

Supply Chain Shareholding and Firm Innovation: Knowledge Spillover or Technology Lock-in?

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Abstract. Supply chain shareholding has the dual attributes of commercial contracts and capital ties. It may generate "knowledge spillover" through resource synergy, or lead to "technology lock-in" due to excessive binding. This paper selects China's A-share listed companies from 2009 to 2023 as samples to empirically examine the impact of supply chain shareholding on firm innovation and its mechanism. The study shows that supply chain shareholding has a significant inhibitory effect on firm innovation, and this conclusion remains valid after multiple robustness tests. Mechanism analysis results indicate that supply chain shareholding inhibits innovation through two paths: first, it increases supply chain concentration and aggravates information homogenization, forming an information redundancy effect; second, it strengthens asset specificity and deepens path dependence, forming a technology lock-in effect. Further analysis finds that this inhibitory effect is more significant in contexts with weak market competition, low supply chain transparency, high-tech enterprises, low institutional shareholding, weak supply chain discourse power, and low operational efficiency. This paper expands supply chain governance research from transaction contracts to capital connection, providing empirical evidence for enterprises to optimize supply chain equity layout and for regulatory authorities to improve supply chain governance.

Keywords: Supply Chain Shareholding, Firm Innovation, Information Redundancy, Technology Lock-in, Supply Chain Governance

1. Introduction

Against the background of the new round of scientific and technological revolution and industrial transformation, firm innovation is not only an important source for micro entities to gain competitive advantages, but also the core driving force for the macro economy to achieve high-quality development and build a new development pattern. In the strategic process of moving from "Made in China" to "Created in China", both the 14th Five-Year Plan and the report to the 20th National Congress of the Communist Party of China emphasize that we should strengthen the dominant position of enterprises in innovation and enhance the resilience and security of industrial and supply chains. As a carrier of resource allocation, knowledge flow and collaborative division of labor, the supply chain governance structure profoundly affects enterprises' technological breakthrough capability and collaborative innovation performance. Existing studies have discussed

the influencing factors of firm innovation, and gradually expanded from internal corporate governance to external organizational relationship networks [1]. However, most existing literature regards the supply chain as an organizational network formed based on commercial contracts or trust mechanisms [2], ignoring the increasingly deepened capital ties behind it.

In recent years, the phenomenon of "supply chain shareholding", formed by core enterprises through cross-shareholding or one-way equity participation in upstream and downstream enterprises, has become increasingly common. Such deep-level equity ties not only reshape the pattern of interest distribution among enterprises, but may also profoundly affect cross-organizational technological exploration and innovation decisions. This raises a key question with rich theoretical and practical value: does supply chain shareholding promote or inhibit firm innovation? Theoretically, supply chain shareholding has obvious dual effects: on the one hand, it helps reduce transaction costs and promote knowledge spillover; on the other hand, it may trigger network rigidity and form technology lock-in [3, 4]. Therefore, expanding the research perspective from loose commercial transaction relationships to tight equity networks and systematically identifying the causal effect of supply chain shareholding on firm innovation and its mechanism are of great significance for revealing the innovation consequences of capitalized supply chain governance.

In view of this, this paper takes China's Shanghai and Shenzhen A-share listed companies as samples and uses the OLS model to test the impact of supply chain shareholding on firm innovation and its micro mechanism. The results show that supply chain shareholding inhibits firm innovation by intensifying information redundancy through improving supply chain concentration on the one hand, and forming technology lock-in through strengthening asset specificity on the other hand. Further heterogeneity analysis finds that this inhibitory effect is more significant in samples with low market competition, insufficient supply chain transparency, high-tech enterprises, low institutional shareholding ratio, weak supply chain discourse power, and low supply chain efficiency.

