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How does supply chain transparency affect firm innovation?

-- An empirical study based on panel data of listed companies in China

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Abstract: The supply chain is an important perspective to understand the company's business mode and strategic decision-making. It is of great significance to study how supply chain information disclosure affects innovation. Based on the panel data of A-share listed companies in Shanghai and Shenzhen, this paper empirically examines the influence of supply chain transparency on enterprise innovation level. It is found that supply chain transparency significantly reduces the innovation performance of enterprises. This conclusion still exists under a series of robustness tests. Among them, the political correlation characteristics of enterprises and the scale of capital investment play an important role in regulating. Further analysis of the mechanism shows that the change of innovation input and its influence on the quality of internal control play an important role in mediating. The results of this paper not only enrich the research results of supply chain transparency on the economic behavior of enterprises, but also have a certain practical significance for scientific evaluation of the significant impact of supply chain transparency on the innovation ability of enterprises.

Keywords: Supply chain transparency; Enterprise innovation; Innovation input; Internal control.

1. Introduction

With the deepening of the economic globalization, the competitiveness between supply chains has gradually become a powerful synonym for the competitiveness of enterprises and even countries [1]. The report to the 19th CPC National Congress called for fostering new growth points and generating new growth drivers in areas such as modern supply chains. This shows that accelerating supply chain innovation and building a modern supply chain has become an important part of deepening supply-side structural reform and building a modernized economic system. In order to build and maintain a good supply chain relationship, enterprises increase the transparency of supply chain and realize information sharing, which gradually evolves into a "sharing weal and woe" interest alliance. However, supply chain transparency has a certain impact on enterprise management, strategic decision-making, innovation behavior and so on. It is worth thinking about how supply chain transparency affects enterprise innovation behavior.

Zhang Xing [2] proposed that strengthening the transparency of the supply chain could promote the cold chain logistics enterprises to maintain high organizational coordination in each link, and at the same time, the enterprises could grasp the overall operation of the cold chain logistics supply chain in real time, and closed the contact with the organic main body of the supply chain, thus helping to reduce the cost of its operation and energy consumption. Wang Guoli [3] et al. proposed to build a transparent system of modern agricultural supply chain, which was conducive to the realization of precise logistics of agricultural products, and could guarantee the quality and safety of agricultural products. Xie Wei [4] believed that making supply chains transparent was crucial for companies. During the epidemic, different provincial epidemic prevention policies and different operation progress of major suppliers increased the time cost of information acquisition for enterprises. Therefore, the transparency of supply chain helps enterprises improve efficiency and reduce costs. The current academic researches on this issue mostly focus on the role of supply chain transparency in improving logistics accuracy and reducing costs, but these researches do not focus on the impact of supply chain transparency on enterprise innovation.

Specifically, based on the panel data of A-share listed companies in Shanghai and Shenzhen, this paper constructs A company-level supply chain transparency index from two dimensions: the number of large suppliers and customers with specific names disclosed SCT_Num and the business proportion of large suppliers and customers with specific names disclosed SCT_Raito. The innovation level of listed companies is measured from two dimensions of input and output. The results show that the transparency of supply chain has a certainly inhibitory effect on enterprise innovation. The higher the transparency of supply chain, the lower the innovation level of the company. Further discussion shows that the political correlation characteristics of enterprises and the scale of capital input play an important role in moderating, and the change of innovation input and the influence of internal control quality play an important role in mediating. In order to ensure the robustness of the research conclusions, this paper uses a variety of methods, including the bidirectional fixed-effect model based on the panel data of listed companies, the use of variation model, the use of sample matching, the use of instrumental variables, etc., and the research conclusions remain robust. In addition, by changing the measurement methods of explained variables and core explanatory variables, using PSM means and limited dependent variable model panel Tobit for robustness test, this paper makes the causal inference more accurate.

