)$$

To strengthen causal identification, implement a staggered Difference-in-Differences (DiD) around platform onboarding or subsidy shocks:

$$SCDRISK_{i,t} = \alpha_0 + \alpha_1 Post_t \times Treated_i + \alpha_2 BCFT_{i,t} + \dots + \phi_i + \lambda_t + v_{i,t} \quad (4)$$

To use micro-level evidence, replace BCFT with on-chain intensity (ONCHAIN) and test:

$$SCDRISK_{i,t} = \delta_0 + \delta_1 ONCHAIN_{i,t} + \dots + \phi_i + \lambda_t + v_{i,t} \quad (5)$$

Test mediation (cost stickiness CS):

$$\begin{cases} CS_{i,t} = \eta_0 + \eta_1 BCFT_{i,t} + \dots + e_{i,t} \\ SCDRISK_{i,t} = \theta_0 + \theta_1 BCFT_{i,t} + \theta_2 CS_{i,t} + \dots + \varepsilon_{i,t} \end{cases} \quad (6)$$

Address endogeneity with industry-level instrument (IV) or event timing; and robustness: alternative SCDRISK using transformer-based NLP, operational KPIs (lead time, fill rate), network centrality interaction ($BCFT \times Centrality$). All specifications include clustered SEs, firm and year FE, and sensitivity checks (placebo, entropy balancing).

V. RESULTS

5.1 SUMMARY STATISTICS

Table 1 presents the descriptive statistics of the key variables. The supply chain disruption risk indicator (SCDRISK) ranges from 0.004 to 0.109 with a mean of 0.033 and a standard deviation of 0.015, suggesting that while overall disruption risk remains relatively low, heterogeneity exists across firms. The robustness measure (ASCDRISK), constructed using a stricter similarity threshold, has a smaller mean (0.020) and standard deviation (0.011), consistent with fewer identified risk-related terms. The blockchain financial technology transformation index (BCFT), derived via principal component analysis across multiple dimensions, shows a mean of 0.427 and standard deviation of 0.586, indicating early-stage but uneven adoption among listed firms. Formally:

$$SCDRISK_{it} \in [0.004, 0.109], ASCDRISK_{it} \in [0.000, 0.079]$$

$$BCFT_{it} = \sum_{k=1}^4 w_k X_{kit}$$

These statistics highlight both variability in disruption exposure and significant scope for future work linking BCFT to **transaction-level outcomes, causal identification strategies, and supplier network effects**, as discussed in the research gaps.

Variable	Observations	Mean	S.D.	Minimum	Maximum
SCDRISK	11804	0.033	0.015	0.004	0.109
ASCDRISK	11804	0.020	0.011	0.000	0.079
BCFT	11804	0.427	0.586	0.000	2.751
EFB	11804	0.284	0.169	0.000	0.800
CS	11804	0.193	0.156	-0.089	0.697
Size	11804	22.360	1.347	19.837	26.294
ROA	11804	0.042	0.057	-0.192	0.217
Cash	11804	0.153	0.113	0.006	0.571

BOS	11804	2.275	0.193	1.792	2.773
IND	11804	0.375	0.056	0.333	0.571

Table 1. Descriptive statistics of variables.

5.2 EFFECTS OF BLOCKCHAIN FINANCIAL TECHNOLOGY TRANSFORMATION

Empirical analysis demonstrates that blockchain financial technology transformation (BCFT) significantly reduces supply chain disruption risk (SCDRISK). Regression results show:

$$SCDRISK_{it} = \alpha + \beta BCFT_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

with $\beta = -0.0075$ ($p < 0.01$) under industry-year fixed effects, and $\beta = -0.0063$ ($p < 0.01$) after controls. This highlights BCFT's risk-mitigating role. Building on these findings, future research should strengthen causal identification (e.g., policy shocks, DiD), incorporate operational outcomes (lead time, cost savings), and evaluate unintended consequences like privacy and governance risks.

Variable	(1)	(2)
	SCDRISK	SCDRISK
BCFT	-0.0075***	-0.0063***
	(-3.36)	(-2.82)
Size		-0.0035**
		(-2.18)
ROA		-0.0186*
		(-1.79)
Cash		-0.0115*
		(-1.68)
BOS		-0.0026
		(-0.83)
IND		-0.0073
		(-0.95)
Constant	0.0464***	0.1264***

	(6.95)	(5.42)
Year	Yes	Yes
Industry	Yes	Yes
Observations	11804	11804
Adjusted R ²	0.156	0.187

Note: t-statistics in parentheses; ***, **, * respectively indicate significance at the 1 %, 5 %, and 10 % levels.

