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Exploring the Factors of Supply Chain Concentration in Chinese A-Share Listed Enterprises

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Abstract: Using data of 1133 Chinese A-share listed enterprises on the Shanghai and Shenzhen Stock Exchanges for the period 2011–2022, this study examines the effects of corporate innovation, firm over-indebtedness, financing constraints, and firm profitability on supply chain concentration. The baseline results show that corporate innovation and profitability reduce supply chain concentration, while over-indebtedness and financing constraints increase it. These findings suggest that higher R&D investments and profitability enable firms to diversify their supply chains, whereas financial pressures lead to consolidation. The results remain robust after addressing endogeneity concerns using the system GMM approach. Heterogeneity analysis reveals stronger responses in large firms, state-owned enterprises, and high-tech industries. These results suggest policy implications of promoting R&D investments, reducing the debt levels, alleviating the financing constraints, and adopting profit-generating activities to diversify supply chain.

Keywords: supply chain concentration; corporate innovation; firm over-indebtedness; financing constraints; firm profitability

1. Introduction

Supply chain concentration, characterized by a firm's dependence on a fewer number of suppliers and customers, comes with both, opportunities and challenges. It allows enterprises to save costs through economies of scale, smooth operations, and improved suppliers and customers' connections [1]. The closer connections with fewer suppliers and customers strengthen quality control and increases the response times to adapt market changes [2]. Additionally, firms relying on fewer suppliers and customers could have greater bargaining power due to interdependence [3]. On negative side, there are significant risks associated with the high supply chain concentrations such as lower flexibility in sourcing, being vulnerable to the supply chain disruptions, and being directly affected by the internal challenges of larger suppliers and customers [4,5]. These challenges can posit severe operational risks, and especially when firms are highly integrated to the global supply chain. Moreover, the interplay between financial deepening and economic growth may further impact supply chain concentration, particularly in emerging markets [6]. Thus, supply chain management must prioritize operational flexibility while using extreme risk models to better assess potential financial shocks from rare events [7]. Similar to information processing methods in certain fields, businesses can enhance system stability in the face of

uncertainty by optimizing and combining various technologies, effectively reducing risks associated with concentration [8–10].

The reversal of globalization may impact China's supply chains, with increasing regionalization and localization, as seen in other sectors [11]. The COVID-19 pandemic sharply highlighted the challenges associated with highly concentrated supply chains. The sudden and widespread disruptions, resulted by COVID-19, exposed the fragility of global supply networks, especially for those companies relying on fewer suppliers and customers [12]. China is known as the world's factory, as its enterprises export the products to almost every country across the world. The corporate sector of China is highly concentrated to the global supply chain, and any challenge to this sector could posit serious challenges to the enterprises across the world. It is reported that firms experienced significant production halts and delays due to inability of concentrated suppliers to deliver essential materials, required for production [13]. The lockdowns and transportation restrictions during COVID-19 pandemic, exacerbated these challenges, resulting in high financial losses and operational bottlenecks [14]. So, the uncertainty associated with supply chain concentration underscored the need for more diversified supply chain [15,16]. Similarly, the application of advanced technologies, such as logistics optimization, can help businesses reduce reliance on single resources through intelligent decision-making, thereby enhancing overall flexibility in supply chain management [17–19]. Based on this need, this study will examine the factors leading to supply chain concentration in Chinese A-share listed enterprises.

Understanding the factors lead to supply chain concentration is crucial to present guideline for enterprises to mitigate the risks associated with reliance on few suppliers and customers. This study will examine the factors of corporate innovation, firm over-indebtedness, financing constraints, and firm profitability, to show whether they tend to be positive or negative contributors to supply chain concentration. Examining these factors will enable the enterprises to make informed decisions and strengthen their internal operations to avoid the potential risks [20]. This study will analyze that how firms can develop a balance between supply chain concentration and need of flexibility and risk management to counteract the sudden vulnerabilities with suppliers [21]. Realizing the challenges with global supply chain, there is growing importance of corporate resilience and it is required to explore the determinants of supply chain concentration to ensure a robust supply chain network [22]. Leveraging advanced AI and deep learning technologies, particularly innovations in recommendation algorithms within social networks, businesses can optimize supply chain decisions without relying on a single supplier, ensuring sustainable and efficient operations [23,24].

Corporate innovation and firm over-indebtedness can be the crucial factors to influence supply chain concentration as innovation drives firms to develop and manage closer connections with its concentrated customers and suppliers to foster market adaption and co-development of new technologies and products [25]. This could allow firms to leverage the specialized capabilities to extend the control over supply chain network to streamline operations [26]. On the other hand, over-indebtedness constraints firm's financial flexibility, and thus pushes the enterprises to rely on fewer customers and suppliers in a pressure to manage financial obligations and reduce costs [27,28]. Highly indebted enterprises tend to adopt risk-averse behavior, making them reluctant to diversify their supplier and customer base [29].

