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Research on the influence of supply chain stability on the innovation ability of enterprises

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Abstract

At a time of increasingly fierce competition in the global economy, corporate innovation is regarded as a key element to gain sustainable competitive ad-vantage, and the stability of the supply chain, as an important link in corporate operations, should not be underestimated in terms of its role in promoting or constraining innovation. This paper analyzes the impact of the stability of up-stream and downstream relationships on the innovation ability of enterprises by taking 3,096 A-share listed companies in China from 2013 to 2023 as the re-search object. The findings show that the stability of both suppliers and custom-ers has a U-shaped relationship on firms' innovation capability, and that digital transformation plays a mediating role in the inverted U-shaped relationship between supply chain stability and innovation capability. In the heterogeneity test, the effect of supply chain stability on firms' innovation capability is more significant in large-scale firms and firms in capital-intensive industries. This paper concludes that enterprises should maintain a moderate degree of supply chain stability and adjust their management strategies for supply chain rela-tionships according to their own characteristics in order to effectively enhance their innovation capability.

Keywords

Supplier Stability; Customer Stability; Firm Innovativeness; U-shaped Relationships

1. Introduction

This Against the backdrop of a changing global economic environment,China is facing an increasingly complex internal and external economic situation.In order to cope with these challenges,the Chinese government attaches great importance to the development of supply chains and has elevated it to the level of national strategy.Supply chain is not only the key to enhance the global competitiveness of China's economy,but also an important force to promote innovation.For enterprises,innovation is the core driving force to enhance competitive advantage and realize high-quality development.For the country,it is an important foundation to ensure the sound operation of the economy.

Since the 18th Party Congress,China has placed science and technology innovation

at the center of its overall development,aiming to enhance its comprehensive national power by stimulating social productivity.At the Fifth Plenary Session of the 19th CPC Central Committee,the position of innovation as a strategic priority in modernization was further emphasized,highlighting the importance of independent innovation capacity in science and technology.The report of the 20th Party Congress re-emphasized the need to take innovation as the core,strengthen the Party's leadership in science and technology,improve the innovation system,consolidate scientific and technological strength,and optimize the allocation of innovation resources.

2. Theoretical background

2.1. The direct impact of supplier/client stability on enterprise innovation ability

When corporate stability in partnerships with suppliers and customers remains low,supply chain environmental uncertainty increases.To mitigate risks and protect corporate interests(Chen Wen et al.,2024),companies tend to reduce existing supplier relationships or even switch suppliers,seeking new collaborations with potential partners offering lower costs or superior product quality.As stability improves to moderate levels,cooperative relationships become stable but not deeply entrenched.suggest that enterprises may fall into innovation inertia and path dependence(Uzzi et al.,2018),remaining complacent with current models while lacking breakthrough motivation.When partnership stability reaches a high stage,enterprises and partners establish strategic coordination and resource-sharing mechanisms through long-term trust(Reba et al.,2025),creating collaborative innovation advantages and resource integration effects that significantly enhance corporate innovation capabilities.Supply chain stability(particularly customer stability)substantially boosts corporate innovation capacity(Jiang et al.,2022),whereas supply chain instability notably diminishes innovation performance.Empirical study reveals an inverted U-shaped relationship between supply chain concentration and excessive investment——When concentration exceeds a specific threshold(Sun et al.,2020),the synergistic integration effect formed with core suppliers/clients can significantly curb excessive investment behavior through optimized governance structures.

H1: Supplier/customer stability has a U-shaped relationship with enterprise innovation ability.

2.2. The influence path of supplier/customer stability on enterprise innovation ability

The widespread adoption and penetration of digital technologies are reshaping corporate innovation models and achievement types.Meanwhile(Tang Xian et al.,2024),the dual effects of digital transformation may accelerate the emergence of inflection points that enhance innovation efficiency.Implementing digital

transformation can reduce innovation costs,thereby stimulating innovation.Cultivating sustainable innovation capabilities remains a crucial strategy for China's technological self-reliance,with digital transformation potentially becoming a key driver to sustain corporate innovation.Digital transformation significantly positively impacts both exploratory and applied innovation sustainability in enterprises(Mao et al.,2023).Strong supplier relationships can substantially improve digital capabilities,likely due to support from stable supply chains,information sharing,and collaborative innovation.By reducing transaction costs and risks,supplier relationships provide a stable environment for digital transformation.Additionally,suppliers'technical expertise and knowledge support enhance corporate digital competencies.A notable"U-shaped"relationship exists between supplier concentration and digital transformation adoption(Liu et al.,2024).