Table 2. Effects of blockchain financial technology transformation.

5.3 VALIDITY CHECKS

Ensuring the reliability and robustness of empirical results is essential when examining the relationship between blockchain financial technology transformation (BCFT) and supply chain disruption risk (SCDRISK). Following established approaches in the literature, several validity checks were employed to confirm that the observed negative association between BCFT and SCDRISK is not spurious but reflects a substantive causal relationship.

Alternative Measurement Test:

To verify that the findings are not driven by a specific operationalization of supply chain disruption risk, an alternative indicator (ASCDRISK) was constructed using a stricter semantic similarity threshold of 0.6 in the textual analysis of MD&A disclosures. Re-estimating the baseline regressions with this revised measure (see Table 3) produced consistent results: the coefficient of BCFT remained negative and statistically significant at the 5% level. Although the absolute value of the coefficient was somewhat smaller than in the baseline model, the direction and significance of the effect remained stable. This confirms that the key conclusions are robust to changes in how disruption risk is measured.

Variable	(1)	(2)
	ASCDRISK	ASCDRISK
BCFT	-0.0053**	-0.0048**
	(-2.46)	(-2.23)
Controls	No	Yes
Year	Yes	Yes
Industry	Yes	Yes
Observations	11804	11804

Adjusted R ²	0.143	0.172
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Table 3. Increasing similarity threshold.

Placebo Test:

To rule out the possibility that the observed relationship arises from random correlations, a placebo test was conducted. The values of the BCFT indicator were randomly shuffled across firms to construct pseudo-variables unrelated to actual technology transformation. This process was repeated 2,000 times, and regression estimates were obtained for each simulated dataset. As shown in Fig. 2, the actual estimated coefficient lies at the extreme tail of the empirical distribution generated by these simulations. This result strongly suggests that the observed relationship is unlikely to be caused by random factors, thereby increasing confidence in the substantive nature of the findings.

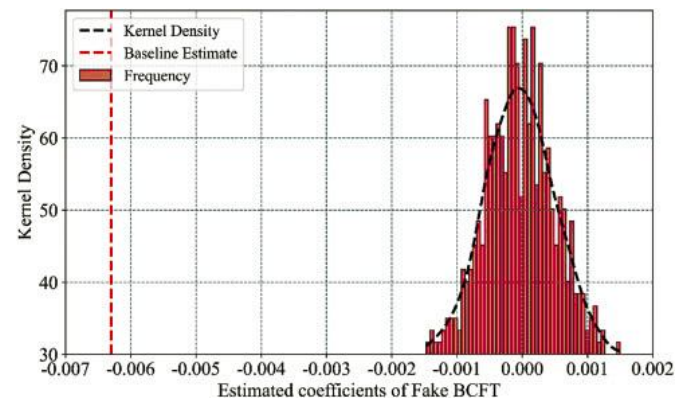


Fig. 2. Placebo test.

Instrumental Variable Analysis.

Endogeneity remains a key concern, as firms that anticipate higher disruption risks may be more inclined to adopt blockchain technology. To mitigate this, a two-stage least squares (2SLS) estimation was applied, using the industry-average BCFT level of other firms as an instrumental variable. This variable is theoretically unrelated to an individual firm’s disruption risk but may influence its adoption decision through demonstration effects. The first-stage results (see Table 4) show a significant positive correlation between the instrument and firm-level BCFT (coefficient = 0.629; t = 6.73), with an F-statistic of 45.29, exceeding the critical threshold of 10, thereby eliminating concerns of weak instruments. In the second stage, the predicted BCFT value significantly reduced SCDRISK (coefficient = -0.0085; t = -2.63), with a magnitude even larger than the OLS estimate, indicating that the baseline regression may understate the true effect.

System GMM Estimation.

To further account for potential dynamic bias and serial correlation, System Generalized Method of Moments (System GMM) estimation was conducted. Results (Table 4, column 3) show that BCFT continues to exert a negative effect on SCDRISK (coefficient = -0.0064; significant at 5%). Diagnostic statistics confirm reliability: the Hansen test ($p = 0.234$) fails to reject the null hypothesis of instrument validity, while the AR(2) test ($p = 0.389$) indicates no second-order autocorrelation. These checks collectively reinforce the robustness of the conclusions.