Financing constraints and firm profitability could also play an essential role frame supply chain concentration of enterprises. Firms encountered with financing constraints, might not have sufficient resources and capabilities to develop and sustain their relationships with suppliers, and this scenario leads higher supply chain concentration [30,31]. The limited access to capital tends to mitigate firm's ability of investing in supply chain diversification and being able to counteract the potential risks associated with supply chain concentration [32]. On the other hand, higher profitability fosters financial strength, allowing the firms to engage with more and more suppliers and customers, and invest in a more resilient supply chain structure [33]. Profitable firms are in a position to bear the costs associated with supply chain flexibility and thus can leverage financial stability to negotiate with a greater number of suppliers and customers [34].

The influence of corporate innovation, firm over-indebtedness, financing constraints, and firm profitability could be explained through the lenses of several theories. Transaction cost economics theory states that firms concentrate supply chains to foster the coordination efficiency and reduce the transaction costs [35]. Resource-

based view theory posits that firms enriched with greater capabilities and resources are more resilient, and thus in a position to counteract the challenges associated with supply chain concentration [36]. The pecking order theory explains the nexus of financing constraints and firm over-indebtedness with supply chain concentration [37], suggesting that firms prefer internal financing over external financing options to avoid the cost of adverse selection. The financing constraints limit firms' access to internal funds, and thus firms resort to excessive debt, which lead them to be highly indebted. In turn, this indebtedness forces firms to concentrate their supply chain to manage cash flow more efficiently and mitigate financing risks. These theoretical perspectives collectively present a comprehensive view that how corporate innovation, firm over indebtedness, financing constraints, and firm profitability could influence supply chain concentration in context of Chinese A-share listed enterprises.

There are several findings presented by this study: First, firms investing in R&D are able to diversify their supplier and customer base, and thus corporate innovation negatively influences supply chain concentration. Second, Over-indebtedness and financing constraints create financial pressure for firms which drive them to consolidate their supply chain. Third, profitability reduces the supply chain concentration through creating greater potential of financial stability. Fourth, this study shows that effects of corporate innovation, firm over-indebtedness, financing constraints, and firm profitability vary across the firm sizes, ownership structure, and industry types.

Remaining of this paper is structured as follow, Section 2 covers the literature review presenting the nexus of corporate innovation, firm over-indebtedness, financing constraints, and firm profitability with supply chain concentration, and constructs hypotheses; Section 3 presents data, variables and empirical model of this paper; Section 4 presents descriptive statistics, correlation analysis results, baseline regression results, robustness check results, and heterogeneity analysis tests' results; Section 5 concludes the paper and presents policy implications.

2. Literature Review and Hypotheses Development

2.1. Nexus between Corporate Innovation and Supply Chain Concentration

Corporate innovation, the process through which firms develop new services, products, and/or process, is a crucial factor to frame the supply chain strategies of enterprises. Innovation tends to develop closer connections of firms with suppliers and customers, as they engaged in leveraging unique capabilities of their supply partners to co-adopt and develop innovative solutions in response to the market changes [38]. The closer connections between them result in being more resilient to the changes being occurred in industry [39]. It can be argued that firms with greater innovation level are more informed about the changes being occurred in market, and thus they collaborate with their larger suppliers and customers to adapt the changes immediately and avoid the potential financial and operational losses. Innovative firms tend to develop long-term connections with suppliers and customers through enhancing trust, coordination, and collaboration, which can further influence supply chain concentration [40].

Innovation drives firms to gain specialized inputs and advanced technologies, and pushes the partners of these firms to adopt these new inputs and technologies as well, thereby shaping a more robust supply chain network [41]. This strategic approach enables the firms to have smoother operations and being capable of adjusting the processes in response to the market changes [42]. It can be argued that enterprises are not only engaged in upgrading their own infrastructure but they are also in an effort to upgrade the overall supply chain mechanism, which can be more resilient and robust to the market vulnerabilities [43]. Previous studies have examined the influence of corporate innovation on supply chain performance; however, it remains unexplored that whether it influences the supply chain concentration and this gap will be filled by existing study.