H2: Digital transformation plays a positive moderating role in the U-shaped relationship between supplier/customer stability and enterprise innovation ability.

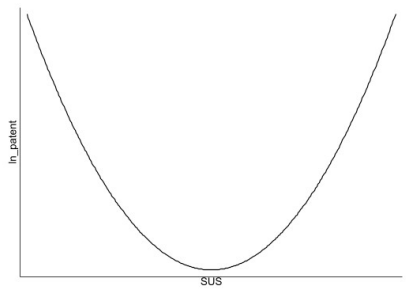

Figure 1. Relationship between enterprise innovation ability and supplier stability

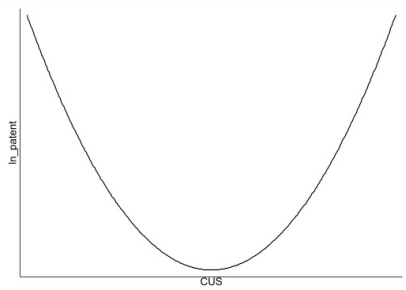

Figure 2. Relationship between enterprise innovation ability and customer stability

3. Research design

3.1. Data sources

This study selects listed companies on the Shanghai and Shenzhen A-share markets from 2013 to 2023 as research samples.After excluding those failing to disclose their top five customers,we verified whether the remaining samples'dis-

closed clients were indeed listed companies.To examine how supplier-customer interactions influence the relationship between supply chain stability and corporate innovation capabilities,and to ensure methodological validity,the sample required information for at least two major clients.Therefore,after eliminating data outliers that might distort results,we excluded cases where only one major client was a listed company.All relevant data were sourced from the CSMAR database and Wind database.

3.2. Variable selection

3.2.1. Measuring corporate innovation

The dependent variable in this study is corporate innovation capability,which existing literature predominantly measures through innovation outputs such as patent counts.Patent applications serve as a key indicator of technological innovation and R&D activities,reflecting an enterprise's innovation achievements within specific time periods.A higher number of patent applications indicates greater investment in technological innovation,which is considered a core factor in evaluating corporate competitiveness.Consistent with prior supply chain innovation studies(Li Shuangyan et al.,2023),we measure corporate innovation capability by the natural logarithm of invention patent applications filed per year.This paper quantifies corporate innovation capability using patent application numbers,with zero-patent enterprises treated by adding 1 and taking natural logarithms.In robustness tests,this study employs R&D expenditure ratio as an alternative indicator of innovation capability.

3.2.2. Measuring supply chain stability

Drawing on the research(Pan et al.,2020),the stability of customer relationships is measured by dividing the retention rate of a company's top five customers from the previous year by 5,with values ranging between 0 and 1.A higher value indicates stronger long-term cooperation between the client and the company,greater customer loyalty,and more stable business relationships.On the supply side,the"stable supplier quantity/5"metric measures supplier stability by counting the number of suppliers that appeared in the year-end list of top five suppliers from the previous year-end.

3.2.3. Measuring Control variables

Drawing on the research methodology(Wu Fei et al.,2021),we utilized Python to extract digital transformation-related terms such as big data and artificial intelligence from publicly disclosed annual reports of listed companies.Through systematic classification and statistical analysis,we constructed a text dictionary that serves as a baseline metric for evaluating corporate digital transformation progress.By analyzing the frequency of these keywords in reports,we developed a comprehensive digital transformation level indicator.

3.2.4. Control variables

The control variables in this study include: firm size (natural logarithm of total annual assets); debt-to-asset ratio (total liabilities to total assets); return on equity (ROE) (net profit to total assets); industry competition intensity (Hefenadar Index); return on invested capital (ROIC) (after-tax operating profit to investment capital); management expense growth rate (ROCE) (management expenses to main business revenue); and ownership concentration (shareholding ratio of the largest shareholder). Additionally, fixed effects for industry and year are controlled.