Variable	(1)	(2)	(3)
	First Stage	Second Stage	GMM
	BCFT	SCDRISK	SCDRISK
IV	0.629***		
	(6.73)		
BCFT		-0.0085***	-0.0064**
		(-2.63)	(-2.38)
L.SCDRISK			0.562***
			(8.34)
Controls	Yes	Yes	Yes
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
Observations	11804	11804	9436
F-statistic	45.29		
Hansen J Test			0.234
AR (2) Test			0.389

Table 4. Endogeneity tests.

Extensions Beyond Baseline Validity:

While the above checks establish strong internal validity, further improvements are possible. For instance, employing quasi-experimental designs such as staggered platform rollouts or regulatory shocks would strengthen causal inference. Likewise, using transaction-level blockchain data or real-time supply-chain KPIs (e.g., lead times, fill rates) would improve measurement validity compared to disclosure-based proxies. Finally, integrating advanced NLP models (e.g., transformers) across multiple text and news sources could provide a more precise and externally valid indicator of disruption risk.

Overall, the combination of robustness tests (Table 3 and Table 4), placebo validation (Fig. 2), and advanced estimation techniques demonstrates that the observed relationship between BCFT and supply chain disruption risk is reliable, while also pointing toward methodological extensions that future research should pursue to enhance validity further.

5.4 CROSS SECTIONAL ANALYSIS

To deepen the understanding of how blockchain financial technology transformation (BCFT) influences supply chain disruption risk (SCDRISK), we conducted a cross-sectional analysis by examining enterprise heterogeneity. Specifically, we focused on two representative characteristics: **enterprise size** and **supply chain concentration**. These dimensions not only reflect the resource capacity and operational structure of firms but also align with prior research gaps, as earlier studies often underexplored firm-level differences in adoption benefits.

Enterprise Size:

Enterprises differ considerably in their ability to implement and exploit technological innovations. Large enterprises generally possess greater financial resources, advanced digital infrastructure, and professional talent pools, which theoretically enable more effective BCFT deployment. Conversely, small-to-medium enterprises (SMEs) often lack sophisticated management systems, creating higher baseline risks but also allowing for stronger marginal improvements when new technologies are introduced. To test these expectations, we divided the sample at the **median enterprise size**, classifying firms above the median as large enterprises and those below as SMEs. The regression results presented in **Table 5** indicate that the negative association between BCFT and SCDRISK is more pronounced among SMEs compared to large enterprises, with inter-group differences statistically significant at the 5% level. This suggests that blockchain-driven transparency and efficiency may substitute for otherwise underdeveloped control mechanisms in SMEs, amplifying their resilience gains.

Supply Chain Concentration:

Another important dimension is the degree of supply chain concentration, measured by the share of procurement from the top five suppliers. Enterprises with high supply chain concentration face elevated disruption risks due to dependency on a limited number of suppliers. In such contexts, even a single supplier failure can cascade into severe operational challenges. Blockchain financial technologies, by improving traceability, enhancing transaction security, and enabling decentralized monitoring, may play a critical role in mitigating these concentrated risks. To test this hypothesis, we partitioned firms into **high-concentration** and **low-concentration** groups using the median concentration ratio as a cutoff. Results reported in

Table 5 demonstrate that BCFT has a significantly larger negative impact on SCDRISK in the high-concentration group, with inter-group differences significant at the 1% level. This finding reinforces the view that firms most vulnerable to supplier dependency gain disproportionately from blockchain-enabled monitoring and financing tools.

Variable	(1)	(2)	(3)	(4)
	Large Enterprises	Small-to-Medium Enterprises	High Concentration	Low Concentration
BCFT	-0.0046**	-0.0082***	-0.0095** *	-0.0038*
	(-2.13)	(-2.94)	(-3.47)	(-1.75)
Controls	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
Observations	3783	8021	3423	8381
Adjusted R ²	0.171	0.198	0.203	0.167
Inter-group difference p-value	0.046		0.012	

Table 5. Cross-sectional analysis.

Interpretation and Research Gaps:

The cross-sectional evidence provides valuable insights but also highlights underexplored areas. First, while **Fig. 3** illustrates the distribution of BCFT effects across firm size and concentration, the analysis remains limited to firm-level heterogeneity. Future research should extend this lens to **supplier-level and network-level factors**, such as geographic diversification, industry centrality, and contractual governance structures. Second, the results are based on proxies derived from disclosures and aggregated measures; incorporating **transaction-level blockchain data or operational performance metrics** (e.g., lead time, order fulfillment rates) would provide a more direct validation of the observed heterogeneity.