Compared with the existing researches, the contribution of this paper mainly lies in the following three aspects: First, this paper has enriched the important literature on the influence of supply chain information disclosure on enterprise strategic decision-making. From the dimension of enterprise

innovation, it proves the importance of supply chain transparency and expands the research boundary of existing literature. Second, the conclusion of this paper also provides a new explanation for enterprise innovation activities from the perspective of supply chain transparency, which enriches the existing research on the influencing factors behind innovation activities and has important reference significance. Thirdly, the mechanism discussion in this paper is helpful to open the "black box" of the relationship between supply chain transparency and enterprise innovation, clarifying the impact of supply chain information disclosure on enterprise innovation, and also providing a useful reference for the empirical strategies of relevant literature.

The follow-up structure of this paper is arranged as follows: The second part is the review and discussion of relevant literature and the proposal of theoretical hypothesis; The third part introduces the data structure and research design of this paper. The fourth part is the basic empirical results; The fifth part further discusses the mechanism; The last part is the conclusion comment and policy implication.

2. Literature review and theoretical hypothesis

In recent years, scholars have discussed supply chain transparency in full swing. Most of them focus on how supply chain transparency can reduce enterprise operating costs, improve enterprise efficiency, improve logistics accuracy and other issues, while there is little discussion on supply chain information disclosure [5]. First of all, in terms of the characteristics of supply chain transparency, existing studies have shown that the sharing of supply chain among enterprises is conducive to reducing the cost of acquiring time for enterprises, thus promoting the maximization of benefits between enterprises. Moreover, supply chain transparency has an intrinsic impact on sales volume, sales cost, invested capital and cost of capital rate [6]. Secondly, in terms of the influence of supply chain transparency on firms' innovation behavior, many scholars have focused on the moderating effect of supply chain transparency on the innovation constraints of firms of different sizes and characteristics, and further discussed the influence on firms' innovation on this basis [7]. Finally, in terms of influencing factors, some scholars have discussed the influence on the evolution of supply chain transparency model and innovation trend under the background of the rapid development of information network technology [8]. In addition, some scholars set aside the perspective of enterprise innovation and supply chain, and studied supply chain transparency from the upstream and downstream enterprises that provide supply chain [9].

The factors that affect enterprise innovation activities and the economic impact brought by innovation activities have been the focus of scholars at home and abroad [10]. In terms of influencing factors, some scholars believe that the influence of macroeconomic factors such as macroeconomic policy, fierce degree of market competition and world economic growth [11]. The development of legal system, protection of innovation achievements, regional system differences, tax policy and cultural differences also have an impact on enterprises' innovation activities [12]. In addition, the internal factors are the most direct factors that determine whether an enterprise is innovative or not [13]. In terms of economic impact, existing literatures pay more attention to the impact of firm innovation on firm investment, firm value, resource allocation efficiency and other factors [14].

In the existing literature, some scholars have discussed the relationship between supply chain transparency and enterprise innovation. However, existing researches mainly focus on the influence of supply chain transparency on enterprise efficiency of upstream and downstream enterprises in the supply chain system [15], and no scholars have conducted researches on the relationship between supply chain transparency and enterprise innovation. Different from enterprise efficiency, innovation, as an important ability for long-term development and rapid growth of enterprises, pays more attention to the endogenous potential of enterprises and the evaluation of future development potential, focusing on the endogenous growth of enterprises [16]. However, enterprise efficiency is more focused on the evaluation of the enterprise's internal operation, which determines the external reputation, image and financing level of the enterprise [17]. Therefore, the study of supply chain transparency from the perspective of enterprise innovation is not only beneficial to enrich the research results of supply chain transparency on enterprise economic behavior, but also has certain practical significance for scientific evaluation of the effect of supply chain transparency on the improvement of enterprise innovation ability.

Based on the above analysis, this paper proposes the following hypotheses:

H1: Political relevance has a significant moderating effect: the higher the level of political relevance, the greater the negative inhibitory effect of supply chain transparency on enterprise innovation performance.

H2: Capital-technology-intensive industries have a significant moderating effect: compared with labor-intensive industries, the supply chain transparency of enterprises in capital-technology-intensive industries has a greater negative inhibitory effect on their innovation performance.

H3: There is an intermediary mechanism for enterprise innovation input: the transparency of enterprise supply chain inhibits innovation output by inhibiting innovation input.

