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Does supply chain concentration promote or inhibit corporate R&D investment?

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Abstract

Purpose – This study aims to investigate the impact of supply chain concentration (SCC) on corporate research and development (R&D) investment and determine the moderating roles of industry concentration and financing constraints on the relationship between SCC and R&D investment.

Design/methodology/approach – The study collected data from Chinese listed companies, used the fixed effects model to test the research hypotheses and further used the two-stage Heckman test and propensity score matching (PSM) to address potential endogeneity issues.

Findings – The result reveals a negative impact of SCC on corporate R&D investment. In addition, industry concentration mitigates the negative impact of SCC on corporate R&D investment, but financing constraints strengthen the negative impact.

Originality/value – This study introduces the concept of SCC and empirically tests its effect on R&D investment, further explaining the lack of corporate innovation. This study inspires companies to strengthen SC management and weigh the level of SCC with environmental factors.

Keywords Supply chain, Innovation, Industry concentration, Financing constraints, Emerging market

Paper type Research paper

1. Introduction

Research and development (R&D) investment is considered one of the most typical forms of learning and a major way of innovation for companies (Koussis *et al.*, 2007; Xiao, 2013). In the current competitive environment, an increasing number of companies recognize the importance of R&D investment in strengthening sustainable competitive advantage and enhancing innovation capability (Qian and Yuan, 2023; Tse *et al.*, 2021). However, in most countries, firms do not invest in R&D at the optimal level proposed by Knott (2012). Why does corporate practical R&D behavior not match their perception? Previous literature has explained the reasons for short-sightedness in R&D activities from different perspectives, such as management compensation gap (Wang *et al.*, 2023), intergenerational power gap (Zhao *et al.*, 2023) and family CEO duality (Lin *et al.*, 2023).

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Although these studies provide important insights into corporate R&D underinvestment, there is a shortcoming that they all focus on the organizational internal factors. R&D investment is not only the result of internal management but is also influenced by external factors. Based on the resource dependency theory (RDT), the organization cannot generate all the resources it needs internally and must obtain the necessary resources through other organizations in the environment to survive, but power imbalance caused by dependency relationship between organizations is one of the sources of uncertainty affecting organizational behavior (Pfeffer and Salancik, 1978; Hillman *et al.*, 2009). Supply chain (SC) is a typical dependency structure (Luo *et al.*, 2023). However, the impact of SC structural characteristics on corporate R&D investment has been largely overlooked (Yoo and Seo, 2017), which provides a good entry point for further research.

Therefore, we attempt to address the existing research gap by exploring how the SC dependence structure factor affects R&D investment. Specifically, SC concentration (SCC), as a structural feature of SC relationship, reflects the dependence degree of a firm on its trading partners (Chen *et al.*, 2023; Schwieterman *et al.*, 2017), like a coin with two sides. For example, high SCC implies that firms are highly dependent on their main SC partners, which reduces their bargaining power and thus disrupts their investment strategy (Ahsan *et al.*, 2023; Zhang *et al.*, 2020). However, concentration also encourages firms to collaborate on R&D to build solid SC relationships (Krolikowski and Yuan, 2017). These possibilities drive us to examine whether SCC positively or negatively affects R&D investment. Moreover, conflicting views point to the need to explore the consequences of SCC in the context of additional conditions. As firms are embedded in industry and society, we develop moderators at the industry (industry concentration) and societal (financing constraints) levels. To sum up, we pose two research questions. First, how does SCC affect corporate R&D investment? Second, what are the contingency impacts of industry concentration and financing constraints on the relationship between SCC and R&D investment?

Actually, high SCC is often accompanied by insufficient R&D investment in many firms and industries. For example, Chinese Hygon Information Technology, which is dedicated to R&D of chip products and systems, maintains a high level of SCC but invests less in R&D than the average of other peer companies. Not coincidentally, SunWin (Hubei) Optoelectronic Technology, as a high-tech company, is also in a situation of higher SCC but lower R&D investment. Many scholars showed that high SCC reduced the bargaining power of midstream firms (Ahsan *et al.*, 2023; Hui, 2023), thus resulting in no spare funds in R&D activities because of lower profits. Moreover, high SCC exposes firms to higher risks (Dhaliwal *et al.*, 2016), which makes them cautious about R&D activities, as R&D activities are also high-risk. Therefore, we argue that SCC inhibits firms from investing in R&D. Besides, we hold the view that the above negative impact is weakened in concentrated industry because industry concentration can strengthen the bargaining power of firms (Xu *et al.*, 2019). Conversely, financing constraints strengthen the negative impact, as financing constraints further limit funds available to firms for R&D.

We take a sample of Chinese-listed companies for the following reasons. First, the China Securities Regulatory Commission advises companies to respectively disclose the names and purchase (sale) amounts of their main suppliers (customers), which supports necessary data availability. Second, SCC is more pronounced in Chinese companies than in companies from other countries (Cao *et al.*, 2023). Empirical results support our conjectures. The above findings still hold after controlling for potential endogeneity problems. This study makes the following contributions. First, this study extends the research boundary of RDT in inter-firm dependence by focusing on the impact of SC dependence on R&D investment. Previous research on inter-firm dependence based on RDT mainly emphasized R&D advantages from dependence (as listed in Table 1). This study starts with SC relationship dependence, in contrast to previous points, which reveal the negative impact of inter-firm dependence on firms' R&D investment. Second, we expand research focusing on SCC. Suppliers and customers together constitute complete resource exchange process of a firm. Therefore, based on previous research focusing on one side of SC (as listed in Table 1), we simultaneously consider supply and demand sides, which highlights overall dependency structure of SC. Third, we introduce industry concentration and financing constraints into research framework to more comprehensively explain the impact of SCC on R&D investment. When considering contingency factors, we emphasize environmental factors, which is an extended study combining the RDT with contingency theory.

The structure of this paper is as follows. Section 2 reviews theory background and sets forth research hypotheses. Section 3 introduces the research model and variable definitions. Section 4 provides descriptive statistics, correlation analysis and empirical results. Section 5 discusses the results. Finally, Section 6 concludes the study, including theoretical contributions, managerial insights and limitations.