4. Empirical analysis

4.1. Basic model construction

In order to test the effect of supply chain relationship on enterprise innovation ability, the following benchmark model is constructed with innovation ability as the dependent variable and supplier stability and customer stability as the explanatory variables:

$$Lnpatent_{it} = \beta_1 + \beta_2 \mathrm{SUS}_{it} + \beta_3 \mathrm{SUS}_{it}^2 + \delta Controls_{it} + \sum Industry + \sum Year + \varepsilon_{it} \quad (1)$$

$$Lnpatent_{it} = \alpha_1 + \alpha_2 \mathrm{CUS}_{it} + \alpha_3 \mathrm{CUS}_{it}^2 + \delta Controls_{it} + \sum Industry + \sum Year + \varepsilon_{it} \quad (2)$$

Where, on behalf of the firm's risk-taking level, on behalf of the stability of suppliers, on behalf of the stability of customers, the article will be used in a different way to verify the robustness of the regression results; on behalf of the individual control variables, used to distinguish between different units of listed companies, used to distinguish between different units of the year is used to represent the random disturbance term. The model also controls for industry and time fixed effects. The primary focus is on the positivity, negativity and significance of the coefficients, which directly reflect the nonlinear impact of supplier stability on firms' innovation capabilities; if the coefficients are significantly positive, Hypothesis 1 is verified. In the model, if the coefficient is significantly positive, hypothesis 1 is again tested.

4.2. Intermediary effect

Since this paper assumes that there is a non-linear relationship between supplier/customer stability and enterprise innovation capability, the "three-step" mediation effect test model commonly used in linear relationship cannot be used here. At the same time, in order to avoid the inherent defects of the three-step regression method, this paper will draw on the method of Pengyi Dai et al. Based on the benchmark model, we will test the impact of X on the mechanism variable M and explore the role of M on Y. The specific steps are: first, check the relation-

ship between supplier/customer stability and corporate innovation capability. The specific steps are: first, check whether the correlation between the explanatory variables and the explained variables is significant; then, test whether the correlation between the explanatory variables and the mediator variables is significant; and finally, analyze the effect of the mediator variables on the explained variables.

$$DCG_{it} = \gamma_1 + \gamma_2 SUS_{it} + \gamma_3 SUS_{it}^2 + \delta Controls_{it} + \sum Industry + \Sigma Year + \varepsilon_{it} \quad (3)$$

$$Lnpatent_{it} = \beta_1 + \beta_2 SUS_{it} + \beta_3 SUS_{it}^2 + \beta_4 DCG_{it} + \beta_5 DCG_{it} * SUS_{it} + \delta Controls_{it} + \sum Industry + \Sigma Year + \varepsilon_{it} \quad (4)$$

$$DCG_{it} = \rho_1 + \rho_2 CUS_{it} + \rho_3 CUS_{it}^2 + \delta Controls_{it} + \sum Industry + \Sigma Year + \varepsilon_{it} \quad (5)$$

$$Lnpatent_{it} = \alpha_1 + \alpha_2 SUS_{it} + \alpha_3 SUS_{it}^2 + \alpha_4 DCG_{it} + \alpha\beta_5 DCG_{it} * SUS_{it} + \delta Controls_{it} + \sum Industry + \Sigma Year \quad (6)$$

According to the predictions of this paper, the coefficients should be significantly positive in model (3); in model (4) the coefficients should be significantly positive and the absolute value of the coefficients should be smaller than the coefficients in model (1). In the same model (5), the coefficients are significantly positive; in model (6), the coefficients are significantly positive and the absolute value of the coefficients should be smaller than the coefficients in model (2).

5. Empirical analysis

5.1. Benchmark regression analysis

Table 1 presents the results of descriptive statistics for the main study variables. The mean value of supplier stability is 0.764, indicating that the supplier stability of the sample enterprises is generally high. The standard deviation is 0.381, indicating that there are moderate differences in supplier stability among enterprises. The mean value of customer stability is 0.773, indicating that customer stability is slightly higher than supplier stability overall. The standard deviation is 0.379, which is comparable to supplier stability, indicating that there are also large differences in customer stability between firms. This study also tested for multicollinearity in the data. The results show that the maximum variance inflation factor for each variable is 2.78 and the overall mean is 1.40, indicating that the model does not have a significant multicollinearity problem.

