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Original Paper

Supply Chain Network Centrality and Corporate Financial Risk: Evidence from Chinese Listed Firms

Chu Wang[1]

[1] Business School, University of Shanghai for Science and Technology (USST) 516 Jungong Road, Shanghai 200093, China

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Abstract

This study investigates the relationship between supply chain network centrality and corporate financial risk using Chinese A-share non-financial listed firms from 2011 to 2023. Firms' supply chain networks are constructed based on major supplier and customer relationships, and network positions are measured using degree, closeness, and betweenness centrality.

Empirical results show a significant inverted U-shaped relationship between network centrality and financial risk. As centrality increases, financial risk initially rises and then declines, with turning points differing across centrality measures. Robustness tests, including U-shape tests, alternative financial risk measures (O-score), and lagged explanatory variables, confirm the main findings.

The results highlight the importance of considering supply chain network structure when analyzing firm financial risk, offering new evidence on the nonlinear impact of network positions on corporate stability.

Keywords

Supply chain network, Network centrality, Financial risk, Nonlinear relationship, Chinese listed firms

1. Introduction

In recent years, the global supply chain system has undergone profound restructuring under the combined influence of geopolitical conflicts, trade frictions, the COVID-19 pandemic, and volatility in key raw material markets. These disruptions have exposed fundamental weaknesses in traditional supply chain models, particularly those built on lean management principles emphasizing efficiency and cost minimization. While such models improve operational efficiency, they often lack the flexibility required to respond to large-scale external shocks, leading to widespread supply chain disruptions and cascading failures across industries.

As a result, resilience has become a central objective in supply chain management. Firms are increasingly shifting toward diversified, flexible, and regionalized supply chain configurations, a transformation further reinforced by policy initiatives such as industrial localization strategies and "friend-shoring." These developments signal a structural transition from efficiency-oriented global supply chains to resilience-oriented network systems.

Against this backdrop, supply chains are increasingly conceptualized as complex networks, where firms are embedded in interconnected structures of material, capital, and information flows. As highlighted by Cui et al. (2024), modeling supply chains through complex network theory enables researchers to capture structural characteristics such as centrality, clustering, and structural holes, and to analyze how these features influence firm behavior and systemic risk. Similarly, Ledwoch et al. (2018) demonstrate that network centrality metrics can effectively identify vulnerability points and assess systemic risk propagation within supply networks.

Building on this perspective, a growing body of literature examines how a firm's network position, particularly centrality, affects firm-level outcomes. On the one hand, centrality is widely recognized as a source of informational and resource advantages. Liu et al. (2026) show that firms with higher centrality exhibit greater stock price efficiency due to improved information dissemination and enhanced information production. Similarly, Song et al. (2016) find that supply chain network embeddedness improves credit quality through information sharing mechanisms, while Kim et al. (2020) demonstrate that customer degree centrality enhances supplier performance, particularly under conditions of high resource dependence.

From a strategic perspective, central positions also facilitate resource integration and corporate expansion. Yuan et al. (2024) document that supply chain centrality increases the likelihood and success of mergers and acquisitions by reducing information asymmetry and easing financing constraints. In a similar vein, Ben-Jebara et al. (2026) show that network betweenness interacts with operational efficiency to improve firm survival and promote M&A activities, highlighting the complementary role of internal capabilities and network structure. Moreover, Fan et al. (2025) provide evidence that supply chain network position significantly enhances innovation performance through improved access to innovation resources and reduced operational risk.

However, an emerging stream of research emphasizes that centrality may also entail significant costs and risks. Hong et al. (2024) find that higher supply chain centrality can negatively affect firm innovation by increasing short-termism, transaction costs, and operational risk. Similarly, Ambulkar et al. (2022) show that product innovation increases supply chain complexity and supplier dependence, thereby raising disruption risk. Patel (2025) further demonstrates that while certain forms of centrality can enhance resilience, others may exacerbate the negative impact of external shocks such as natural disasters due to coordination complexity. These findings suggest that the benefits of centrality are contingent and may be offset by increased exposure to systemic vulnerabilities.

In addition, supply chain structures play a critical role in shaping financial risk through multiple

channels. Rajagopal et al. (2017) identify disruption risk, demand uncertainty, and supply risk as key components of supply chain risk, while emphasizing the importance of network design and coordination mechanisms. Shi et al. (2022) provide evidence that supply chain centrality reduces stock price crash risk by improving information transparency and investor sentiment. Similarly, Carnovale et al. (2025) highlight that network characteristics such as centrality and clustering interact with firm-level risk management strategies to influence disruption risk, and that these relationships may exhibit nonlinear patterns.