2. Theoretical foundation and hypotheses development

2.1 Resource dependency theory

The RDT suggests that an organization primarily depends on resources from other organizations within its environment to survive. SC is an important approach for companies to access critical resources, thus playing an increasingly important role in gaining a competitive advantage for companies (Hofmann, 2010). However, the RBT also points out that power is directly related to resource dependence, which means that the power of one organization over another is equal to the degree of dependence of the latter on the resources held by the former (Pfeffer and Salancik, 1978). In a resource-dependent relationship, there is a tendency for power imbalance between business partners (Hillman *et al.*, 2009). As the proportion of supply (demand) from suppliers (customers) rises, the company's dependence on them also increases, which increases the power of suppliers or customers over the company, resulting in a power imbalance that exacerbates hindrance problem. Therefore, we doubt that high SCC is detrimental to corporate R&D investment.

2.2 Hypothesis development

2.2.1 Supply chain concentration and research and development investment. First, when a corporation has high SCC, it is at a disadvantage because of the increased bargaining power

Research stream	Research content	Exemplar studies	Research gaps
Inter-firm dependence	Interlocking firms Firms in the innovation ecosystems R&D consortium	Lin *et al.* (2023) Mei *et al.* (2019) Yang (2022)	Emphasizing cooperative dependence while ignoring transactional dependence
SC structure	Supply side	Feng *et al.* (2023) Cheng *et al.* (2022) Dong *et al.* (2022)	Separately focusing on one side of SC
	Demand side	Fu (2023) Cao *et al.* (2023) Zhu *et al.* (2022)	

Source: Table created by authors

Table 1.
A review of literature

of its limited number of suppliers and customers (Dowlatshahi, 1999). Porter's five forces model considers that the bargaining powers of suppliers and customers, threats of substitutes and potential entrants and competition between existing competitors can affect product price, cost and necessary investment decisions (Porter, 1992). Christopher and Gattorna (2005) also indicated that SC, rather than a corporation's internal operations, is the last opportunity for companies to cut major costs. However, bargaining power may lead to benefit encroachment. On the one hand, suppliers with strong bargaining power may seek more profit for themselves by requesting early payment and increasing raw material prices, thus increasing the procurement costs of companies (Feng *et al.*, 2023). On the other hand, major customers tend to demand lower product prices and delay payments, which makes it more difficult to raise funds and directly reduces corporate cash flow (Campello and Gao, 2017; Yang, 2017). These may occupy funds and reduce the profitability of corporations, thus decreasing the resources allocated to R&D activities. Therefore, high SCC may reduce the bargaining power of companies, thus resulting in insufficient funds for R&D activities.

Second, high SCC can increase operational risks. If suppliers and customers face financial difficulties or declare bankruptcy, the corporation's normal operation can be disrupted and suffer losses. Corporations hedge risk for precautionary motives by holding more cash (Zhang *et al.*, 2020). At the same time, the high risks associated with SCC reduce corporate risk-taking. As R&D involves high investment and risk, companies will reduce R&D investment to control absolute risk. Besides, R&D investment is often considered the critical aspect of relational dedicated asset investment in SC relationships (Bowen *et al.*, 1995). The uncertainty in liquidation value of assets increases with specialization, according to the asset specificity theory (Williamson, 1988). Therefore, companies will lose the value of their relationship-specific assets and face high conversion costs if the transaction is suddenly interrupted (Ketokivi and Mahoney, 2020), which reduces the input of relationship-specific assets. Therefore, considering the risks, the corporation tends to be more cautious and reduce its R&D investment when it has high SCC.

Moreover, high SCC means that firms have less access to heterogeneous resources that are necessary for realizing R&D activities. Hence, some scholars have argued that heterogeneous resources positively influence corporate innovation. The number of new products that companies develop increases with partner heterogeneity (Hoskisson *et al.*, 2002). Suppliers are crucial in providing corporations with the necessary raw materials and services. Integrating suppliers into the new product development process directly impacts decisions on manufacturing process design and production configuration (Petersen *et al.*, 2005). Customers boost corporate R&D activities by providing market demand (Christensen *et al.*, 2005). Thus, when the number of suppliers is limited, corporations may have restricted access to knowledge and technology. Similarly, a concentrated customer base limits the focal corporation's grasp of market demand and increases information asymmetry. Therefore, high SCC, which implies the reduction of heterogeneous resources, inhibits corporate innovation activities, thus reducing R&D investment.

In summary, the following hypothesis is proposed:

H1. SCC inhibits corporate R&D investment.

2.2.2 Moderating role of industry concentration. Recent studies have found that industry concentration determines the degree of competition in the industry and further influences companies' business strategies by affecting the distribution of resources and risk (Mithas *et al.*, 2013; Pham, 2018). When industry concentration is low, competition increases due to fragmentation within the industry. The competitive landscape increases business risks of companies, especially those with high SCC. The bargaining power of their suppliers and customers is further enhanced. Because companies with high SCC face greater risks if their procurement and supply models are disrupted (Zu and Zhang, 2023). In this case, companies are more concerned about short-term benefits, such as changes in market share and declining performance, rather than long-term sustainable development. The characteristics of R&D activities, including long lead time and inability to achieve returns in a short time, may put corporations in more serious trouble (McKinley *et al.*, 2014). Therefore, companies in highly competitive industries prefer to adopt cost-leading strategies (Li and Luo, 2021). At the same time, high industry competition heightens business concerns. Corporations respond to the risk of being preyed upon by competitors in a highly competitive market by holding more cash reserves (Haushalter *et al.*, 2007). Under this circumstance, the motivation of companies to reduce R&D investment is further amplified.