The contributions of this paper based on existing research include: First, the research on supply chain governance is expanded from traditional commercial contracts and concentration characteristics to the dimension of capital ties. Taking "knowledge spillover or technology lock-in" as the theoretical framework, it reveals the possible negative backlash effect of equity binding in innovation networks [5]. Second, a dual mechanism test framework is introduced to accurately verify the inhibitory paths of "technology lock-in" and "information redundancy", providing micro empirical evidence from emerging capital markets for understanding the theory of "internal network rigidity". Third, the research conclusions suggest that regulatory authorities and enterprise managers should prudently evaluate the supply chain equity penetration strategy, build an open heterogeneous resource introduction mechanism while maintaining moderate capital ties, and provide reference for building a flexible modern industrial system.

2. Research hypotheses

As a deep cross-organizational network structure, the economic consequences of supply chain shareholding theoretically have two distinct explanations: "collaborative empowerment" and "network rigidity". This divergence stems from the dual attributes of equity ties as both "resource interaction pipelines" and "organizational boundary barriers" [6, 7]. Combined with China's institutional background and industrial chain characteristics, this paper systematically sorts out the internal logic of supply chain shareholding affecting firm innovation and proposes opposing hypotheses.

2.1. Theoretical logic of supply chain shareholding promoting firm innovation

From the perspective of collaborative governance and resource integration, supply chain shareholding can significantly reduce market frictions and provide resource endowments and governance support for firm innovation.

First, innovation activities are usually accompanied by high uncertainty, long cycles and high sunk costs, which make enterprises face severe external constraints in financing. Supply chain shareholding binds upstream and downstream enterprises into a community of interests through property rights ties, plays the role of "resource reservoir" and "credit endorsement", reduces market transaction uncertainty, and enables management to have sufficient risk tolerance for long-term R&D investment. Studies by Dai Chuanye and Fan Linlin [8] confirm that supply chain equity ties significantly improve the technological specialization innovation capability of specialized, refined, differential and innovative enterprises.

Second, the knowledge spillover effect. In traditional market transactions, incomplete contracts and asset specificity are likely to induce the "hold-up" risk, resulting in low efficiency of collaborative innovation [9]. Supply chain shareholding builds a long-term oriented trust mechanism and benefit-sharing contract, effectively restrains opportunistic behavior, promotes cross-border flow and cross-validation of tacit knowledge, and thus improves innovation output [10]. Studies by Yuan Tianrong and Zhou Siyang [2] also show that supply chain common equity effectively promotes firm innovation activities.

Third, the myopia correction effect. As strategic investors with industrial background, core enterprises have richer information advantages and industry expertise than traditional financial investors, and can correct management's myopic tendency to cut R&D expenditure to cater to short-term performance, and guide them to focus on long-term value creation. Pan Yue et al. [5] found that institutional shareholding can promote corporate R&D investment through active supervision.

Based on the above logic, this paper proposes the following research hypothesis:

H1a: Under other conditions being constant, supply chain shareholding significantly improves firm innovation.

2.2. Supply chain shareholding inhibiting firm innovation

Although equity ties have collaborative advantages, in a network structure with deep capital binding, excessive organizational embeddedness may derive a serious "relationship trap" [7]. Cross-company equity binding does not resolve the core contradiction of innovation, but inhibits firms' breakthrough innovation through the dual paths of information redundancy and technology lock-in.

On the one hand, high-intensity equity ties are prone to the "information redundancy" effect. Innovation relies on diversified knowledge search and heterogeneous information recombination [1]. While strengthening ties with specific partners, tight supply chain shareholding can easily breed a closed information field in the local network, leading to highly homogenized information flow. It is difficult for managers to identify key innovation signals, and the scope of knowledge search is narrowed, eventually falling into cognitive rigidity [3].

On the other hand, deep capital binding will induce an irreversible "technology lock-in" effect. To meet the non-standard demands of core enterprises, the shareholding party needs to invest a large amount of relationship-specific assets [9]. Once investment precipitation is formed, extremely high sunk costs and switching costs force enterprises not to easily switch tracks, and can only make marginal repairs along the established path, forming a "technology lock-in" dilemma [11]. At the same time, deep resource dependence makes the shareholding party cede strategic autonomy, and

innovation incentives are severely squeezed, eventually locking in a low-level technological evolution path [4].