At the same time, supply chain dependencies can amplify financial vulnerability. Yao et al. (2025) show that supply chain concentration increases financial distress, although digital transformation can mitigate this effect by alleviating financing constraints. Ren et al. (2026) further demonstrate that peripheral firms earn higher expected returns as compensation for greater exposure to operational and asset-specific risks, suggesting that network position is closely linked to systematic risk pricing. Moreover, Luo et al. (2024) find that supply chain network structures significantly affect firm financial performance, with international factors moderating these relationships.

Despite these important insights, the existing literature exhibits several limitations. First, prior studies provide mixed evidence regarding the effects of supply chain centrality, with some highlighting its benefits and others emphasizing its risks. Second, most studies adopt a linear perspective, implicitly assuming that the impact of centrality on firm outcomes is monotonic. Third, the underlying mechanisms—particularly the dynamic interaction between cost pressures and network benefits—remain insufficiently explored.

To address these gaps, this study develops an integrated analytical framework to examine how supply chain network centrality affects firm financial risk. Drawing on cost theory, social network theory, and resource dependence theory, we propose that the impact of centrality is characterized by a dynamic interplay between cost effects and benefit effects.

In the early stage of supply chain network expansion, firms face substantial cost pressures. These include customer acquisition costs, extended trade credit, increased working capital requirements, and significant investments in fixed assets and production capacity. As noted by Chedid et al. (2021), managing complex and geographically dispersed networks can also lead to diminishing marginal returns due to coordination challenges. In addition, learning and coordination costs increase as firms integrate new partners into the network. These factors result in a mismatch between cash inflows and outflows, leading to declining liquidity, rising leverage, and increasing financial risk.

As the network expands and matures, however, firms begin to benefit from scale effects and network effects. Larger transaction volumes allow firms to spread fixed costs and improve operational efficiency, while enhanced bargaining power reduces procurement costs and improves payment terms. More importantly, network embeddedness generates information and resource advantages. Firms can access superior information, reduce asymmetry, and obtain external financing more easily (Liu et al., 2026). At the same time, supply chain relationships facilitate resource sharing, including capital, technology, and

managerial expertise, consistent with the resource-based view and social network theory (Yuan et al., 2024; Ben-Jebara et al., 2026).

Furthermore, long-term relationships within the supply chain foster governance mechanisms that reduce opportunistic behavior and enhance contractual reliability. As emphasized by Golgeci and Ponomarov (2013), firm capabilities such as innovativeness and adaptability further strengthen supply chain resilience, enabling firms to better respond to disruptions. These mechanisms collectively stabilize cash flows, improve financial flexibility, and mitigate financial risk.

The overall effect of supply chain centrality on financial risk depends on the relative strength and timing of these opposing forces. In the early stage, the cost effect dominates, leading to an increase in financial risk as centrality rises. However, beyond a certain threshold, the marginal benefits from scale, information, and resource effects exceed the marginal costs. Moreover, as Carnovale et al. (2025) suggest, network characteristics may exhibit nonlinear relationships with risk outcomes, reinforcing the possibility of a curvilinear effect.

Therefore, this study proposes that the relationship between supply chain network centrality and firm financial risk is nonlinear, specifically exhibiting an inverted U-shaped pattern. Financial risk increases during the initial stage of network expansion but decreases once the network reaches a sufficient scale and level of embeddedness.

Based on this analysis, the core hypothesis of this study is that supply chain network centrality has an inverted U-shaped effect on firm financial risk.

This study contributes to the literature in several ways. First, it extends existing research by introducing a nonlinear perspective into the analysis of supply chain networks and financial risk, addressing the limitations of linear models. Second, it develops a comprehensive mechanism framework that integrates cost, information, and resource effects, providing a deeper understanding of how network structures influence financial outcomes. Third, it offers practical implications for managers by highlighting the importance of balancing short-term cost pressures with long-term network benefits when designing supply chain strategies.

Overall, in the context of ongoing global supply chain restructuring, this study provides new insights into the complex relationship between network position and financial risk, offering both theoretical and practical contributions to the field.