On the contrary, companies always have significant market positions when the industry concentration is high (Zu and Zhang, 2023). In this case, the disadvantages for companies with high SCC are eliminated and may even change to favorable conditions. Companies in highly concentrated industries are able to achieve economies of scale and scope and capture greater excess returns (Nieto and González-Álvarez, 2014). Therefore, companies with high SCC have an advantage in limited competition. They have more opportunities to reap more economic benefits, thus having sufficient funds to invest in R&D activities (Schumpeter, 1942). Moreover, they face less uncertainty and are more likely to benefit from R&D investment, which increases their incentive to invest in R&D (Tishler and Milstein, 2009). In addition, when the external environment is stable, the gap between peer companies is obvious. Companies prefer differentiation strategies to maintain competitive advantage. And when market competition is low, it is easier for them to build intellectual property protection barriers and benefit better from R&D. Companies with high SCC are also likely to engage in collaborative R&D to preserve SC relationships.

Based on the discussion, the following hypothesis is proposed:

H2. In the case of higher industry concentration, the impact of SCC on corporate R&D investment is mitigated.

2.2.3 Moderating role of financing constraints. Prior studies have pointed out that companies typically prioritize endogenous financing over exogenous financing for corporate R&D investment (Himmelberg and Petersen, 1994). Although internal funding is one source of R&D funding, companies must rely on more than endogenous financing. R&D activity is a continuous and cumulative process, and it is difficult to cover the huge investments required for R&D activities by only relying on endogenous financing sources is difficult. Hence, external financing is gradually becoming an important source of R&D investment for corporations (Czarnitzki and Hottenrott, 2011). Therefore, R&D investment is sensitive to the external financing environment (Jones and Williams, 1998). Financing constraints mean that companies are unable to obtain stable and sufficient financial support due to the lack of capital caused by the high cost of external financing.

Investment decisions and risk management become more important when companies face high financing constraints. Because if a company experiences financial difficulties, its SC may also be shaken. Under financing constraints, companies with high SCC face worse financial conditions. At this point, the opportunity cost of corporate investment decision is small. However, R&D activities require large sunk costs and products are difficult to liquidate (Williamson, 1988), which makes it more difficult for struggling companies to accept the risks associated with R&D investment. Moreover, companies with high SCC tend to allocate capital to projects with less risk and stable returns rather than to high-risk R&D

activities. Therefore, as financing constraints grow, the negative impact of SCC on R&D investment of companies increases.

Based on the discussion, the following hypothesis is proposed:

H3. In the case of higher financing constraints, the impact of SCC on corporate R&D investment is strengthened.

The theoretical framework is shown in Figure 1.

3. Research methodology

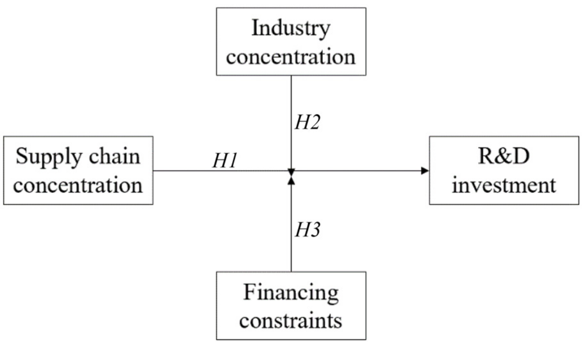
3.1 Data source and sample

To investigate the three previously mentioned hypotheses, we use a sample of Chinese corporations listed on the Shenzhen and Shanghai Stock Exchange from 2006 to 2019. Such corporations are more mature and stable with better transparent data disclosure, which provides convenience and feasibility for research. Besides, 2006 was chosen as the starting year because new accounting standards issued in China in 2006 provided new and clear regulations on corporate R&D expenses and improved information disclosure. Following Zheng *et al.* (2023), this study selects the initial sample according to the following methods. First, we exclude financial and insurance industries because they have specific objectives and financial indicators that make it impossible to compare data (Yuan and Wen, 2018). Second, we exclude companies indicated as "ST" and "*ST" because of their abnormal operating conditions that would bias the regression results (Ren *et al.*, 2021). Finally, we delete annual observations for companies with missing data. The final sample includes 2,354 companies with a total of 11,990 observations. We collect data from three main sources, the China Stock Market and Accounting Research database, Wind database and corporate annual reports. All continuous variables are winsorized at the 1% and 99% levels in this study to remove the effect of extreme values.

3.2 Measures

3.2.1 Dependent variable. The widely used indicators to measure R&D investment are R&D investment decisions and R&D intensity. This study follows Gao *et al.* (2023) using the ratio of R&D expenditure to total assets to measure corporate R&D investment.

3.2.2 Independent variable. SCC mainly refers to the number of partners upstream and downstream in the SC as well as its degree of business concentration, including supplier and



Source: Figure created by authors

Figure 1.
Logical framework of this study

customer concentration (Kwak and Kim, 2020; Zhang *et al.*, 2020). We follow Patatoukas (2012) and Xu *et al.* (2022) and use the mean of the upstream and downstream concentrations as the overall SCC.

3.2.3 Moderating variables. In this study, we introduce industry concentration and financing constraints as moderating variables.

We use the Herfindahl–Hirschman index (HHI) to measure the degree of industry concentration. A lower HHI value indicates a less concentrated and more fragmented industry, whereas a higher HHI value indicates a more concentrated market and a stronger monopoly of companies in the industry. The HHI is a common measure of industry concentration and is calculated as the sum of the squares of each corporation's revenue as a percentage of the industry's total revenue, which is calculated as follows:

$$HHI = \sum_{i=1}^{N} \left(\frac{S_i}{S}\right)^2 \tag{1}$$

where N is the number of listed corporations in the industry, S_i is corporate I's revenue for the year as a percentage of the same industry's total revenue (S). We use the last two codes of the industry classification standard of the China Securities Regulatory Commission to classify industries in this study.

In this study, we use the WW (Whited and Wu, 2006) index because it considers both external industry characteristics and internal financial characteristics, which gives it a broader economic significance. The WW index is calculated as follows:

$$WW_{i,t} = b_1 CF_{i,t} + b_2 DIVPOS_{i,t} + b_3 TLD_{i,t} + b_4 LNTA_{i,t} + b_5 ISG_{i,t} + b_6 SG_{i,t} \tag{2}$$

where CF is the ratio of cash flow to total assets, $DIVPOS$ is a dummy variable that takes the value of 1 at the time of the dividend, TLD is the ratio of long-term liabilities to total assets, and $LNTA$ is the natural logarithm of total assets. Meanwhile, ISG and SG are the sales growth rate of the industry and corporation, respectively. The coefficient vector b is given by Whited and Wu (2006) as follows: a higher value indicates a higher degree of financing constraints for the corporation.