The influence of corporate innovation on supply chain concentration can be explained by the resource-based view theory. This theory posits that firms achieve sustainable competitive advantage through utilizing valuable, rare, inimitable, and non-substitutable resources and capabilities [44]. Corporate innovation is a valuable resource for a firm that could be leveraged to gain the sustainable competitive advantage. The utilization of corporate innovation to frame supply chain network, could be a substantial element which is required to manage efficiently for achieving the potential goals. By concentrating supply chains, firms can manage and integrate

innovative resources, to achieve enhanced performance and gain sustained competitive advantage [45]. This perspective underscores the importance of corporate innovation to frame the supply chain concentration, and thus we can postulate this hypothesis;

H1: Corporate innovation negatively influences the supply chain concentration in Chinese A-share listed enterprises.

2.2. Nexus between Firm Over-Indebtedness and Supply Chain Concentration

Firm over-indebtedness, a situation when firm's actual debt level is higher than its expected debt level, could significantly influence a firm's ability to concentrate or diversify its supply chain. Highly indebted enterprises could experience higher financial constraints that restraints them to diversify their supplier or customer base [46]. These firms are required to manage their financial obligations, so they are in need of concentrating their supply chain to improve operational efficiency and reduce costs [47]. In addition to this, over-indebtedness firms, due to financial obligations, are risk-averse, so they need to rely on existing trusted suppliers and customers to minimize disruptions and uncertainty [48]. The high debt level mitigates firm's ability to adopt the processes through which it can develop new products or services, and thus not being in a position to find the new suppliers as well.

The pressure to maintain liquidity and meet debt covenant complicates the nexus between over-indebtedness and supply chain concentration [49]. Firm with high debt levels are more concerned about their short-term financial stability instead of long-term strategic goals, which tends them to rely on fewer suppliers and customers [50]. It can be claimed that high debt can significantly influence the firms to adopt those strategies through which they can be able to maintain their current operations only, instead of focusing the future prospectives [51]. The influence of firm over-indebtedness on supply chain concentration is not been explained by any study yet, which is an ultimate gap and will be filled by current study.

The trade-off theory presents a theoretical framework to explain the nexus between firm over-indebtedness and supply chain concentration. This theory argues that firms balance benefits and costs to determine an optimal capital structure [52]. In context of the nexus of over-indebtedness and supply chain concentration, it can be argued that firms with high debt levels could concentrate their supply chains to reduce the costs associated with financial distress. This approach enables the firms to have enhanced control over their supply chain network, and thus improves their ability to manage debt-related risks and improve overall financial stability. Drawing on these theoretical views, we can postulate this hypothesis;

H2: Firm over-indebtedness fosters the supply chain concentration in Chinese A-share listed enterprises.

2.3. Nexus between Financing Constraints and Supply Chain Concentration

Financing constraints, known as the firm's limit to get access to external capital, would have a significant impact on supply chain concentration. Firms facing financing constraints, are lacked in accessing required financial resources which can allow them to diversify supplier base, and tend to have higher supply chain concentration [53]. These firms are required to rely on fewer suppliers and customers to reduce the transaction costs and improve the coordination, so they could not face any disruption or bottleneck on any stage. These firms would have to manage their limited financial resources more effectively to ensure smooth operations, so they require concentration of supply chain. Furthermore, financing constraints restrict a firms' ability of investing in new supplier and customer relationships and thus exposes them to supply chain risks [54,55].

The nexus between financing constraints and supply chain concentration is also framed by the firm's ability of responding toward market opportunities and threats. Firms with limited access to capital tend to focus on their short-term financial stability and resilience, instead of having long-term strategic perspectives, that could result in more concentrated supply chain [56]. The financing constraints could influence the supply chain concentration through creating the challenges for firms to expand their operations and thus being dependent on fewer customers and suppliers. It can be claim that there is significant influence posited by financing constraints on supply chain concentration, and it is not explained by the prior literature yet.

The relationship of financing constraints with supply chain concentration can be theoretically explained via

the lenses of pecking order theory. This theory suggests that firms prioritize internal financing over external financing because of the transaction costs and asymmetric information [28]. Firm face financing constraints, could be engaged in concentrating their supply chain for optimizing their limited financial resources and reducing the reliance on costly external financing [57]. This approach tends firms to maintain financial flexibility and control over supply chain, and thus mitigates the risks associated with the financing constraints. Based on these theoretical views, we can postulate this hypothesis:

H3: Financing constraints increases the supply chain concentration in Chinese A-share listed enterprises.

2.4. Nexus between Firm Profitability and Supply Chain Concentration

Firm profitability, characterized as the firm's ability of generating higher earning relative to its expenses, can mitigate the supply chain concentration through pushing the firms to increase their customer and supplier base, due to having higher potential of moving toward new suppliers and customers. It can be explained as that profitable firms tend greater financial resources to invest in diversified supplier base, which lowers the supply chain concentration [58]. These firms have the potential to engage with multiple suppliers and invest in supply chain risk management practices, and thus enhance the overall supply chain resilience [59]. Additionally, higher profitability allows the firms to have better financial stability, requires to manage favorable terms with broader range of suppliers [60], and thereby reducing the supply chain concentration.