Based on this, this paper proposes the following hypothesis:

H1b: Under other conditions being constant, supply chain shareholding significantly inhibits firm innovation.

3. Research design

3.1. Sample selection and data sources

This paper takes China's Shanghai and Shenzhen A-share listed companies from 2009 to 2023 as samples to analyze the impact of supply chain shareholding on firm innovation. Supply chain shareholding data are manually sorted from the shareholding information of the top five customers and suppliers disclosed in the annual report, and cross-validated by Wind Financial Database and CNRDS China Research Data Service Platform; firm innovation data are from the Patent Database of the State Intellectual Property Office; financial and governance data are mainly from CSMAR Database and Wind Financial Database; industry classification is based on the CSRC Industry Classification Guidelines. Sample screening includes: ① Excluding financial and insurance listed companies; ② Excluding companies with abnormal financial status marked by ST, *ST and PT; ③ Excluding observations with missing key variable data; ④ Winsorizing all continuous variables at the 1% level before and after to exclude the impact of extreme values. Finally, unbalanced panel data containing 13,602 observations are obtained.

3.2. Variable definition

3.2.1. Explained variable: firm innovation (patent)

Referring to the studies of Bellamy et al. [12] and Wang Shilei et al. [3], this paper uses the natural logarithm of the total number of granted patents of the enterprise in the current year plus 1 to measure the level of firm innovation. Compared with patent application volume, patent grant volume can better reflect the actual output quality of firm innovation, and can avoid the interference of external factors such as patent examination cycle on innovation timeliness.

3.2.2. Core explanatory variable: supply chain shareholding (Sceo)

Referring to the studies of Hu Haifeng et al. [13] and Yuan Tianrong and Zhou Siyang [2], this paper uses the supply chain shareholding ratio Sceo as the core explanatory variable to characterize the level of supply chain shareholding of enterprises. The specific calculation method of Sceo is: calculate the sum of the shareholding ratios of shareholders belonging to the top five suppliers or customers among the top ten shareholders of each listed company in the current year.

3.2.3. Control variables

Considering other factors that may affect firm innovation, referring to the literature of Liu Xia [14], this paper selects control variables such as firm size (Size), profitability (Roa), asset-liability ratio (Lev), growth capability (Growth), listing age (Age), independent director ratio (Indep), property right nature (Owner), dual position (Dual), shareholding ratio of the largest shareholder (Top1), and operating cash flow (Cash). In addition, this paper also incorporates year fixed effect (Year) and

industry fixed effect (Industry) into the control to absorb the potential impact of macroeconomic fluctuations and industry heterogeneity on regression results. The specific description of core variables is shown in Table 1.

Table 1. Definition of core variables

Variable Name	Variable Symbol	Variable Definition
Firm Innovation	Patent	Natural logarithm of total granted patents plus 1
Supply Chain Shareholding	Sceo	Sum of shareholding ratios of supply chain enterprises among the top ten shareholders
Firm Size	Size	Natural logarithm of total assets at the end of the period
Profitability	Roa	Net profit / average balance of total assets
Asset-Liability Ratio	Lev	Total liabilities / total assets
Growth Capability	Growth	(Operating revenue at the end of the period - operating revenue at the beginning of the period) / operating revenue at the beginning of the period
Listing Age	Age	Difference between the sample year and the company's listing year + 1, taken as natural logarithm
Independent Director Ratio	Indep	Number of independent directors / number of board members
Nature of Property Right	Owner	1 for state-owned, 0 for non-state-owned
Dual Position	Dual	1 if the chairman and CEO are the same person, otherwise 0
Equity Concentration	Top1	Shareholding ratio of the largest shareholder
Operating Cash Flow	Cash	Net cash flow from operating activities / total assets