Table 1. Descriptive statistics

Variable	Sample	Mean	Std. Dev.	Min	Max
Lnpatent	10176	3.253	1.628	0	7.358

Variable	Sample	Mean	Std. Dev.	Min	Max
Lnpatent	10176	3.253	1.628	0	7.358
SUS	10176	0.764	0.381	0	1
CUS	10176	0.773	0.379	0	1
DCG	10176	1.627	1.403	0	5.142
ROE	10176	-0.035	2.891	-186.557	64.056
Lev	10176	0.432	0.197	0.074	0.953
Glfyr	10176	0.148	2.35	-.829	226.828
TOP1	10176	31.661	14.09	1.844	87.705
HHI	10176	0.192	0.16	0.041	0.917
ROIC	10176	0.041	0.103	-0.534	0.274

5.2. Benchmark regression analysis

Table 2 presents the effect of supplier/customer stability on firms' innovation capabilities. The quadratic term of supplier stability is significantly positive at the 1% level and the coefficient of the primary term is significant at the 1% level at 0.001.The U-test in the last row is significant with a p-value of 0.0004.This suggests that there exists a significant U-shape relationship between supplier stability and firms' ability to innovate. This indicates that there is a significant U-shaped relationship between supplier stability and firms' innovation capability, i.e., as supplier stability increases, firms' innovation capability shows a tendency of decreasing first and then increasing. When supplier stability is low, too low a degree of stability may make the enterprise face problems such as supply interruption and unstable quality, thus interfering with the normal operation and innovation activities of the enterprise and restricting the growth of the enterprise's innovation capability. When supplier stability reaches a certain level, the enterprise can obtain a stable supply of raw materials, technical support and opportunities for collaborative innovation,

which helps the enterprise to invest more resources in R&D and innovation, thus promoting the enhancement of the enterprise's innovation capability. The quadratic term of customer stability is significantly positive at the 1% level, and the coefficient of the primary term is significantly negative, and the U-shaped test result in the last row is significant, with a p-value of 0.00008. This indicates that there also exists a significant U-shaped relationship between customer stability and enterprise innovation ability. Hypothesis 1 is verified.

Table 2. Baseline regression results.

	(1)	(2)	(3)	(4)
Variable	Lnpatent	Lnpatent	Lnpatent	Lnpatent
SUS	0.27***	-0.69***		
	(7.12)	(-3.34)		
SUS_2		0.91***		
		(4.73)		
CUS			0.27***	-0.80***
			(6.99)	(-3.76)
CUS_2				1.02***
				(5.09)
Constant	3.05***	3.12***	3.05***	3.12***
	(95.09)	(88.52)	(93.85)	(88.11)
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
R-squared	0.259	0.261	0.259	0.261
Utest_P value	-	0.000416	-	0.000084

Note: Parentheses indicate the robustness of standard errors of the coefficients; the symbols ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively;Utest_P values report p-values for U-test results.

5.3. Intermediary effect

In order to explore the influence mechanism of supply chain stability on enterprise innovation capability, this paper, based on model (3) to model (6), examines the mediating effect of digital transformation in which exists, and the results are shown in Table 3. There is a U-shaped relationship between supply chain stability and digital transformation, and when digital transformation is added to the base regression model, the degree of digital transformation is significantly and positively correlated with the enterprise's innovation capacity at the 1% level, with a coefficient of 0.213, and the coefficient of the quadratic term of supplier stability is 0.781, which is significant at the 1% level, with an absolute value smaller than the absolute value of the quadratic coefficient of the supplier stability of the baseline regression, which indicates that Supplier stability affects the enterprise's innovation capability by influencing the degree of digital transfor-

mation of the enterprise. From the client side, it can be seen that there is a U-shaped relationship between customer stability and the degree of digital transformation. After adding digital transformation to the baseline regression, the degree of digital transformation is significantly and positively related to the innovation capability of the enterprise at the 1% level, with a coefficient of 0.201, and the coefficient of the quadratic term of client stability is 0.890, which is significant at the 1% level, and the absolute value is smaller than the absolute value of the coefficient of the quadratic term of client stability in the baseline regression.