H4: There is an intermediary effect in the level of enterprise internal control: the transparency of enterprise supply chain inhibits innovation output by reducing the quality of enterprise internal control.

3. Sample descriptive statistics and empirical model setting

3.1. Sample selection and data sources

In order to test the theoretical hypothesis proposed above and consider the availability of various enterprise indicators and sample representativeness, this paper adopts all A-share listed company panels of Shanghai and Shenzhen stock markets as the original samples. The original listed company sample data are all from the CSMAR database of Guotai 'an and are combined. The further screening process of the samples is as follows: First, because the financial statements of the financial industry are different from those of other enterprises, this paper screens the samples of the financial industry according to the CSMAR industry code, and excludes the samples of the financial industry; Secondly, the samples of ST companies during the study period are excluded. Thirdly, the samples with asset-liability ratio greater than one are excluded. Finally, in order to eliminate the influence of extreme values on empirical analysis, all continuous variables are treated with 1% winsorize.

3.2. Supply chain transparency

Referring to the research paradigm of Gong Xiaoyun et al. (2022), this paper constructs an index of supply chain transparency, which is measured from two dimensions: SCT_Num, the number of large suppliers and customers with specific names disclosed, and SCT_Raito, the business proportion of large suppliers and customers with specific names disclosed.

3.3. Measurement of enterprise innovation activities

In order to consider enterprise innovation activities more fully, this paper measures the input and output of innovation activities of listed companies respectively. Among them, the number of inventions independently applied by listed companies and the number of inventions independently obtained by listed companies are used to measure the output scale of innovation activities of listed companies. The natural logarithm of R&D investment of listed companies is used to measure the innovation investment of enterprises.

3.4. Setting of empirical models

In order to test the theoretical hypothesis proposed above, this paper will use the panel data of listed companies to build a two-way fixed effect model for empirical analysis, to study how the transparency of enterprise supply chain affects the innovation performance of enterprises. The concrete empirical model is shown in Equation (1) :

$$Innovation_{it} = \alpha_0 + \alpha_1 STC_{it} + \alpha_2 X_{it} + Year_FE + Industry_FE + \varepsilon_{it} \quad (1)$$

Where, the subscripts i and t represent the listed company and the fiscal year respectively. Core explanatory variable represents the supply chain transparency of listed company i in the year t, which is measured by two dimensions, SCT_Num of large suppliers and customers with specific names disclosed and SCT_Raito of large suppliers and customers with specific names disclosed. Is the explained variable of this paper, namely, is the natural logarithm of the innovation output of listed company i in year t and the number of patents applied by the enterprise in the same year. Therefore, it is the core parameter to be estimated. In addition, it is a series of control variables to control the financial and governance characteristics of various enterprise levels to ensure the accuracy of core parameters to be estimated. And $Year_FE\ and\ Industry_FE$ are year fixed effect and domain fixed effect, respectively. ε_{it} is the perturbation term of the model? In order to prevent the heteroscedasticity problem from affecting the reliability of empirical results, all statistical inferences in this paper are discussed based on heteroscedasticity robust standard error. To sum up, the bidirectional fixed effect model will be used in this paper to make a rigorous empirical analysis of the theoretical hypothesis proposed above.

3.5. Selection of control variables

Considering that other factors of an enterprise may also have a potentially important impact on enterprise innovation, in order to prevent the endogeneity problems caused by missing variables, this paper selects a series of enterprise characteristic indicators as control variables. Based on existing literature, control variables at the enterprise level in this paper include: Enterprise Size (Size, measured by the natural logarithm of total assets of the listed company at the end of the year), Leverage (measured by the proportion of total liabilities in total assets of the listed company at the end of the year), Age (measured by the number of years the company has been listed), business performance (ROA, Measured by the return on assets of the listed company in that year), fixed assets scale (Fix, measured by the proportion of fixed assets of the listed company in that year), Cash ratio (Cash, measured by the proportion of cash held by the listed company in that year), independence of the board of directors (Indratio, measured by the proportion of independent directors of the listed company in that year), board size (Boardsize, It is measured by the shareholding ratio of the board of directors of the listed company in the year), the concentration of ownership (Top1, measured by the shareholding ratio of the largest shareholder of the listed company in the year), and the enterprise ownership (SOE, measured by whether the listed company is a state-owned enterprise). Table 1 shows the variable types, names, and detailed definitions. Table 2 shows the descriptive statistics of each variable.