4. Empirical results and analysis

4.1. Descriptive statistics

Table 2 reports the descriptive statistics of core variables. The mean value of the explained variable firm innovation Patent_Award is 1.393, the median is 1.099, the standard deviation is 1.308, and the value range is [0, 5.826]. This indicates that there are large differences in innovation output among sample enterprises, and some enterprises have zero innovation. The mean value is greater than the median, indicating that the innovation distribution is right-skewed, and a few high-innovation enterprises raise the overall average level, which is consistent with the findings of existing literature on the innovation distribution characteristics of Chinese listed companies [12, 3]. The mean value of the explanatory variable supply chain shareholding ratio Sceo is 0.005, the median is 0.000, the standard deviation is 0.050, and the value range is [0, 0.756]. It shows that supply chain shareholding is not common in the sample, and most enterprises do not have supply chain equity ties, but a few enterprises have a shareholding ratio of 75.6%, showing strong capital tie strength and presenting a "sparse but concentrated" distribution feature [13]. The statistical results of other control variables are basically consistent with existing literature. Correlation analysis shows that supply chain shareholding is significantly negatively correlated with firm innovation, which initially

supports hypothesis H1b; multicollinearity test shows that the maximum variance inflation factor is 1.96 and the mean is 1.41, so there is no serious collinearity problem. Due to space limitations, relevant results are not listed.

Table 2. Descriptive statistics of core variables

Variable	Sample Size	Mean	Median	Standard Deviation	Minimum	Maximum
<i>Patent_Award</i>	13602	1.393	1.099	1.308	0.000	5.826
<i>Sceo</i>	13602	0.005	0.000	0.050	0.000	0.756
<i>Size</i>	13602	22.320	22.163	1.259	20.053	26.135
<i>Roa</i>	13602	0.039	0.038	0.054	-0.201	0.191
<i>Lev</i>	13602	0.428	0.423	0.193	0.061	0.861
<i>Growth</i>	13602	-0.002	0.001	0.029	-0.170	0.111
<i>Age</i>	13602	2.153	2.197	0.745	0.693	3.526
<i>Indep</i>	13602	0.376	0.364	0.054	0.143	0.800
<i>Owner</i>	13602	0.294	0.000	0.456	0.000	1.000
<i>Dual</i>	13602	0.304	0.000	0.460	0.000	1.000
<i>Top1</i>	13602	0.333	0.311	0.142	0.086	0.708
<i>Cash</i>	13602	0.046	0.045	0.071	-0.662	0.661

4.2. Benchmark regression analysis

To investigate the impact of supply chain shareholding on firm innovation, this paper uses a two-way fixed effect model for benchmark regression, and the results are shown in Table 3. Column (1) only includes the core variable *Sceo*, and its coefficient is significantly negative at the 1% level; after adding control variables in column (2), the *Sceo* coefficient is still significantly negative (at the 1% level); column (3) further controls industry and year fixed effects, and the results remain consistent. This indicates that there is a significant negative correlation between supply chain shareholding and innovation, supporting hypothesis H1b. Economically, column (3) shows that for every 1 percentage point increase in *Sceo*, innovation output decreases by about 0.58% on average. In summary, the benchmark regression verifies the inhibitory effect of supply chain shareholding on innovation.

Table 3. Benchmark regression results

Variable	(1)	(2)	(3)
	Patent	Patent	Patent
<i>Sceo</i>	-1.0303*** (-3.5125)	-0.9952*** (-3.0615)	-0.5828*** (-2.7369)
<i>Size</i>		0.5404*** (17.3546)	0.5282*** (21.7678)
<i>Roa</i>		0.0220 (0.0553)	0.1908 (0.5962)
<i>Lev</i>		-1.2074*** (-8.7633)	-0.4971*** (-4.3203)

Table 3. (continued)