Furthermore, firm's strategic priorities and risk tolerance approaches could influence the nexus between firm profitability and supply chain concentration. Profitable firms pursue long-term strategic goals, such as supply chain innovation and diversification, to gain and sustain competitive advantage [61]. The risk tolerance behavior of firms enables them to follow different practices in response to the changing market conditions such as if there are uncertain conditions, firm tend to follow higher risk tolerance behavior [62]. Previous studies explain of firm profitability's impact on supply chain performance; however, its influence on supply chain concentration remained unexplained, which will be focused by existing study.

The dynamic capabilities theory offers theoretical framework to understand the influence of firm profitability on supply chain concentration in context of Chinese A-share listed enterprises. This theory states firms achieve competitive advantage via developing and utilizing dynamic capabilities that could enable them to adapt changing circumstances [26]. In context of supply chain management, profitable firms are engaged in leveraging their financial resources to develop dynamic capabilities, such as supply chain diversification and risk management, thereby results in lowering supply chain concentration. Drawing on these theoretical views, we postulate this hypothesis;

H4: Firm profitability mitigates the supply chain concentration in Chinese A-share listed enterprises.

3. Data, Variables Selection, and Empirical Model

3.1. Data

This study uses data of 1133 Chinese A-share listed enterprises over the period of 2011–2022. The sample is finalized as follow; initially, we excluded the enterprises of financial industries, second, we excluded enterprises having partial or special treatment in any years of selected time period, third, the enterprises have any missing values for the variables of study in any year, are dropped from final sample. The sample is further winsorized, and ensured that final sample is valid for study.

3.2. Variables of Study

3.2.1. Explanatory Variables

1. Corporate Innovation (R&D)

It is measured as the proportion of R&D expenditures of the total sales revenue of the enterprise.

2. Firm over-indebtedness (OD)

The data of firm over-indebtedness (OD) is directly sourced from CSMAR, and is measured as the actual

debt level minus expected debt level.

3. Financing constraints (FC)

SA index (FC) is used as the measure of the firm's financing constraints, and it is based on the firm's age and size. It is also sourced from CSMAR, and it is measured as;

$$\text{SA index} = -0.737 \times \text{Size} + 0.043 \times \text{Size}^2 - 0.040 \times \text{Age}$$

4. Firm profitability (Profit)

Firm profitability is measured as the return on total assets, indicating the earning generated by enterprise on each unit of asset.

3.2.2. Explained Variables

1. Supply chain concentration (SCC)

It represents the dependence of an enterprise on five largest suppliers and five largest customers, and it is measured as;

SC = (proportion of the amount of purchase from five largest suppliers + proportion of the amount of sales to five largest costumers)/2

3.3.3. Control Variables

The control variables of this study include Firm liquidity (Liq) measured as the current assets divided by current liabilities, Firm age (Age) measured as the log of 1 plus number of operating years, Firm size (Size) measured as natural logarithm of total assets, Debt ratio (Debt) measured as total debt divided by total assets, Firm Growth (Grth) measured as the change in operating revenue of enterprise over a year, and Fixed Assets ratio (FA) ratio of the fixed assets in total assets of enterprise.

3.3. Empirical Model

This study employs two-way fixed effects regression model with time and firm year fixed effects. Based on the hypotheses of study, this study constructs these empirical models;

$$\text{SCC}_{i,t} = \beta_0 + \beta_1 \text{R\&D}_{i,t} + \beta_2 \text{Control}_{i,t} + \text{year}_t + \text{firm}_i + \varepsilon_{i,t} \tag{1}$$

$$\text{SCC}_{i,t} = \beta_0 + \beta_1 \text{OD}_{i,t} + \beta_2 \text{Control}_{i,t} + \text{year}_t + \text{firm}_i + \varepsilon_{i,t} \tag{2}$$

$$\text{SCC}_{i,t} = \beta_0 + \beta_1 \text{FC}_{i,t} + \beta_2 \text{Control}_{i,t} + \text{year}_t + \text{firm}_i + \varepsilon_{i,t} \tag{3}$$

$$\text{SCC}_{i,t} = \beta_0 + \beta_1 \text{Profit}_{i,t} + \beta_2 \text{Control}_{i,t} + \text{year}_t + \text{firm}_i + \varepsilon_{i,t} \tag{4}$$

where *SCC* denotes the supply chain concentration, *R&D* represents corporate innovation, *OD* denotes firm over-indebtedness, *FC* is the financing constraints experienced by enterprises, *Profit* is the firm profitability, β_1 is the regression coefficient of independent variable, Control is the control variables, i and t represent firm and time fixed effects, and ε is the error term.