Table 3. Intermediary effect

	SUS			CUS		
Variable	Lnpatent	DCG	Lnpatent	Lnpatent	DCG	Lnpatent
SUS	-0.69***	-0.44***	-0.68***			
	(-3.29)	(-2.74)	(-3.23)			
SUS_2	0.91***	0.53***	0.78***			
	(4.68)	(3.57)	(4.08)			
DCG			0.21***			0.20***
			(8.80)			(8.18)
CUS			0.06**			
			(2.34)			
CUS_2				-0.80***	-0.43***	-0.81***
				(-3.68)	(-2.60)	(-3.74)
Constant				1.02***	0.52***	0.89***
				(5.02)	(3.36)	(4.47)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.259	0.413	0.289	0.259	0.413	0.289

Note: Parentheses indicate the robustness of standard errors of the coefficients; the symbols ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

5.4. Robustness tests

5.4.1. lagged one-period test

Reverse causation is a common endogeneity problem. To alleviate this problem, first, the explanatory variables are lagged by one period, and the reliability of the effect of supply chain stability on firms' innovation capability is verified by replacing the explanatory variables and introducing explanatory variables lagged by one period. Specifically, firstly, the logarithmic value of the firm's innovation capability (Lnpatent) is taken as an explanatory variable, and it is found that the lagged one-period of both the supplier stability (SUS) and its squared term (SUS_2) exhibit a significant U-shape relationship, and the lagged one-period of the customer stability (CUS) also exhibits a significant negative effect. Further,

replacing the explanatory variable with R&D investment share (R&D) shows that supplier stability (SUS) still has a significant negative effect on R&D investment, and the significance of its squared term (SUS_2) further corroborates the existence of a U-shaped relationship, and even though the direct effect of customer stability (CUS) is no longer significant, its squared term (CUS_2) exhibits at the 5% level of significance. Overall, the U-shaped association between supply chain stability and firms' innovation capability is supported by robustness tests regardless of the indicators used to measure firms' innovation capability, highlighting the key role of maintaining moderate supply chain stability in stimulating firms' innovation dynamics.

5.4.2. Replacement of Core Variables

In this paper, the level of R&D is used as a proxy variable for the robustness test (Gu et al.,2018), the ratio of corporate R&D expenditures to operating revenues as a measure of the innovative capacity of the enterprise. The results of columns (3) and (4) in Table 7 remain significant.

5.4.3. Instrumental variable method

The endogeneity problem caused by possible omitted variables has an impact on the supply chain stability as well as the firm's innovation capability. Yu Guansheng et al. (2024) use the mean value of supply chain resilience of the industry and province where the enterprise is located as an instrumental variable, which is reasonable because the mean value is not directly related to the innovation capability of the enterprise, which fulfills the requirement of exogeneity, and at the same time is affected by the common factors of the industry and the province, which is correlated with the stability of the enterprise's supply chain.

Table 4. Robustness tests

	(1)	(2)		(3)	(4)		(5)	(6)
Variable	**Lnpaten**	**Lnpatent**		**R&D**	**R&D**		**Lnpatent**	**Lnpatent**
L.SUS	-0.67***		SUS	-0.04***		SUS	-1.19***	
	(-3.70)			(-3.57)			(-5.88)	
L.SUS_2	0.77***		SUS_2	0.04***		SUS_2	1.28***	

	(1)	(2)		(3)	(4)		(5)	(6)
Variable	**Lnpaten**	**Lnpatent**		**R&D**	**R&D**		**Lnpatent**	**Lnpatent**
	(4.60)			(4.06)			(6.83)	
L.CUS		-1.02***	CUS		-0.02	CUS		-1.34***
		(-5.44)			(-1.64)			(-6.31)
L.CUS_2		1.13***	CUS_2		0.02**	CUS_2		1.43***
		(6.43)			(2.25)			(7.16)
Constant	-114.20***	-112.27***	cons	-1.28	-1.42	cons	0.310	0.310
	(-3.15)	(-3.10)		(-0.64)	(-0.71)	F	533.3	533.8
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.510	0.511	R2	0.178	0.177	R2	0.315	0.315

Note: Parentheses indicate the robustness of standard errors of the coefficients; the symbols ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