3.2.4 Control variables. Consistent with the existing literature on exploring factors affecting R&D investment, we control for many corporate characteristics to eliminate alternative explanations. First, we calculate the current ratio (Lev) by using the total current assets to the total current liabilities ratio. The increase in corporate liabilities prompts firms to increase R&D expenditures (Aaboen *et al.*, 2006). Large corporations have larger market shares and greater risk management abilities than smaller ones. Therefore, corporate size has a significant positive effect on R&D investment (Muhammad *et al.*, 2022; Shefer and Frenkel, 2005). We use the log of a corporation's total assets to measure corporate size (Size). We add corporate age to the control variables because younger corporations are more interested in R&D ideas (Coad *et al.*, 2016). Meanwhile, corporations with better financial performance are more likely to engage in R&D activities because they can afford such investment. Corporate performances, indicated by return on equity (ROE) and increased rate of main business revenue (Growth), are thus controlled. We also control the nature of property rights of companies based on the Chinese institutional context.

Second, we control for board characteristics because good board characteristics can impact corporate investments (Menshawy *et al.*, 2023). Therefore, we control for board size (*Board*), independent directors ratio (*Indep*) and the duality of chairman and general manager (*Dual*). The checks and balances among shareholders facilitate the management to make investment decisions that are consistent with the corporation's continued growth (Gomes and Novaes, 2001). Thus, we include power balance with shareholder structure (Balance) as a control variable.

Finally, we control for industry and year. Notably, the industry codes are referred from China's two-digit industrial classification and code. Table 2 presents the description of the variables in detail.

3.3 Regression model

This study adopts the following models to examine our hypotheses:

$$R\&D_{i,t} = \alpha_0 + \alpha_1 \mathrm{SCC}_{i,t} + \alpha_2 \mathrm{Controls}_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t} \tag{3}$$

$$R\&D_{i,t} = \alpha_0 + \alpha_1 \mathrm{SCC}_{i,t} + \alpha_2 HHI_{i,t} + \alpha_3 SCC_{i,t} \times HHI_{i,t} + \alpha_4 Controls_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t} \tag{4}$$

$$R\&D_{i,t} = \alpha_0 + \alpha_1 \mathrm{SCC}_{i,t} + \alpha_2 WW_{i,t} + \alpha_3 SCC_{i,t} \times WW_{i,t} + \alpha_4 Controls_{i,t} + \sum Year + \sum Industry + \varepsilon_{i,t} \tag{5}$$

Model 3 is used to test *H1*. Based on Model 3, we added industry concentration, financing constraints and their interaction terms with SCC to test *H2* to *H3* in Models 4 and 5.

Table 2.
Variable definition

Variable name	Variable symbol	Variable description
R&D Investment	R&D	The ratio of R&D investment of total asset
SC Concentration	SCC	The average of purchases from TOP5 suppliers to total purchases and sales to TOP5 customers to total sales
Leverage	Lev	The proportion of total corporate liabilities to total corporate assets
Firm size	Size	The natural logarithm of the total asset at the end of the year
Firm age	Age	The logarithm of the current year minus the year the corporation was founded plus one
Firm growth	Growth	The sales growth rate
Nature of ownership	SOE	If the enterprise is a state-owned enterprise, it is represented by 1, otherwise it is equal to 0
Return on equity	ROE	The ratio of net profits divided by book value of equity
Board size	Board	The natural logarithm of the number of board members
Percentage of independent directors	Indep	The ratio of the number of independent directors divided by the number of directors
Dual role of chairman and general manage	Dual	If the chairman and the general manager are one and the same person, it is denoted by 1 and equals 0 otherwise
Shareholding checks and balances	Balance	The ratio of the sum of the shareholdings of the second to fifth largest shareholders to that of the first largest shareholder
Industry concentration	HHI	The sum of the squared operating revenues of each corporation in the industry as a percentage of total industry operating revenues
Financing constraints	WW	The WW index proposed by White and Wu

Source: Table created by authors

4. Results

4.1 Descriptive statistics

Table 3 shows descriptive statistics. The maximum value of R&D is 0.102, indicating that R&D expenditure intensity among sample companies is relatively low. The mean value of SCC is 0.052. The maximum and minimum values of SCC are 0.354 and 0.001, respectively, showing a significant difference in corporate SCC.

4.2 Correlations between variables

We perform a correlation analysis on the study variables. Table 4 shows the Pearson correlation coefficients between all variables. The coefficient between SCC and R&D investment is significantly negative, which initially validates the main hypothesis of this study. Most other correlation coefficients are low. We also check the variance inflation factor (VIF) values for each regression, with a maximum VIF of 5.33, which is significantly less than 10. This implies that no serious multicollinearity problem exists in this study's regression analysis.

4.3 Baseline regression results and analysis

According to Cameron and Trivedi (2009), when using panel data, we can use either the fixed effects model or the random effects model regression. We perform Hausman specification test to determine the best regression method for our panel data analysis. Based on the Hausman test results, we finally apply the fixed effects model. Table 5 presents the regression results. *H1* predicts that SCC inhibits R&D investment of companies. Column 1 includes SCC and all control variables to test *H1*. The regression coefficient of SCC is significantly at the 1% level, suggesting that high SCC can significantly discourage companies from investing in R&D activities. *H1* is supported. The coefficient estimate of SCC suggests that *ceteris paribus*, SCC is associated, on average, with a decrease of –0.008 in R&D investment. Column 2 adds HHI and the interaction between SCC and HHI to test *H2*. The regression coefficient of SCC × HHI is 0.075 and is significant at the 5% level, thus supporting *H2*. Column 3 reports the moderating effect of financing constraints on the relationship between SCC and R&D investment. The regression coefficient of SCC×WW is –0.062 and is significant at the 5% level, suggesting that the negative impact of SCC on R&D investment is strengthened in the case of higher financing constraints. The result supports *H3*.