4. Empirical Results and Analysis

4.1. Descriptive Statistics

Table 1 presents the descriptive statistics of all variables of study including mean, standard deviation, minimum, and maximum values. The mean value for SCC is 29.44, which indicates that there is significant existence of the supply chain concentration in Chinese A-share listed enterprises. Corporate innovation (*R&D*) has mean value of 15.126 with standard deviation of 6.823 which shows that Chinese A-share listed enterprises has a crucial focus on innovation which could serve as the factor to influence supply chain concentration. Chinese firms also experience significant financing constraints as indicated by the mean value of −3.857 for *SA* index. *OD* has the mean value of −0.00897, which shows that overall, there is lower level of the over-indebtedness held by the Chinese enterprises. Additionally, *Profit* has mean value of 0.0296, reflecting the profitability position of the enterprises of China for the sample period.

Table 1. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
SCC	13,596	29.44519	16.54397	0.29	100
R&D	13,596	15.12599	6.823058	0	24.6
SA	13,596	−3.856727	0.292994	−5.79795	−2.09361
OD	13,596	−0.0089787	0.1552037	−0.635561	0.762535
Profit	13,596	0.0296462	0.0786979	−1.64791	0.864125
Liq	13,596	2.291307	1.401795	0.067224	14.869
Age	13,596	1.283207	0.1520877	0.4771213	1.838849
Size	13,596	8.647222	1.308988	3.847832	14.80876
Debt	13,596	0.4478077	0.2054906	0.007521	0.995793
Grth	13,596	0.1338461	0.528172	−0.929032	37.0287
FA	13,596	0.2192952	0.1612912	0.0002	0.9542

4.2. Correlation Analysis Results

Correlation matrix results are shown in Table 2. It can be seemed that there is a negative relationship exists between *R&D* and *SCC*, reflected by correlation value of −0.018. It shows that with the increase in R&D expenses, there is decrease in supply chain concentration of Chinese enterprises. The correlation coefficient between *SA* and *SCC* is positive and significant at 1%, 0.127, which indicates increased financing constraints lead to increase the supply chain concentration for enterprises. The relationship between *OD* and *SCC* is also found positive as reflected by the value of 0.060, which shows that with the increase in over-indebtedness, there could have been greater supply chain concentration. For firm profitability, it is found that relationship between *Profit* and *SCC* is negative, reflected by correlation coefficient of −0.097. It can be argued that firm profitability reduces the supply chain concentration of Chinese enterprises.

Table 2. Correlation matrix results.

Variable	SCC	R&D	SA	OD	Profit	Liq	Age	Size	Debt	Grth	FA
SCC	1.000										
R&D	−0.018*	1.000									
	(0.03)										
SA	0.127***	0.051***	1.000								
	(0.00)	(0.00)									
OD	0.060***	−0.011	−0.090***	1.000							
	(0.00)	(0.19)	(0.00)								
Profit	−0.097***	0.026**	0.071***	−0.163***	1.000						
	(0.00)	(0.00)	(0.00)	(0.00)							
Liq	0.037***	0.022**	0.121***	−0.347***	0.113***	1.000					
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)						
Age	0.116***	−0.049***	−0.870***	0.088***	−0.085***	−0.166***	1.000				
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)					
Size	−0.133***	0.057***	0.017	0.069***	0.071***	−0.232***	0.217***	1.000			
	(0.00)	(0.00)	(0.05)	(0.00)	(0.00)	(0.00)	(0.00)				
Debt	−0.059***	−0.130***	−0.100***	0.786***	−0.280***	−0.460***	0.212***	0.473***	1.000		

Cont.

Variable	SCC	R&D	SA	OD	Profit	Liq	Age	Size	Debt	Grth	FA
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)			
Grth	0.002	−0.002	0.041***	0.073***	0.141***	0.019*	−0.060***	0.031***	−0.014	1.000	
	(0.82)	(0.85)	(0.00)	(0.00)	(0.00)	(0.03)	(0.00)	(0.00)	(0.10)		
FA	0.131***	−0.020*	0.049***	−0.014	−0.048***	−0.164***	−0.011	0.034***	0.036***	−0.096***	1.000
	(0.00)	(0.02)	(0.00)	(0.12)	(0.00)	(0.00)	(0.20)	(0.00)	(0.00)	(0.00)	

Note: p-values reported in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% respectively.