5.4.4. Propensity score matching

The research process in this paper may suffer from selection bias, and in order to mitigate this endogeneity problem, this paper uses the propensity score matching

method to conduct the test. Referring to Qin et al.(2020) , customer concentration and supplier concentration are generated as dummy variables in accordance with their respective annual averages, the sample companies greater than or equal to the average are taken as the experimental group (high supply chain concentration group), and the rest of the sample companies are taken as the control group (low supply chain concentration group), and then the dummy variables are regressed with all control variables in the regression model to conduct a Logistics regression to obtain the propensity scores, and finally the 1-to-1 nearest-neighbor matching method with put-back is adopted for matching, and the regression is re-run again using the successfully matched samples, consistent with the previous results.

5.5. Heterogeneous analysis

The impact of supply chain stability on firms' innovation capability is influenced by firm size, nature and resource intensity.

5.5.1. Firm size and nature

Firm size heterogeneity is shown in columns (1)~(4) of Table 8, the supplier stability (SUS) of large firms shows a significant U-shaped effect (primary term -0.78, secondary term 0.987), the increase in stability inhibits innovation in the initial stage, and then turns into a facilitator after crossing the threshold, and the customer stability (CUS) also shows a U-shape, whereas the effect of Small and medium enterprises' supplier concentration is insignificant (SUS coefficient -1.055, p>0.1), innovation is insensitive to changes in supply chain structure, and there is also no significant effect of customer stability. 1.055, p>0.1), innovation is not sensitive to changes in supply chain structure, and customer stability also has no significant effect; ownership heterogeneity is shown in Table 9 columns (5)~(8), the U-shaped curve of supply chain concentration of state-owned enterprises is stronger (primary term-0.795, secondary term 0.986), the mechanism of innovation by the supply chain reconstruction has a significant impact, and the concentration of customers triggers the depth of adjustment, and the innovation performance of non-state-owned enterprises to the changes in supply chain concentration has a significant impact on innovation. The innovation performance of non-state-owned enterprises is rigid to the change of supply chain concentration (SUS coefficient - 0.410, p>0.1), and only weakly positive linear relationship to customer concentration; the regulation implication is that large-scale enterprises and state-owned enterprises need to be vigilant against the initial innovation inhibition of supply chain over-concentration, and cross the U-shape inflection point by optimizing the supplier portfolio, while small and medium-sized enterprises can maintain the flexibility of the supply chain, and need to cultivate the ability of customer relationship management to release their innovation poten-

tials. Small and medium enterprises can maintain supply chain flexibility, and non-state-owned enterprises need to cultivate customer relationship management capability to release innovation potential.

5.5.2. Resource Intensity

As shown in column 9 of Table 9, supplier and customer stability significantly enhance the innovation capability of technology-intensive firms, but the effect on labor-intensive and capital-intensive firms is not significant. The reason for this is that this is mainly due to the fact that these types of firms focus on R&D and technological innovation, and a stable supply chain effectively reduces the uncertainty in the innovation process, reduces R&D costs, and accelerates the transformation of scientific research results into actual products, which in turn significantly promotes the enhancement of the firm's innovation capability. On the contrary, in capital-intensive and labor-intensive enterprises, the impact of supplier stability on innovation capability is not obvious. This is because capital-intensive enterprises pay more attention to large-scale capital investment and capital operation efficiency, while labor-intensive enterprises rely more on human resources allocation and management optimization. These enterprises mainly enhance their competitiveness by expanding production scale or improving labor efficiency, and the improvement of supply chain stability has a relatively small impact on their innovation ability.

Table 6. Heterogeneous analysis

	industry							
	major	small and medium	major	small and medium	**state**	non-state	**state**	non-state
Variable	**Lnpatent**	**Lnpatent**	**Lnpatent**	**Lnpatent**	**Lnpatent**	**Lnpatent**	**Lnpatent**	**Lnpatent**
SUS	-0.761***	-1.055			-0.795**	-0.410		
	(-3.862)	(-0.387)			(-2.566)	(-0.362)		