Variable	Obs	Mean	Std.	Min.	Max.
R&D	11,990	0.023	0.019	0.000	0.102
SCC	11,990	0.051	0.064	0.001	0.354
HHI	11,990	0.085	0.078	0.015	0.445
WW	11,990	−1.003	0.061	−1.171	−0.865
Lev	11,990	0.396	0.194	0.053	0.859
Size	11,990	21.976	1.106	19.969	25.391
Age	11,990	2.802	0.342	1.792	3.466
Growth	11,990	0.184	0.388	−0.486	2.343
SOE	11,990	0.229	0.420	0.000	1.000
ROE	11,990	0.059	0.128	−0.659	0.334
Board	11,990	2.110	0.190	1.609	2.565
Indep	11,990	0.376	0.053	0.333	0.571
Dual	11,990	0.320	0.467	0.000	1.000
Balance	11,990	0.797	0.626	0.037	2.895

Source: Table created by authors

Table 3. Descriptive statistics

Table 4.
Correlation of all variables

	1	2	3	4	5	6	7	8	9	10	11	12	13		VIF
R&D	1.000														
SCC	−0.059 ***	1.000													1.02
HHI	−0.234 ***	0.083 ***	1.000												1.03
WW	0.086 ***	0.074 ***	−0.056 ***	1.000											5.21
Lev	−0.202 ***	−0.009	0.097 ***	−0.292 ***	1.000										1.57
Size	−0.205 ***	−0.057 ***	0.093 ***	−0.828 ***	0.505 ***	1.000									5.33
Age	−0.057 ***	0.003	−0.007	−0.083 ***	0.116 ***	0.159 ***	1.000								1.06
Growth	0.023 **	0.019 **	−0.022 **	−0.305 ***	0.014	0.058 ***	−0.040 ***	1.000							1.32
ROE	0.095 ***	−0.038 ***	−0.031 ***	−0.356 ***	−0.213 ***	0.090 ***	−0.033 ***	0.274 ***	1.000						1.42
Board	−0.075 ***	−0.018 *	0.071 ***	−0.191 ***	0.123 ***	0.220 ***	0.024 ***	−0.008	0.053 ***	1.000					1.71
Indep	0.035 ***	−0.000	−0.042 ***	0.041 ***	−0.013	−0.027 ***	0.010	−0.014	−0.030 ***	−0.591 ***	1.000				1.58
Dual	0.090 ***	−0.025 ***	−0.056 ***	0.099 ***	−0.096 ***	−0.147 ***	−0.073 ***	0.033 ***	0.012	−0.169 ***	0.130 ***	1.000			1.09
Balance	0.096 ***	−0.006	−0.037 ***	0.066 ***	−0.140 ***	−0.101 ***	−0.006	0.073 ***	−0.019 **	0.024 ***	−0.035 ***	0.021 **	1.000		1.08
SOE	−0.121 ***	0.061***	0.083***	−0.217 ***	0.274***	0.332***	0.191***	−0.080 ***	−0.026 ***	0.243***	−0.079 ***	−0.250 ***	−0.223 ***	1.000	1.33

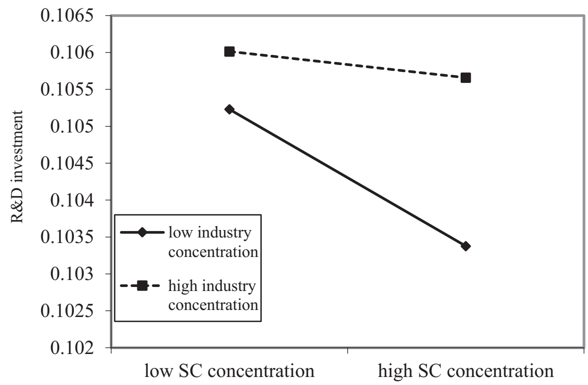
Notes: The coefficients with *, ** and ***represent significance at 10, 5 and 1% level
Source: Table created by authors

	Model 1 R&D	Model 2 R&D	Model 3 R&D
Lev	0.0002 (0.23)	0.0004 (0.39)	0.0003 (0.31)
Size	−0.004*** (−17.07)	−0.004*** (−17.08)	−0.005*** (−14.74)
Age	0.001 (0.51)	0.001 (0.50)	0.001 (0.50)
Growth	0.001** (2.08)	0.001** (2.16)	0.0004 (1.42)
ROE	−0.001* (−1.67)	−0.001 (−1.63)	−0.002* (−1.77)
Board	0.003*** (2.74)	0.003*** (2.70)	0.003*** (2.74)
Indep	−0.002 (−0.57)	−0.002 (−0.62)	−0.002 (−0.60)
Dual	0.0002 (0.69)	0.0002 (0.66)	0.0002 (0.67)
Balance	0.001** (2.46)	0.001** (2.53)	0.001** (2.44)
SOE	0.001 (0.77)	0.001 (0.74)	0.001 (0.76)
SCC	−0.008*** (−3.46)	−0.015*** (−4.05)	−0.070** (−2.26)
HHI		0.006 (1.51)	
SCC × HHI		0.075** (2.30)	
WW			0.001 (0.16)
SCC × WW			−0.062** (−2.00)
_cons	0.101*** (9.86)	0.102*** (9.92)	0.105*** (10.06)
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
N	11,990	11,990	11,990
R^2	0.103	0.104	0.103

Notes: *t*-statistics are reported in parentheses. The coefficients with *, ** and ***represent significance at 10, 5 and 1% levels, respectively
Source: Table created by authors

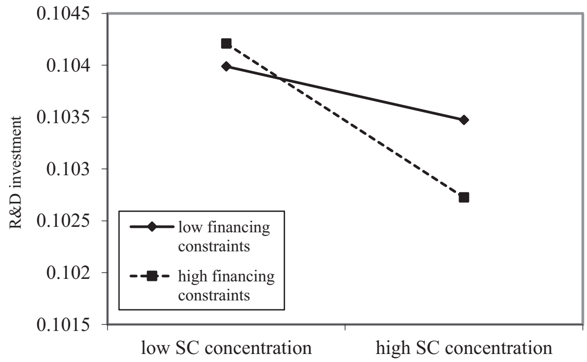
Table 5. The result of SC concentration on R&D investment