4.3. Baseline Regression Results

The baseline regression results, reported in Table 3 show the impact of corporate innovation, over-indebtedness, financing constraints, and firm profitability on supply chain concentration in content of Chinese A-share listed enterprises. In Column (1), corporate innovation (R&D) has a significant negative coefficient of −0.087, which indicates that higher levels of R&D activities are associated with lower supply chain concentration. This suggests that firms investing more in innovation tend to have less concentrated supply chains. Column (2) of Table 3 shows the effect of over-indebtedness (OD), with a significant positive coefficient of 5.259, showing that those higher levels of debt lead to increased supply chain concentration. Column (3) of Table 3 presents the regression coefficient 5.316, which demonstrates that firms with greater financing constraints tend to have more concentrated supply chains. Finally, Column (4) of Table 3 reveals the impact of firm profitability (Profit) with a significant negative coefficient of −1.359, implying that that more profitable firms are likely to have less concentrated supply chains.

Table 3. Baseline regression results.

Variable	Column (1) SCC	Column (2) SCC	Column (3) SCC	Column (4) SCC
R&D	−0.087***			
	(−3.96)			
OD		5.259***		
		(3.69)		
SA			5.316***	
			(4.22)	
Profit				−1.359***
				(−3.01)
Liq	0.096**	0.090**	0.104**	0.097**
	(2.86)	(2.69)	(3.11)	(2.88)
Age	37.426***	38.492***	31.014***	38.205***
	(28.09)	(29.38)	(14.19)	(28.84)
Size	−2.953***	−2.628***	−2.885***	−2.772***
	(−13.99)	(−12.37)	(−13.84)	(−13.27)
Debt	0.902	−3.560*	0.795	0.353
	(1.01)	(−2.47)	(0.89)	(0.38)
Grth	0.881***	0.734***	0.849***	0.880***
	(5.21)	(4.26)	(5.02)	(5.16)
FA	−6.237***	−5.737***	−5.496***	−6.219***

Cont.

Variable	Column (1) SCC	Column (2) SCC	Column (3) SCC	Column (4) SCC
	(−5.18)	(−4.75)	(−4.53)	(−5.16)
Cons.	6.264***	5.370***	−5.414	5.301***
	(3.99)	(3.48)	(−1.85)	(3.41)
N	13,596	13,596	13,596	13,596
R−squared	0.273	0.262	0.286	0.279

Note：t-statistics reported in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% respectively.

The supply chain concentration is positively contributed by over-indebtedness and financing constraints, while reduced by the corporate innovation and firm profitability. The negative impact of R&D on supply chain concentration is logical and in line with the prior literature Kang, et al. [63], suggesting that innovative firms tend to diversify their supplier base to access a wider range of specialized inputs and technologies, thereby reducing supply chain concentration. The results show that high debt levels tend to increase the supply chain concentration, and this finding is line with the findings of Liu, et al. [64], who show that firms with higher debt levels often consolidate their supplier base to manage costs more effectively. Financing constraints increase supply chain concentration of Chinese A-share listed enterprises, as the firms have limited access to capital are not able to diversify their supply chain. The negative association between firm profitability and supply chain concentration shows that profitable firms tend to diversify their supplier and customer base due to having the required financial health and potential.

4.4. Robustness Test Results

This study uses System Generalized Method of Moments (GMM) to check the robustness of baseline regression results. This method addresses the potential endogeneity concerns, which could be common in panel data analysis like our study's analysis. This method is well-suited for dynamic panel data models where explained variable could be endogenous, and there can be unobserved individual effects as well. System GMM address the endogeneity concerns, counteracts the reverse causality, and accounts for the serial autocorrelation. In addition to this, system GMM mitigates the bias arising from omitted variables and measurement errors, which makes it a robust choice to ensure the validity and reliability of results. The results of System GMM are presented in Table 4.

The columns (1) to (4) of Table 4 report the results of four empirical models of this study. The negative coefficient for R&D shown in column (1) −0.114, reinforces the baseline result that higher levels of corporate innovation lower the supply chain concentration for Chinese enterprises. The positive and significant coefficients for Over-indebtedness (OD) and financing constraints (FC) indicate that firms with higher debt levels and those experiencing greater financing constraints would reliance on fewer customers and suppliers. These results are also in line with the baseline results, and reflect their robustness. The regression coefficient of firm profitability is −2.215, shown in Column (4), supporting the baseline conclusion that more profitable firms have less concentrated supply chains. These robust findings, validated through System GMM, underscore the reliability and consistency of the relationships identified in the baseline regressions. These findings also accept all hypotheses of this study.