Critical Extensions:

Compared to earlier studies, this analysis contributes by explicitly linking firm characteristics to BCFT’s differential effects, yet it also opens several research directions. Future work could investigate whether these heterogeneity patterns hold across different blockchain architectures (public vs. permissioned) and regulatory regimes, thereby addressing the external validity gap. Similarly, applying more advanced **natural language processing models** (e.g., transformer-based embeddings) to measure SCDRISK could refine the robustness of cross-sectional comparisons. Finally, mixed-methods approaches, combining quantitative results with qualitative case studies of SMEs and high-concentration firms, could uncover organizational and behavioral mechanisms underlying the stronger observed effects.

In sum, the cross-sectional analysis suggests that BCFT is particularly valuable for **SMEs and firms with highly concentrated supply chains**, where structural vulnerabilities amplify the benefits of blockchain-enabled financial transparency and cost management. By identifying where BCFT yields the most pronounced resilience improvements, this section not only reinforces the significance of enterprise heterogeneity but also sets the stage for **network-level and causal investigations** in subsequent research.

5.5 MACHANISM EXPLORATION

Based on theoretical reasoning and prior empirical evidence, blockchain financial technology transformation (BCFT) influences supply chain disruption risk (SCDRISK) through both **managerial cognition** and **operational efficiency** pathways. Executives with financial backgrounds (EFB) are better positioned to understand and apply financial innovations, thereby strengthening the effectiveness of blockchain adoption in mitigating supply chain risks. This is reflected in the significant negative interaction between BCFT and EFB, confirming that managerial expertise amplifies the resilience benefits of blockchain technology (see *Table 6*). At the same time, blockchain-driven transparency and efficiency allow firms to reallocate resources more dynamically, thereby reducing cost stickiness (CS). Lower CS enhances a firm’s flexibility in responding to demand fluctuations, directly curbing the adverse effects of disruptions (see *Fig. 2* for the conceptual framework).

Variable	(1)	(2)	(3)	(4)
	SCDRISK	SCDRISK	CS	SCDRISK
BCFT	-0.0057* *	-0.0041* *	-0.0866* **	-0.0052* *
	(-2.55)	(-1.84)	(-3.15)	(-2.33)

EFB	-0.0185*	-0.0162*		
	(-2.24)	(-1.96)		
BCFT × EF B		-0.0094*		
		(-2.38)		
CS				0.0127**
				(2.73)
Controls	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
Observations	11804	11804	11804	11804
Adjusted R ²	0.193	0.196	0.247	0.195

Table 6. Mechanism tests.

Beyond these established channels, further exploration is warranted to capture additional mechanisms such as **network-level adoption effects**, **transaction-level efficiencies**, and **unintended governance trade-offs**. While the existing evidence demonstrates that BCFT lowers SCDRISK partly via reduced cost stickiness and moderated by executive expertise, the current approach relies heavily on disclosure-based proxies. Incorporating operational performance data (e.g., lead times, supplier defaults) and transaction-level blockchain activity would provide deeper insights into how technological transformation reshapes adaptive capacity across supply networks.

VI. DISCUSSION

Blockchain financial technology transformation reduces supply chain disruption risk primarily by **enhancing information transparency and traceability**. Its decentralization, immutability, and smart contract features enable real-time sharing of verified transaction records across supply-chain partners, mitigating information asymmetry and opportunistic behavior (S. E. Chang et al., 2019). This transparency allows firms to detect early warning signals of potential disruptions—such as delayed shipments or supplier defaults—and to coordinate proactive responses. By embedding trust into digital records, blockchain lowers the dependency on intermediaries and reduces delays in decision-making, ultimately strengthening supply-chain resilience in

line with theoretical expectations of technology-enabled risk reduction.

Beyond information flow, blockchain reshapes **enterprise cost structures and operational flexibility**. The study by Xu et al. (2024) shows that blockchain reduces cost stickiness, meaning firms can adjust expenses more responsively during demand shocks or supply interruptions. This mechanism links technological innovation with operational efficiency: automated smart contracts reduce transaction costs, real-time financial settlement improves liquidity, and distributed ledgers minimize reconciliation delays. Together, these factors enhance an enterprise's ability to reconfigure resources swiftly during disruptions. However, much of the existing research—including the referenced study—relies on textual proxies of risk, leaving an open gap for empirical evidence that connects blockchain adoption to concrete operational outcomes such as reduced lead times, inventory turnover, or financing costs.