Figures 2 and 3 illustrate the regulatory effect diagrams to demonstrate the regulatory effects better. Figure 2 shows that when the industry concentration is low, the relationship between SCC and R&D investment is negative and the slope is steep. Conversely, when industry concentration is high, this relationship becomes less negative and the slope is flatter. The results show that industry concentration weakens the negative role of SCC in inhibiting corporate R&D investment, which is consistent with the theoretical expectations. Figure 3 shows that when the financing constraints are low, the relationship between SCC



Source: Figure created by authors

Figure 2. Moderating effect of industry concentration



Source: Figure created by authors

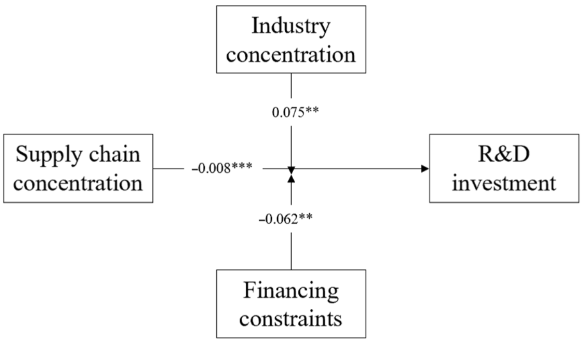
Figure 3.
Moderating effect of financing constraints

and R&D investment is negative and the slope is flat. Conversely, when financing constraints are high, this relationship becomes more negative and the slope is steeper. The results show that financing constraints strengthen the negative role of SCC in inhibiting corporate R&D investment, which is consistent with the theoretical expectations.

The empirical analysis framework is shown in Figure 4.

4.4 Robustness checks

4.4.1 Alternative measure of independent variable. We re-measure SCC using the average of the percentage of sales revenue to the top five customers and the percentage of purchases from the top five suppliers for robustness testing to conduct the regression analysis. Table 6 presents the regression analysis results of robustness tests. Column 4 shows that SCC has a negative impact on R&D investment ($\beta = -0.007$, $p < 0.01$). Moreover, Column 5 shows that the industry concentration weakens the negative effect of SCC on R&D investment ($\beta = 0.032$, $p < 0.05$). Column 6 shows that financing constraints strengthen the negative effect of SCC on R&D investment ($\beta = -0.025$, $p < 0.01$). The above results demonstrate the robustness of this study's main empirical findings.



Source: Figure created by authors

Figure 4.
Result framework of this study

	Model 4 R&D	Model 5 R&D	Model 6 R&D
Lev	0.0002 (0.25)	0.0004 (0.42)	0.0004 (0.38)
Size	−0.005*** (−17.67)	−0.005*** (−17.71)	−0.005*** (−15.30)
Age	0.001 (0.39)	0.001 (0.38)	0.001 (0.38)
Growth	0.001** (2.18)	0.001** (2.29)	0.0004 (1.43)
ROE	−0.001 (−1.56)	−0.001 (−1.50)	−0.001 (−1.62)
Board	0.003*** (2.71)	0.003*** (2.69)	0.003*** (2.71)
Indep	−0.002 (−0.62)	−0.002 (−0.64)	−0.002 (−0.60)
Dual	0.0002 (0.73)	0.0002 (0.71)	0.0002 (0.76)
Balance	0.001** (2.52)	0.001*** (2.60)	0.001** (2.48)
SOE	0.001 (0.84)	0.001 (0.85)	0.001 (0.82)
SCC	−0.007*** (−6.33)	−0.010*** (−6.25)	−0.032*** (−2.69)
HHI		−0.001 (−0.09)	−0.001 (−0.09)
SCC × HHI		0.032** (2.43)	0.032** (2.42)
WW			0.006 (1.12)
SCC × WW			−0.025** (−2.11)
_cons	0.108*** (10.45)	0.109*** (10.57)	0.117*** (10.48)
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
N	11,990	11,990	11,990
R^2	0.105	0.106	0.106

Notes: *t*-statistics are reported in parentheses. The coefficients with *, ** and ***represent significance at 10, 5 and 1% levels, respectively
Source: Table created by authors

Table 6. Results of robustness test: alternative measure of independent variable

4.4.2 Alternative measure of dependent variable. We use the R&D expenditure to operating revenue ratio to measure R&D investment intensity, referencing Zhao *et al.* (2023). Table 7 shows the shows the results of the robustness test. After the above tests, the conclusions of this study do not change substantially.

4.5 Endogeneity tests

4.5.1 Two-stage Heckman method. The decision to disclose R&D investment costs is a corporate choice that may lead to possible sample selection bias in our study (Li *et al.*, 2022). We apply the Heckman two-stage method for re-testing to alleviate the potential sample selection bias (Heckman, 1979). In the first stage, we use the Probit model to calculate the inverse Mills ratio (IMR). We further include IMR as a control variable into the Heckman second-stage model for regression analysis. Table 8 represents the results, and these results indicate that while the coefficients of IMR are significant, our findings are robust.

4.5.2 Propensity score matching. Propensity score matching (PSM) and Heckman two-step methods are not interchangeable because they attempt to solve different endogeneity problems (Tucker, 2010). We further use PSM to correct the bias related to self-selection problem. First, data matching and the balance test are carried out. The companies are divided into two groups. Specifically, we treat companies with SCC greater than the sample median as the treatment group. The rest of the sample companies are treated as the control group. We match the treatment and control groups with the above control variables acting as covariates and using the radius matching method. Subsequently, we perform a balance test to test whether there is a significant difference between the treatment and the control groups after matching. The balance test results are shown in Table 9. The absolute value of