2. Model

2.1 Data

This study uses non-financial A-share listed firms in China from 2011 to 2023 as the initial sample. Following prior literature, the sample is processed as follows. First, financial firms are excluded due to their distinct financial structures and regulatory environments. Second, observations with missing values for key variables are removed. After these procedures, the final sample consists of 5,060 firm-year observations, covering 1,506 firms.

To mitigate the influence of outliers, all continuous variables are winsorized at the 1% level in both tails. Financial data and supply chain disclosure data are obtained from the CSMAR database, which is widely used in empirical research on Chinese capital markets.

2.2 Model Specification

To examine the impact of supply chain networks on corporate financial risk, the following baseline regression model is constructed:

$$Zscore_{i,t}=\beta_0+\beta_1 Networks_{i,t}+\beta_2 Networks\_squ_{i,t}+\gamma' Controls_{i,t}+\sum_j Industry_j+\sum_k Year_k+\varepsilon_{i,t}$$

where $Zscore_{i,t}$ represents the financial stability of firm *i* in year *t*, serving as a proxy for financial risk. A higher Z-score indicates lower financial risk.

$Networks_{i,t}$ denotes the firm's position in the supply chain network, measured using four network centrality indicators: degree centrality, closeness centrality, betweenness centrality, and structural holes.

$Networks\_squ_{i,t}$ is the squared term of the network variables, used to test the potential nonlinear relationship between supply chain centrality and financial risk.

$Controls_{i,t}$ is a vector of control variables.

Industry and Year represent industry and year fixed effects, respectively, controlling for unobservable heterogeneity across industries and time. $\varepsilon_{i,t}$ is the error term.

2.3 Variable Definitions

2.3.1 Dependent Variable

The dependent variable is corporate financial risk, measured by the Altman Z-score. This indicator integrates multiple dimensions of firm performance, including profitability, solvency, and operating efficiency. A higher Z-score indicates greater financial stability and lower financial risk.

Following Altman (2000), the adjusted Z-score model for non-manufacturing firms is adopted:

$$Zscore=6.56X_1+3.26X_2+6.72X_3+1.05X_4$$

2.3.2 Independent Variables

The key independent variables capture firms' positions in the supply chain network. The network is constructed based on disclosed data of the top five suppliers and customers of listed firms. Using social network analysis (SNA), four network metrics are employed:

Degree centrality: measures the number of direct connections a firm has in the network, reflecting its level of activity and transaction intensity.

Closeness centrality: captures how close a firm is to all other firms in the network, indicating its ability to access information efficiently.

Betweenness centrality: reflects the extent to which a firm lies on the shortest paths between other firms, capturing its intermediary and control power within the network.

Structural holes: measure the extent to which a firm bridges otherwise disconnected partners, indicating its advantage in accessing diverse and non-redundant information.

2.3.3 Control Variables

Following prior literature, this study controls for a set of firm-level characteristics that may affect financial risk. Specifically, we include firm size (Size), firm age (FirmAge), leverage (Lev), return on assets (ROA), revenue growth (Growth), Tobin's Q (TobinQ), ownership structure (SOE), CEO duality (Dual), board size (Board), and the proportion of independent directors (Indep). These variables are incorporated to mitigate potential omitted variable bias and to isolate the effect of supply chain network characteristics on financial risk.

All variables used in this study are defined in Table 1

Table 1. Variable Definitions

Variable	Symbol	Definition
Financial risk	Zscore	Composite indicator based on profitability, solvency, and operating efficiency (Altman Z-score)
Degree centrality	Degree	Number of direct connections a firm has in the supply chain network
Closeness centrality	Closeness	Inverse of the average shortest path length from the firm to all other firms in the network
Betweenness centrality	Betweenness	Proportion of shortest paths between all firm pairs that pass through the focal firm
State ownership	SOE	Dummy variable equal to 1 if the ultimate controller is a state-owned entity, and 0 otherwise
Firm size	Size	Natural logarithm of total assets at year-end
Leverage	Lev	Total liabilities divided by total assets
Return on assets	ROA	Net income divided by average total assets
Firm growth	Growth	Annual growth rate of operating revenue
Tobin's Q	TobinQ	(Market value of equity + book value of liabilities) divided by total assets
Firm age	FirmAge	Number of years since firm establishment
CEO duality	Dual	Dummy variable equal to 1 if the CEO also serves as board chair, and 0 otherwise
Board size	Board	Total number of board directors
Board independence	Indep	Proportion of independent directors on the board

3. Empirical Results

3.1 Descriptive Statistics

Overall, supply chain network centrality indicators exhibit a pattern of low average levels with substantial variation across firms. The mean values of Degree (0.0027), Closeness (0.0055), and Betweenness (0.0002) are all relatively small, suggesting that most firms occupy peripheral positions in the network, with limited direct connections and weak intermediary roles. This indicates that the overall supply chain network is relatively sparse.