A further mechanism operates through **managerial cognition and capability**. Executives with financial backgrounds can interpret blockchain's financial applications more effectively and facilitate its integration into supply-chain decision processes (Choi et al., 2011; Kim & Chung, 2017). Their expertise amplifies the technology's impact by aligning digital tools with financial risk management practices. Nevertheless, heterogeneity in managerial backgrounds, industry regulations, and cross-border governance remains underexplored. Future research could examine how leadership traits interact with blockchain implementation to affect disruption outcomes, and whether regulatory frameworks either enable or constrain these mechanisms (Tsai, 2023). This extension would not only validate the mediating role of cost efficiency and managerial expertise but also highlight governance and policy contexts as critical boundary conditions.

VII. IMPLICATION AND FUTURE DIRECTION

The transformative potential of blockchain financial technology in supply chain risk management primarily operates through enhancing information transparency and transmission efficiency. By providing an immutable and decentralized record of transactions, blockchain enables firms to share real-time data across different nodes of the supply chain. This reduces information asymmetry, mitigates delays, and enhances the credibility of inter-firm transactions. As the reference study highlights, such transparency allows enterprises to allocate resources more flexibly, thereby reducing cost stickiness and strengthening adaptive responses to sudden demand fluctuations. In essence, blockchain technology transforms supply chains from reactive structures into proactive, information-driven systems capable of anticipating and mitigating disruption risks.

Beyond transparency, a crucial mechanism lies in the integration of blockchain with managerial expertise and organizational capabilities. The earlier study found that executives with financial backgrounds play an amplifying role in the effectiveness of blockchain transformation. This suggests that technology adoption alone is insufficient; managerial interpretation and strategic application determine the extent of realized benefits. In practice, blockchain provides the infrastructure for financial traceability and resource optimization, but it is managers with financial acumen who translate technical outputs into cost management strategies, credit risk controls, and flexible financing solutions. Thus, blockchain's impact on supply chain resilience is mediated by the firm's governance and leadership structures, highlighting the socio-technical nature of technological transformation.

However, blockchain adoption also introduces new layers of complexity and heterogeneity that shape its risk mitigation capacity. Implementation costs, interoperability across different blockchain platforms, and privacy concerns may hinder diffusion across entire supply networks, especially for small suppliers. Addressing these challenges requires not only technological integration but also supportive institutional frameworks and policy initiatives. Future research, therefore, must examine how network-wide adoption, transaction-level activity, and regulatory support interact with blockchain-enabled mechanisms to generate resilience. By capturing these dimensions, scholars and practitioners can move beyond firm-level cost stickiness and identify systemic conditions under which blockchain delivers its full risk-reducing potential.

VIII. CONCLUSION

In an era where global supply chains are increasingly vulnerable to uncertainty, the adoption of blockchain financial technology emerges as a critical strategy for enhancing resilience. This research builds on prior studies demonstrating that blockchain adoption significantly reduces supply chain disruption risk, while extending the discussion by highlighting mechanisms, limitations, and avenues for further exploration. The findings underscore that blockchain technology achieves risk mitigation not only by reducing cost stickiness but also by strengthening transparency, improving transaction credibility, and enabling more flexible allocation of financial and operational resources.

Moreover, the effectiveness of blockchain transformation is shown to be highly contingent on the role of managerial expertise. Firms led by executives with financial backgrounds are better positioned to leverage blockchain's full potential, translating technical innovations into practical strategies that improve cost control, financing access, and adaptive capacity. This alignment between technological infrastructure and managerial capability reinforces the view

that digital transformation is as much a socio-technical process as it is a technological one.

At the same time, challenges such as interoperability, privacy concerns, and uneven adoption across supply chain partners remain pressing barriers. These factors suggest that blockchain's impact cannot be fully realized without complementary institutional support, policy interventions, and greater inclusion of small and medium-sized enterprises in blockchain platforms. By addressing these gaps, future research can shift beyond firm-level outcomes to examine systemic effects across networks and industries.

Ultimately, this research contributes by clarifying how blockchain financial technology serves as both a technological and organizational enabler of supply chain resilience. For practitioners, it offers evidence-based insights into cost management, governance, and adoption strategies. For policymakers, it highlights the need for balanced regulations and platform-building initiatives. Taken together, blockchain's transformative potential lies in fostering not just resilient firms, but resilient supply networks capable of withstanding the disruptions of a volatile global economy.

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