	industry							
	major	small and medium	major	small and medium	**state**	non-state	**state**	non-state
SUS_2	0.967***	0.361			0.986***	0.916		
	(5.258)	(0.136)			(3.453)	(0.858)		
CUS			-0.894***	2.348			-1.154***	0.284
			(-4.378)	(1.155)			(-3.672)	(0.249)
CUS_2			1.081***	-2.953			1.309***	0.220
			(5.652)	(-1.500)			(4.500)	(0.204)
Con-stant	67.436*	18.114	66.632*	37.071	153.018**	505.690**	157.788***	486.558**
	(1.724)	(0.041)	(1.704)	(0.085)	(2.225)	(2.201)	(2.295)	(2.097)

	industry							
	major	small and medium	major	small and medium	**state**	non-state	**state**	non-state
Observations	10054	112	10054	112	3317	306	3317	306
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.319	0.372	0.319	0.382	0.380	0.500	0.381	0.497

Note: Parentheses indicate the robustness of standard errors of the coefficients; the symbols ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 7. Analysis of resource intensity heterogeneity

	Intensive					
	Technology	Labor	Capital	Technology	Labor	Capital
Variable	Lnpatent	Lnpatent	Lnpatent	Lnpatent	Lnpatent	Lnpatent
SUS	-1.318**	-0.499	-0.544			
	(-2.387)	(-0.441)	(-0.745)			
SUS_2	1.487***	0.543	0.846			
	(2.672)	(0.483)	(1.146)			
CUS				-1.239**	-0.503	-0.789
				(-2.371)	(-0.382)	(-1.043)
CUS_2				1.458***	0.479	0.867
				(2.812)	(0.362)	(1.170)
Constant	128.999	-747.386***	274.261	131.629	-750.769***	216.813
	(1.005)	(-2.874)	(0.904)	(1.025)	(-2.856)	(0.703)

	Intensive					
	Technology	Labor	Capital	Technology	Labor	Capital
Variable	Lnpatent	Lnpatent	Lnpatent	Lnpatent	Lnpatent	Lnpatent
Observations	4257	1082	1381	4257	1082	1381
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.312	0.226	0.264	0.312	0.225	0.258

Note: Parentheses indicate the robustness of standard errors of the coefficients; the symbols ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

6. Research findings and policy recommendations

6.1. Conclusion

The main findings of this paper are as follows:(1) There is a significant U-shaped relationship between supplier and customer stability and enterprise innovation capability, i.e., with the improvement of supply chain stability, the enterprise innovation capability shows a trend of decreasing and then increasing, which means that moderate supply chain stability may have an inhibitory effect on enterprise innovation, whereas too much or too little stability contributes to innovation (2) Digital transformation plays a mediating effect in the supply chain stability plays a mediating effect in the influence of enterprise innovation ability level, indicating that digital transformation can effectively conduct the influence of supply chain stability on innovation ability and promote the improvement of enterprise innovation level. (3) The heterogeneity test shows that the positive effect of supply chain stability on enterprise innovation ability is more significant in state-owned enterprises and large-scale enterprises.

From their own perspective, enterprises should systematically optimize supply chain partnerships to effectively prevent financial risks and enhance the resilience of the industry chain. In terms of supply chain management, enterprises need to seek moderate stability, avoid excessive pursuit of solid structure, stimulate innovation vitality by maintaining reasonable liquidity, and regularly evaluate and adjust supply chain strategies to enhance flexibility; at the same time, they should actively promote the diversification of suppliers and customer groups, and reduce the dependence on a single node, so as to reduce the risk of chain breakage and expand innovation resources. Digital transformation is the key support, should strengthen the construction of digital infrastructure such as cloud computing, Internet of Things and artificial intelligence, improve data processing and intelligent analysis capabilities, and focus on the introduction of digital talent, build data-driven decision-making mechanism, in order to achieve real-time monitoring and dynamic optimization of the supply chain. For state-owned and large-scale enterprises, they should rely on policy support such

as R&D subsidies, tax incentives and special funds, and take advantage of their resources and scale to promote innovation, as well as deepen cooperation and innovation with universities, research institutes and other entities to promote the transformation of achievements. The government needs to strengthen guidance, formulate industrial policies for industry chain stability and innovation, provide digital transformation subsidies and innovation incentives, and enhance the supply chain management and digital application capabilities of enterprises through training conducted by industry associations to jointly build a supply chain ecosystem of continuous innovation and risk control.

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