However, the large gaps between maximum and mean values imply significant heterogeneity. For instance, the maximum value of Betweenness is more than 100 times its mean, and Closeness has a minimum value of zero. These results suggest a typical core–periphery structure, where a small number of central firms dominate network connections, while the majority of firms remain at the periphery.

Regarding financial risk, the mean Z-score is 4.226, with a relatively large standard deviation (6.477), indicating considerable variation in financial stability across firms. The wide range of Z-score values further reflects the coexistence of financially distressed and highly stable firms in the sample.

For control variables, the average leverage (Lev) is 0.482, indicating a moderate debt level. The mean ROA is 0.0604, suggesting relatively low profitability, while its minimum value indicates that some firms experience significant losses. The average revenue growth rate (Growth) is 0.308, with high dispersion, reflecting substantial heterogeneity in firm growth.

In terms of firm characteristics, 49.0% of the sample firms are state-owned enterprises. The mean firm size and age indicate that most firms are relatively mature. Overall, the variation in key variables provides a solid foundation for subsequent empirical analysis.

Table 2. Descriptive Statistics

Variable	N	Mean	SD	Min	Max
Zscore	5052	4.226	6.477	-9.097	124.0
Degree	5052	0.00270	0.00210	0.00120	0.0271
Closeness	5052	0.005	0.00580	0	0.0524
Betweenness	5052	0.0002	0.00100	0	0.0226
SOE	5052	0.490	0.500	0	1
Size	5052	22.65	1.536	19.48	26.45
Lev	5052	0.482	0.202	0.0278	0.934
ROE	5052	0.0604	0.151	-2.175	0.418
Growth	5052	0.308	0.943	-0.926	17.11
TobinQ	5052	1.899	1.316	0.795	17.68
Age	5052	2.905	0.340	1.099	3.689
Dual	5052	0.215	0.411	0	1
Board	5052	2.176	0.202	1.609	2.708
Indep	5052	0.371	0.0530	0.250	0.600

3.2 Regression Results

Table 3 reports the baseline regression results.The results show that supply chain network centrality exhibits a significant inverted U-shaped relationship with corporate financial risk. For Degree centrality (Column 1), the coefficient of the linear term is significantly negative, while the squared term is significantly positive at the 1% level. The turning point is approximately 0.0077. This indicates that in the early stage of network expansion, increasing connections raises coordination and information-processing costs, thereby increasing financial risk. Once the threshold is exceeded, network scale and resource advantages begin to dominate, leading to improved financial stability.

A similar nonlinear pattern is observed for Closeness centrality (Column 2). The linear term is significantly negative and the squared term is significantly positive, with a turning point of 0.0138. This suggests that although improving accessibility initially requires substantial resource investment, higher levels of closeness eventually enhance firms' ability to access and integrate resources efficiently, reducing financial risk. Notably, the higher turning point implies that the benefits of accessibility require deeper network embeddedness to materialize.

For Betweenness centrality (Column 3), the results remain consistent. The linear term is significantly negative, while the squared term is significantly positive, with a turning point of 0.0051. This indicates that firms acting as intermediaries initially face high coordination and governance costs. However, once a certain level is reached, their control over resource flows generates information advantages and bargaining power, thereby improving financial stability. The relatively lower turning point suggests that the value of intermediary roles can be realized at a lower level of network centrality.

Overall, the empirical results strongly support the hypothesized inverted U-shaped relationship.