Table 4. System GMM results.

Variable	Column (1) SCC	Column (2) SCC	Column (3) SCC	Column (4) SCC
R&D	−0.114*			
	(−2.18)			
OD		0.954***		

Cont.

Variable	Column (1) SCC	Column (2) SCC	Column (3) SCC	Column (4) SCC
		(2.52)		
SA			35.213***	
			(5.27)	
Profit				−2.215**
				(−2.03)
Liq	0.016	0.009	0.009	0.015
	(0.16)	(0.09)	(0.10)	(0.15)
Age	37.901***	36.917***	86.693***	37.558***
	(7.33)	(7.33)	(8.37)	(7.36)
Size	−3.359**	−3.517***	−2.991*	−3.623***
	(−3.05)	(−3.23)	(−2.35)	(−3.30)
Debt	5.524**	6.376*	4.208*	6.320**
	(2.67)	(2.41)	(2.11)	(2.83)
Grth	0.596	0.587	0.812	0.549
	(0.86)	(0.94)	(1.06)	(0.92)
FA	0.452	0.139	−3.872	0.469
	(0.15)	(0.05)	(−1.24)	(0.16)
Cons.	15.586*	15.996**	85.450***	15.969**
	(2.53)	(2.57)	(5.81)	(2.59)
N	11,330	11,330	11,330	11,330
R−squared	0.073	0.073	0.073	0.072
AR (1) Pr > z	0.000	0.023	0.001	0.000
AR (2) Pr > z	0.298	0.341	0.510	0.218
Hansen test − Prob > chi2	0.319	0.211	0.671	0.185

Note: z-statistics reported in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% respectively.

5. Heterogeneity Analysis Results

5.1. Firm Size

The firm size heterogeneity analysis results are presented in Table 5. The results show that increased corporate innovation (R&D) has greater inhibitory effects to reduce the supply chain concentration for the large size enterprises. Over-indebtedness's positive impact on supply chain concentration is found significant only for the large size enterprises, indicating that large firms having lower debt levels could be more effective to diversify their supplier and customer base. The effects of financing constraints are found larger for the small sized enterprises to increase the supply chain concentration. It can be argued that small sized enterprises experience greater financing constraints which tend them to rely on fewer suppliers and customers. Lastly, firm profitability reduces the supply chain concentration only for the small size enterprises, implying that firm profits are relatively higher for small sized firms so they can invest their profits to diversify their supply chain.

Table 5. Firm Size heterogeneity results.

	Large Firms				Small Firms			
	Column (1)	Column (2)	Column (3)	Column (4)	Column (5)	Column (6)	Column (7)	Column (8)
Variable	SCC	SCC	SCC	SCC	SCC	SCC	SCC	SCC
R&D	−0.101***				−0.070*			
	(−3.80)				(−1.82)			
OD		10.559***				1.002		
		(4.96)				(0.51)		
SA			4.636***				6.504***	
			(2.88)				(2.58)	
Profit				2.157				−2.949*
				(0.82)				(−1.83)
Cons.	8.738***	7.519***	−3.914	6.392***	3.127	2.769	−6.815	3.122
	(4.23)	(3.75)	(−0.93)	(3.11)	(1.26)	(1.12)	(−1.53)	(1.26)
N	7,152	7,152	7,152	7,152	6,444	6,444	6,444	6,444
R−squared	0.267	0.268	0.266	0.265	0.280	0.284	0.281	0.286

Note: t-statistics reported in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% respectively.

5.2. Firm Ownership Structure

The heterogeneity results for SOEs and Non-SOEs are shown in Table 6. It can be seemed that corporate innovation (R&D) has the significant influence on supply chain concentration only for the SOEs, which indicates that state-owned enterprises leverage greater benefits of innovation to diversify their supply chains. The results for over-indebtedness (OD) and financing constraints (FC) show that firms having state-owned ownership structure tend to greater the supply chain concentration relative to those having the non-stated owned ownership structure. However, non-SOEs have the more significant influence of the firm profitability to reduce the supply chain concentration. It can be argued that firm over-indebtedness and financing constraints have positive effects for both SOEs and Non-SOEs, however corporate innovation reduces supply chain concentration for only SOEs and firm profitability diversify supply chains for only non-SOEs.

Table 6. Ownership structure heterogeneity results.