Table 7.
Results of robustness test: alternative measure of dependent variable

	Model 7 R&D	Model 8 R&D	Model 9 R&D
Lev	−0.019*** (−8.42)	−0.019*** (−8.32)	−0.020*** (−8.84)
Size	0.003*** (4.52)	0.003*** (4.53)	0.004*** (6.13)
Age	−0.005 (−1.34)	−0.005 (−1.35)	−0.006 (−1.48)
Growth	−0.008*** (−14.58)	−0.008*** (−14.52)	−0.006*** (−10.57)
ROE	−0.026*** (−13.97)	−0.026*** (−13.95)	−0.024*** (−12.40)
Board	−0.0002 (−0.09)	−0.0003 (−0.11)	−0.0003 (−0.12)
Indep	−0.010 (−1.44)	−0.011 (−1.47)	−0.012 (−1.61)
Dual	0.001 (0.71)	0.001 (0.70)	0.0004 (0.66)
Balance	0.002*** (3.42)	0.002*** (3.44)	0.002*** (3.34)
SOE	0.00004 (0.02)	0.00001 0.00	−0.00004 (−0.02)
SCC	−0.042*** (−7.65)	−0.055*** (−6.57)	−0.209*** (−2.93)
HHI		0.0040 (0.43)	−0.001 (−0.09)
SCC × HHI		0.154** (2.04)	0.032** (2.42)
WW			0.044*** (4.89)
SCC × WW			−0.167** (−2.35)
_cons	0.010 (0.40)	0.010 (0.43)	0.020 (0.81)
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
N	11,990	11,990	11,990
R^2	0.134	0.135	0.137

Notes: *t*-statistics are reported in parentheses. The coefficients with *, ** and ***represent significance at 10, 5 and 1% levels, respectively
Source: Table created by authors

the standard deviation after matching is less than 10%, indicating a good matching result. We further re-implement the regression analysis based on the samples after PSM. Table 10 represents the regression results. The results demonstrate that the main empirical results of this study are robust.

5. Discussion

This study explores the impact of SCC on corporate R&D investment. We discuss our main findings in the following sections.

Although SCC is regarded as an important structural feature in SC relationship and is widely focused on its impacts on various aspects of a company, there is limited research on the relationship between SCC and corporate R&D behavior after reviewing previous studies. We reveal the negative impact of SCC on corporate R&D investment from the RDT perspective. This result is due to an increase in bargaining power of suppliers and customers, which reduces profitability and risk-taking capacity of focal companies (Cao *et al.*, 2021; Gu *et al.*, 2022), thus investing less in R&D activities. Additionally, companies with high SCC tend to focus more on these key partners, which limits companies' search breadth and access to resources and information (Zhong *et al.*, 2021), thus reducing new product development. These findings echo the view that concentration implies high dependence of focal company on its SC, which fosters investment of the focal company (Hui, 2023).

In addition, we further examine whether contingent factors (industry concentration and financing constraints) could affect the impact of SCC. Our study finds that industry concentration weakens the negative impact of SCC on corporate R&D investment. Uneven industry markets generate more complex dependence relationship (Cheng and Nault, 2012).

	Model 10 R&D	Model 11 R&D	Model 12 R&D
Lev	−0.001 (−0.62)	0.000 (−0.47)	−0.001 (−0.55)
Size	−0.005*** (−14.08)	−0.005*** (−14.06)	−0.005*** (−13.30)
Age	−0.0004 (−0.25)	−0.0004 (−0.26)	−0.0004 (−0.25)
Growth	−0.0002 (−0.55)	−0.0001 (−0.45)	−0.0003 (−0.74)
ROE	0.007** (2.41)	0.007** (2.35)	0.006** (2.32)
Board	0.003*** (3.13)	0.003*** (3.11)	0.003*** (3.12)
Indep	−0.003 (−0.83)	−0.003 (−0.85)	−0.003 (−0.86)
Dual	0.001* (1.72)	0.001* (1.67)	0.001* (1.70)
Balance	0.001** (2.29)	0.001** (2.36)	0.001** (2.26)
SOE	0.001 (1.01)	0.001 (0.99)	0.001 (1.00)
IMR	0.007*** (3.15)	0.007*** (3.08)	0.007*** (3.12)
SCC	−0.010*** (−4.15)	−0.015*** (−4.15)	−0.079** (−2.53)
HHI		0.007 (1.63)	
SCC × HHI		0.061* (1.83)	
WW			0.001 (0.37)
SCC × WW			−0.070** (−2.21)
_cons	0.123*** (12.60)	0.122*** (12.51)	0.127*** (12.77)
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
N	11,803	11,803	11,803
R^2	0.103	0.104	0.103

Notes: *t*-statistics are reported in parentheses. The coefficients with *, ** and ***represent significance at 10, 5 and 1% levels, respectively
Source: Table created by authors

Table 8. Results of the two-stage Heckman method

Industry concentration reflects the intensity of competition within an industry (Ali *et al.*, 2009). Companies operating in low industry concentration environment face greater power from suppliers and customers as well as greater operational risk because of larger numbers of competitors in a limited market, leading them to prefer conservative investment strategies. In contrast, high industry concentration implies that the focal company has a degree of dominance. Thus, when companies with high SCC operate in a more concentrated industry market, their disadvantage in reducing R&D investment is weakened. We indirectly confirm the view that companies in more concentrated industries are less risky and thus tend to innovate (Gallagher *et al.*, 2015). In addition, as R&D investment requires significant financial support, financing environment may have a contingent effect. Our study finds that financing constraints strengthen the negative effect of SCC on corporate R&D investment. This is because increased financing constraints further limit available funds for companies. At this point, companies may prioritize maintaining normal SC operations while further reducing R&D investment. Our study thus complements the previous view that financing constraints are detrimental to corporate R&D investment.

6. Conclusions

Based on Chinese listed companies, we empirically investigate the impact of SCC on corporate R&D investment and further determine boundary conditions of this impact. Guided by the RDT, we find the negative of SCC on R&D investment. Besides, industry concentration mitigates the impact, but financing constraints strengthen it.