Growth		-1.0109*	-0.2092
		(-1.9482)	(-0.5022)
Age		-0.0958***	-0.0191
		(-2.5806)	(-0.6174)
Indep		1.0174**	0.3541
		(2.4484)	(1.0585)
Owner		-0.0966	0.1096**
		(-1.3261)	(1.9904)
Dual		0.1452***	0.0375
		(3.3241)	(1.0287)
Top1		-0.9917***	-0.0939
		(-5.5732)	(-0.6881)
Cash		0.2053	0.2991*
		(0.9545)	(1.7642)
Constant	1.3982***	-10.0209***	-11.4388***
	(49.8393)	(-15.2494)	(-20.0865)
Year	Not controlled	Not controlled	Controlled
Industry	Not controlled	Not controlled	Controlled
Sample Size	13,602	13,602	13,602
Adjusted R ²	0.002	0.182	0.435

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

4.3. Robustness checks

To ensure the high reliability of the benchmark regression results, this paper uses a variety of methods to test its robustness.

4.3.1. Replacement of variable measurement

First, replace the explanatory variable. This paper uses whether there is supply chain shareholding Sceo as a new measurement index. This variable is a dummy variable, which takes 1 if there are upstream and downstream supply chain enterprises holding shares among the top ten shareholders of the listed company in the current year, otherwise 0. Second, replace the explained variable. This paper uses the enterprise patent grant innovation output variable Patent_Award as the substitute index of firm innovation. After replacing the variable measurement, the negative relationship between supply chain shareholding and firm innovation still holds, and the regression results are consistent with the benchmark regression.

4.3.2. Excluding special samples

First, exclude samples from the four municipalities directly under the central government. Considering that Beijing, Shanghai, Chongqing and Tianjin have high economic development levels and significant differences in policy environments, this paper excludes the above samples and re-runs the regression. The coefficient of Sceo is still significantly negative at the 1% level. Second, exclude samples with low supply chain concentration (the proportion of top five supplier purchases

or top five customer sales is lower than the median) to avoid estimation bias caused by weak supply chain relationships. At this time, the coefficient of Sceo is significantly negative at the 10% level. Third, exclude samples during the 2008-2009 global financial crisis and the 2020-2022 public health events to exclude the interference of major external shocks. The coefficient of Sceo is still significantly negative at the 1% level. In summary, the core conclusions remain robust, indicating that the inhibitory effect of supply chain shareholding on innovation is not driven by sample selection.

4.3.3. Adding city fixed effects

To exclude the possible interference of unobservable heterogeneity at the city level on the regression results, this paper further introduces city fixed effects (CityFE) on the basis of the benchmark regression model. The regression results show that the coefficient of supply chain shareholding Sceo is still significantly negative at the 1% level, which is consistent with the findings of the benchmark regression; meanwhile, the model goodness of fit (R^2) has also improved compared with the benchmark regression.

Table 4. Robustness checks

Variable	Variable Replacement	Variable Replacement	Excluding Special Samples	Excluding Special Samples	Excluding Special Samples	Adding City Fixed Effects
	(1)	(2)	(3)	(4)	(5)	(6)
Sceo	-0.2426\ (-2.39)	-0.6740* (-1.7682)	-0.5922\ * (-2.8253)	-0.3974* (-1.9200)	-0.7867\ * (-3.6194)	-0.4752\ (-2.3134)
Constant	-11.4332\ * (-20.10)	-13.8574\ * (-22.7041)	-10.5767\ * (-16.5783)	-9.8962\ * (-12.8857)	-10.7342\ * (-18.2325)	-11.8252\ * (-20.5214)
Control Variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Year	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Industry	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Sample Size	13,602	13,602	11,127	4,269	9,732	13,602
Adjusted R^2	0.435	0.528	0.422	0.390	0.434	0.491

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

4.3.4. Propensity Score Matching (PSM) test

To alleviate the endogeneity problem caused by sample self-selection bias, this paper uses the propensity score matching method, takes whether the enterprise has supply chain shareholding Sceo as the treatment variable, and takes all control variables as covariates for 1:1 nearest neighbor matching. The balance test results show that after matching, most covariates no longer have significant differences between the treatment group and the control group, and the matching quality is good. Regression analysis is re-conducted based on the matched samples. The results in column (1) of Table 5 show that the regression coefficient of supply chain shareholding is still negative at the 10% significance level, indicating that after alleviating self-selection bias, the core research conclusions remain robust.