	SOEs				Non-SOEs			
	Column (1)	Column (2)	Column (3)	Column (4)	Column (5)	Column (6)	Column (7)	Column (8)
Variable	SCC	SCC	SCC	SCC	SCC	SCC	SCC	SCC
R&D	−0.121***				−0.021			
	(−4.10)				(−0.63)			
OD		7.843***				2.502***		
		(3.01)				(2.40)		
SA			9.050***				2.635***	
			(4.74)				(3.54)	
Profit				−1.376				−1.643***
				(−0.46)				(−3.08)
Cons.	−1.780	−2.138	−24.362***	−4.866	10.071***	9.652***	4.896	10.220***

Cont.

Variable	SOEs				Non-SOEs			
	Column (1)	Column (2)	Column (3)	Column (4)	Column (5)	Column (6)	Column (7)	Column (8)
	SCC	SCC	SCC	SCC	SCC	SCC	SCC	SCC
	(−0.62)	(−0.73)	(−4.93)	(−1.74)	(5.33)	(5.11)	(1.30)	(5.39)
N	5,580	5,580	5,580	5,580	8,016	8,016	8,016	8,016
R-squared	0.292	0.291	0.231	0.289	0.265	0.235	0.212	0.257

Note: t-statistics reported in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% respectively.

5.3. High Tech Industry

The heterogeneity results for high tech and non-high-tech industries are presented in Table 7. In high tech industries, corporate innovation (R&D) significantly reduces supply chain concentration as shown by the negative coefficient in column (1) of Table 7, which implies that firms in high tech sectors invest heavily in R&D, and thus diversify their supply chain. On the other hand, non-high-tech industries have non-significant influence of R&D on SCC. The impact of firm over-indebtedness and financing constraints is found significant and relatively higher for the high-tech industries, showing that firms of these industries are greatly influenced by these both to increase the supply chain concentration. Firm profitability (*Profit*) shows that there is not significant effects of this factor for high-tech or non-high tech enterprises.

Table 7. High tech industry heterogeneity results.

Variable	High Tech				Non-High Tech			
	Column (1)	Column (2)	Column (3)	Column (4)	Column (5)	Column (6)	Column (7)	Column (8)
	SCC	SCC	SCC	SCC	SCC	SCC	SCC	SCC
R&D	−0.281***				0.029			
	(−6.17)				(1.14)			
OD		5.607**				5.233**		
		(2.55)				(2.78)		
SA			5.143*				3.717*	
			(2.24)				(2.33)	
Profit				−0.843				−0.461
				(−0.41)				(−0.26)
Cons.	14.841***	13.739***	3.951	13.913***	3.993	3.917	−4.279	3.481
	(6.20)	(5.73)	(0.79)	(5.76)	(1.83)	(1.85)	(−1.09)	(1.63)
N	4,915	4,915	4,915	4,915	8,681	8,681	8,681	8,681
R-squared	0.365	0.359	0.358	0.357	0.287	0.288	0.271	0.257

Note: t-statistics reported in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% respectively.

6. Conclusion and Policy Implications

Using data of 1133 Chinese A-share listed enterprises on Shanghai Stock Exchange and Shenzhen Stock Exchange for the period of 2011–2022, this study examines the effects of corporate innovation, firm over-indebtedness, financing constraints, and firm profitability on supply chain concentration. The baseline results show that corporate innovation and firm profitability reduce the supply chain concentration, while firm over-indebtedness and financing constraints increase supply chain concentration. These results imply that higher

R&D investments reduce the reliance on fewer suppliers and customers, over-indebtedness and financing constraints drive financial pressure for firms and leading them to consolidate supply chain network, and firm profitability increases the financial health of firms to diversify their supply chains. These results are remained robust after addressing the endogeneity concerns by system GMM approach. Heterogeneity analysis results show that large firm, state-owned enterprises, and high-tech industries exhibit stronger responses to the financial constraints and innovation pressures to their counterparts.

The findings of this study offer several policy implications. First, policymakers should promote R&D activities through tax subsidies and incentives at regional level, to allow the enterprises to counteract their supply chain challenges. Second, managers are required to foster the innovative environment within their organizations to get the stronger potential to reduce the supply chain concentration. Third, firms should not move toward higher volume of debt as it can mitigates their potential to manage the supply chain risks. Fourth, policymakers should promote the digital finance across the regions for being able to increase the financial inclusion, and thus allowing the enterprises to alleviate their financing constraints so they can manage their supply chain practices more efficiently. Fifth, firms should adopt profit-generating strategies to be able to diversify the supply chain concentration and achieving overall corporate resilience. Last, there should have been support for small sized enterprises, privately owned enterprises, and enterprises of non-high-tech industries to allow them to extend their potential to achieve better outcomes via getting control over their supply chain network. Methods such as machine learning can be also leveraged to improve the efficiency of the work represented in this paper [65–76].

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The authors declare no conflict of interest.

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