Variable	Unmatched Matched	Mean Treated	Mean Control	%reduc %bias	*t*-test *t*	*p* > t
Lev	U	0.387	0.405	−9.1	−4.97	0.000
	M	0.387	0.388	−0.6	−0.33	0.740
Size	U	21.825	22.121	−27	−14.78	0.000
	M	21.826	21.815	1.1	0.61	0.544
Age	U	2.797	2.807	−3	−1.62	0.105
	M	2.797	2.797	0	0.02	0.986
Growth	U	0.195	0.172	5.8	3.18	0.001
	M	0.194	0.202	−2.1	−1.05	0.295
ROE	U	0.052	0.066	−11.2	−6.1	0.000
	M	0.052	0.050	1.2	0.59	0.554
Board	U	2.098	2.122	−12.7	−6.96	0.000
	M	2.098	2.093	2.7	1.4	0.162
Indep	U	0.376	0.375	2.5	1.36	0.173
	M	0.376	0.377	−1.2	−0.64	0.522
Dual	U	0.330	0.308	4.7	2.57	0.010
	M	0.330	0.337	−1.4	−0.77	0.439
Balance	U	0.787	0.808	−3.4	−1.85	0.064
	M	0.787	0.788	−0.1	−0.08	0.935
SOE	U	0.229	0.230	−0.1	−0.08	0.936
	M	0.229	0.224	1	0.56	0.574

Source: Table created by authors

Table 9.
Equilibrium test results

Variable	Model 13 R&D	Model 14 R&D	Model 15 R&D
Lev	0.0003 (0.31)	0.0005 (0.47)	0.0004 (0.39)
Size	−0.004*** (−17.12)	−0.004*** (−17.14)	−0.005*** (−14.81)
Age	0.001 (0.39)	0.001 (0.39)	0.001 (0.39)
Growth	0.001** (2.16)	0.001** (2.24)	0.0004 (1.49)
ROE	−0.001 (−1.64)	−0.001 (−1.60)	−0.001* (−1.75)
Board	0.003*** (2.75)	0.003*** (2.71)	0.003*** (2.74)
Indep	−0.002 (−0.51)	−0.002 (−0.55)	−0.002 (−0.54)
Dual	0.0002 (0.69)	0.0002 (0.66)	0.0002 (0.67)
Balance	0.001** (2.42)	0.001** (2.49)	0.001** (2.40)
SOE	0.001 (0.77)	0.001 (0.75)	0.001 (0.77)
SCC	−0.008*** (−3.43)	−0.015*** (−4.03)	−0.071** (−2.28)
HHI		0.006 (1.54)	
SCC × HHI		0.076** (2.31)	
WW			0.001 (0.15)
SCC × WW			−0.063** (−2.02)
_cons	0.102*** (9.95)	0.103*** (10.01)	0.106*** (10.15)
Year	Yes	Yes	Yes
Industry	Yes	Yes	Yes
N	11,929	11,929	11,929
R^2	0.101	0.102	0.101

Notes: *t*-statistics are reported in parentheses. The coefficients with *, ** and ***represent significance at 10, 5 and 1% levels, respectively
Source: Table created by authors

Table 10.
Results of PSM test

Our study contributes to the literature in several ways. First, it contributes to the R&D literature by focusing on SC relationship structure. For example, Huang *et al.* (2022) explained the impact of SC structure on R&D investment in terms of both network power and network cohesion. Although they do not consider the linkage strength factor, they emphasize the necessity to explore the impact of SC relationship on R&D investment from the structural embeddedness perspective. As previous studies have argued that resource dependence leads to power imbalance problems, we demonstrate that firms with high SCC are reluctant to invest in R&D activities for some reasons (e.g. low bargaining power). We complement previous research from SC structural feature. Second, we add to the SC literature by emphasizing the impact of overall SCC on firms' behavior. Previous research on SCC focused on one side of SC relationship. For example, a concentrated customer base affects firms' financial position and performance (Han *et al.*, 2023; Xin *et al.*, 2022). However, suppliers and customers together form a complete SC relationship for midstream organizations (Hui, 2023), so it is necessary for firms to consider both supply and demand side factors. In view of this, we focus on the overall concentration of both upstream and downstream components, which allows for a comprehensive measure of all instances of a firm's SC concentration. Third, we also consider the moderating roles of industry concentration and financing constraints in the relationship between SCC and R&D investment. Although exploring the consequences of SCC extends the research scope of RDT, considering environmental factors could more systematically understand the consequences of SC linkage strength. We introduce industry concentration because industry environment may affect discourse and dependence (Fu, 2023; Han *et al.*, 2023). In addition, financing constraints are taken into account as external financing situation affects funding constraints of firms (Calabrese *et al.*, 2023). We reveal that industry concentration (financing constraints) may weaken (strengthen) the impact of SCC concentration on R&D investment. These results suggest that SC dependence's consequences need to be considered in a broader context.

Our findings provide the following management insights for companies. R&D is critical for companies to grow and compete. With deeper specialization and division of labor, many firms' SCC is increasing. However, our main result finds that SCC leads firms to reduce their R&D investment. In light of this, firms should strengthen SC management. On the one hand, firms should raise awareness of SC risks, be alert to SC and capital chain breaks that may be caused by a high degree of SCC and prevent asymmetric dependence from becoming passive. On the other hand, firms should strive to enhance their voice and improve the autonomy and flexibility of SC. For example, firms can strengthen coordination and mutual trust between upstream and downstream partners and adjust dependency structure by forming equal, interdependent and risk-sharing R&D alliances to enhance core competitiveness. In addition, firms can also seek diversified SC partners and build a stable and reliable SC system to reduce dependence on a few partners. Second, from the perspective of organizational–environmental coupling, firms need to weigh the level of SCC in relation to environment and own situation. Specifically, for firms in concentrated industries, they should emphasize advantages of market position to balance disadvantages of SCC. And firms with financing constraints should shape broader SC network relationships to avoid double binds.

Like any other research, this study has some limitations. First, our findings are based on Chinese-listed companies. Whether the results can be extended to Chinese small- and medium-sized enterprises or companies in other countries deserves a future investigation. Moreover, beyond our focus on the boundary effects of industry concentration and financing constraints, future research could further explore situational factors that may affect the impact of SCC on corporate R&D behavior. Finally, our research methodology is singular. Specifically, due to limitations on research length, we only briefly clarify with cases. Future research could combine qualitative and quantitative methods to enhance the comprehensiveness and credibility of main findings.

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