4.3.5. Lagging the independent variable by one period

To avoid endogeneity bias caused by reverse causality (that is, low firm innovation level may in turn affect supply chain shareholding decisions), this paper lags the core explanatory variable supply chain shareholding *Sceo* by one period and re-runs the regression analysis. The regression results in column (2) of Table 5 show that the coefficient of the lagged variable is significantly negative at the 1% statistical level, which is consistent with the conclusion of the benchmark regression, indicating that the reverse causality problem does not substantially interfere with the conclusion of this paper.

4.3.6. Instrumental variable method

To alleviate the interference of endogeneity on the research conclusions, this paper takes the interaction term of topographic relief and the median of supply chain shareholding in the same province, same industry and same year as the instrumental variable, and uses the two-stage least squares method for parameter estimation. This instrumental variable meets the correlation requirement: topographic relief is related to supply chain concentration, and the median shareholding of the same industry and province reflects the overall characteristics of the regional industry, and the interaction term of the two affects enterprise shareholding decisions; it also meets the exogeneity requirement: topographic relief, as a natural geographical feature, does not directly affect firm innovation, and the industry-province median is exogenous to individual enterprises. According to the first-stage regression results, the coefficient of the instrumental variable is positive at the 1% significance level, and the Cragg-Donald Wald F statistic is higher than the critical value at the 10% level, indicating that there is no weak instrumental variable problem; the second-stage results show that the coefficient of supply chain shareholding is negative at the 10% significance level, which means that after controlling for endogeneity, the research conclusions remain robust.

Table 5. Endogeneity tests

Variable	PSM Matching	Lagged Independent Variable	Instrumental Variable Method	Instrumental Variable Method
	(1)	(2)	(3)	(4)
			First Stage	Second Stage
<i>Sceo</i>	-0.5355* (-1.6931)	-0.6550\ * (-2.7569)		-0.688* (-1.663)
IV			0.3457\ * (4.36)	
Constant	-11.1012\ * (-8.1674)	-11.6524\ * (-18.3412)	-0.0002 (-0.01)	-11.439\ * (-20.17)
Control Variables	Controlled	Controlled	Controlled	Controlled
Sample Size	472	10,232	13,602	13,602
Year	Controlled	Controlled	Controlled	Controlled
Industry	Controlled	Controlled	Controlled	Controlled
Adjusted R ²	0.588	0.435	0.225	0.435
F Value			19.05	

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

5. Mechanism effects

To explore the internal action path of supply chain shareholding's inhibitory effect on firm innovation, this paper refers to the research of Jiang Ting [15] and conducts regression analysis with supply chain concentration (SCC) and asset specificity (AS) as variables respectively.

5.1. Information redundancy effect

Since supply chain shareholding deeply binds upstream and downstream enterprises through equity ties, it prompts enterprises to concentrate procurement and sales activities on a few core partners, leading to a significant increase in supply chain concentration. Although a highly concentrated supply chain network enhances collaboration stability, it also brings the problem of information homogenization — the information frequently interacted among enterprises is mostly repetitive and low-value operational data, rather than heterogeneous cutting-edge technical information. It is difficult for managers to effectively identify innovation signals with strategic value when processing massive redundant information, which eventually narrows the scope of enterprise knowledge search and inhibits innovation vitality [3]. The regression results in column (1) of Table 6 show that the regression coefficient of supply chain shareholding on supply chain concentration SCC is significantly positive at the 1% level, indicating that supply chain shareholding significantly improves the supply chain concentration of enterprises, verifying the precondition of the information redundancy effect.