Table 3. Regression Results

	(1)	(2)	(3)
VARIABLES	Zscore	Zscore	Zscore
Degree	-279.58***		
	(71.06)		
degree_squ	18,113.80***		
	(5,006.71)		
Closeness		-128.18***	
		(28.55)	
Closeness_squ		4,624.71***	
		(1,083.94)	

Betweenness			-495.98***
			(148.81)
Betweenness_squ			48,447.05***
			(11,773.00)
Extrem point	0.0077	0.0138	0.0051
Constant	-7.87***	-8.38***	-8.47***
	(1.73)	(1.72)	(1.72)
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Observations	5,052	5,052	5,052
R-squared	0.55	0.55	0.47

3.3 Robustness Checks

3.3.1 U-shape Test

To formally verify the nonlinear relationship, we employ the U-test proposed in prior literature using the utest command in Stata. As reported in Table 4, the estimated turning point for Degree centrality is 0.0077. The test rejects the null hypothesis of a monotonic or inverse U-shaped relationship at the 1% significance level, confirming the presence of a statistically significant U-shaped pattern. This provides strong support for the nonlinear effect identified in the baseline regression.

Table 4. U shape test

Specification: f(x)=x^2		
Extreme point: .0077173		
Test:		
H1: U shape		
vs. H0: Monotone or Inverse U shape		
	Lower bound	Lower bound
Slope	-237.5513	703.634
t-value	-3.900891	3.339778
P>|t|	.0000486	.0004223
Overall test of presence of a U shape:	t-value =3.34	P>|t|=.000422

3.3.2 Alternative Measure of Financial Risk

To ensure robustness, we replace the dependent variable with the O-score, following Altman (2002).

Unlike the Z-score, a higher O-score indicates a higher probability of financial distress. The O-score incorporates multiple dimensions of firm performance, including solvency, profitability, and operating efficiency.

The regression results are reported in Table 5. The coefficients of Degree, Closeness, and Betweenness are significantly positive, while their squared terms are significantly negative, indicating an inverted U-shaped relationship between network centrality and financial risk. These findings are consistent with the baseline results, suggesting that our conclusions are robust to alternative measures of financial risk.

Table 5. Alternative Measure of Financial Risk

	(1)	(2)	(3)
VARIABLES	OScore	OScore	OScore
Degree	55.70***		
	(18.87)		
degree_squ	-3,311.97**		
	(1,329.54)		
Closeness		20.29***	
		(7.59)	
Closeness_squ		-657.99**	
		(288.02)	
Betweenness			131.66***
			(39.52)
Betweenness_squ			-9,861.69***
			(3,126.24)
Constant	-7.87***	-8.38***	-8.47***
	(1.73)	(1.72)	(1.72)
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Observations	5,052	5,052	5,052
R-squared	0.55	0.55	0.55

3.3.3 Endogeneity Test

To alleviate potential endogeneity concerns, particularly reverse causality, we lag all network centrality variables by one period. The results, reported in Table 6, remain qualitatively unchanged. The coefficients of the linear terms are significantly negative, while the squared terms are significantly

positive, confirming the robustness of the inverted U-shaped relationship.

Overall, the robustness checks consistently support the main findings of this study.

Table 6. Endogeneity Test

	(1)	(2)	(3)
VARIABLES	zscore	zscore	zscore
L.Degree	-175.9**		
	(79.00)		
L.degree_squ	11,098**		
	(5,452)		
L.Closeness		-113.5***	
		(30.84)	
L.Closeness_squ		4,056***	
		(1,076)	
L.Betweenness			-373.2***
			(144.2)
L.Betweenness_squ			44,541***
			(11,330)
Constant	-10.02***	-10.59***	-10.50***
	(1.933)	(1.917)	(1.915)
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes
Observations	2,960	2,960	2,960
R-squared	0.556	0.558	0.559

4. Conclusion

This study investigates the relationship between supply chain network centrality and corporate financial risk using a sample of Chinese A-share listed firms from 2011 to 2023. Based on supply chain data from major suppliers and customers, this paper constructs firm-level network indicators and conducts empirical analysis.

The results show that supply chain network centrality has a significant inverted U-shaped relationship with financial risk. Specifically, for degree, closeness, and betweenness centrality, the coefficients of the linear terms are significantly negative, while the squared terms are significantly positive, indicating

that financial risk first increases and then decreases as network centrality rises. The estimated turning points further suggest that the effect of centrality on financial risk varies across different dimensions of network position.

In addition, robustness checks confirm the reliability of the findings. The U-shape test formally supports the existence of a nonlinear relationship. The results remain consistent after replacing the dependent variable with the O-score, and after using lagged explanatory variables to address potential endogeneity concerns.

Overall, the empirical evidence suggests that the relationship between supply chain network position and financial risk is nonlinear rather than monotonic. The findings highlight the importance of considering nonlinear effects when examining the economic consequences of supply chain networks.

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