5.2. Technology lock-in effect

Since supply chain shareholding prompts the shareholding party to invest a large amount of relationship-specific assets to meet the technical standards and non-standard demands of core enterprises, once investment precipitation is formed, enterprises will face extremely high sunk costs and switching costs, dare not easily switch technology tracks, and can only make marginal repairs along the established path; at the same time, deep resource dependence makes enterprises cede strategic autonomy, innovation benefits are easily seized by core enterprises, and innovation incentives are severely squeezed, eventually falling into a low-level technological evolution path [4]. According to the regression analysis results in column (2) of Table 6, the regression coefficient of supply chain shareholding on asset specificity AS shows a significant positive relationship at the 1% statistical level, indicating that supply chain shareholding significantly improves the level of enterprise asset specificity, verifying the precondition of the technology lock-in effect.

Table 6. Mechanism tests

Variable	Information Redundancy Effect	Technology Lock-in Effect
	(1) SCC	(2) AS
Sceo	9.5057* (3.8831)	0.0631* (2.6188)
Constant	89.4905* (25.5453)	0.2866* (8.3092)
Control Variables	Controlled	Controlled
Year	Controlled	Controlled

Table 6. (continued)

Industry	Controlled	Controlled
Sample Size	13,592	13,602
Adjusted R ²	0.281	0.463

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

6. Research conclusions and implications

Supply chain shareholding is becoming a key force reshaping supply chain governance and affecting firm innovation. Based on the relevant data of A-share listed companies from 2009 to 2023, this paper systematically investigates the effect of this factor on firm innovation and its internal mechanism. The study finds that supply chain shareholding significantly inhibits firm innovation, and after a variety of robustness tests, the conclusion remains consistent, indicating that supply chain capital ties may alienate into "network rigidity" rather than an effective way of knowledge spillover. Mechanism tests reveal two paths: one is the information redundancy effect, which intensifies information homogenization by improving supply chain concentration; the other is the technology lock-in effect, which strengthens path dependence and switching costs by improving asset specificity. Heterogeneity analysis shows that the inhibitory effect is more significant in contexts with weak market competition, low supply chain transparency, high-tech enterprises, low institutional shareholding, weak discourse power and low operational efficiency, indicating that external competition, information transparency, supervision and governance, as well as own bargaining power and efficiency can effectively alleviate this effect.

Based on the above research conclusions, this paper extracts the following practical implications: Enterprises should prudently evaluate the supply chain equity penetration strategy to avoid falling into the "technology lock-in" dilemma due to excessive capital binding. Especially in high-tech and low-competition industries, they should be alert to the risk of innovation rigidity, maintain moderate capital ties while promoting supply chain collaboration, and build an open heterogeneous knowledge introduction mechanism to balance stable collaboration and innovation vitality; meanwhile, enterprises should strive to improve supply chain transparency, discourse power and operational efficiency, alleviate information redundancy and cognitive shielding by strengthening information sharing, enhance bargaining power to protect strategic autonomy and innovation benefits, so as to effectively resist the innovation inhibitory effect brought by capital ties. Government departments should actively create a good market competition environment, improve the supply chain information disclosure system, and guide institutional investors to play the role of supervision and governance. On the one hand, use anti-monopoly and competition policies to maintain moderate competition intensity to stimulate enterprise innovation momentum; on the other hand, promote the standardization and transparency of supply chain information, reduce information asymmetry among enterprises, and provide institutional guarantee for supply chain capital governance. Regulatory authorities should pay attention to the technology lock-in problem that may be caused by equity penetration in high-tech industries. While guiding enterprises to build safe and stable industrial and supply chains, they should advocate the governance concept of "moderate connection and open collaboration", prevent excessive capital embedding from eroding the innovation ecosystem, and provide micro governance reference for building a safe, efficient and flexible modern industrial system.

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