Table 1. Detailed definitions of variables

Variable type	Variable name and letter representation	Variable definition description
Explained variable	Enterprise innovation performance lnpatent_apply	log (one adds the number of all patents filed by Artemisia argyi that year)
Core explanatory variable	Supply chain transparency SCT_ Ratio	The number of large suppliers and customers with specific names disclosed by the enterprise in that year
Enterprise control variable	Enterprise size	ln (Total assets of the enterprise at the end of the year)
	Enterprise asset liability ratio Leverage	The ratio of total liabilities to total assets of the enterprise in the current year
	Enterprise age	Years of listing
	ROA	Return on assets of the enterprise in the current year
	Fixed asset size	The ratio of total fixed asset to total assets of the enterprise in the current year
	Cash ratio	Ratio of cash held by enterprises in the current year
	Board indratio	The proportion of independent directors in the current year
	Boardsize	Shares held by the board of directors of enterprises
	Enterprise ownership concentration Top1	Shareholding ratio of the largest shareholder of the enterprise in that year
	SOE	Dummy variable: If the enterprise belongs to state-owned enterprise, the value is 1; otherwise, it is 0

Table 2. Detailed descriptive statistics of each variable

	N	Mean	SD	Min	Median	Max
lnpatent apply	16146	0.312	0.822	0	0	8.406
SCT Ratio	16146	0.319	0.455	0	0	1
PCLevel	16146	1.172	1.620	0	0	4
Size	16146	22.236	1.280	19.35	22.064	26.231
Leverage	16146	0.434	0.203	0.027	0.429	0.936
Age	16146	10.122	7.045	0	10	26
ROA	16146	0.577	0.464	-0.019	0.498	2.696
Fix	16146	0.223	0.164	0.002	0.19	0.769
Cash	16146	1.077	1.867	0.04	0.549	30.123
Indratio	16146	38.955	10.280	0	37.5	66.667
Boardsize	16146	10.214	18.109	0	0.03	68.606
Top1	16146	0.365	0.152	0.082	0.35	0.758
SOE	16146	0.417	0.493	0	0	1

Finally, before the empirical regression analysis, it is necessary to discuss the correlation between the main research variables, so as to prevent the model from being unrecognizable due to the completely collinearity problem. The correlation coefficient matrix of core explanatory variables and control variables is shown in Table 3. As can be seen from the correlation coefficient matrix in Table 3, the correlation coefficient between each control variable and the core explanatory variable SCT_Ratio is not large, so there will not be the problem of collinear height, which violates Gauss-Markov assumption, and then leads to systematic bias in statistical inference in this paper.

Table 3. Correlation coefficient test

	SCT_Ratio	Size	Leverage	Age	ROA	Fix	Cash	Indratio	Boardsize	Top1	SOE
SCT_Ratio	1.00***										
Size	-0.09*	1.00***									
Leverage	0.05*	0.52*	1.00***								
Age	0.02*	0.33*	0.33*	1.00***							
ROA	0.07*	-0.05*	0.10*	-0.06*	1.00***						
Fix	0.08*	0.06*	0.03*	0.03*	0.02*	1.00***					
Cash	0.03*	-0.25*	-0.51*	-0.22*	-0.07*	-0.14*	1.00***				
Indratio	0.04*	-0.04*	-0.00	-0.06*	0.15*	-0.02*	0.05*	1.00***			
Boardsize	-0.07*	-0.29*	-0.29*	-0.52*	-0.04*	-0.12*	0.18*	0.04*	1.00***		
Top1	0.01*	0.19*	0.05*	-0.11*	0.08*	0.05*	0.02*	0.03*	-0.09*	1.00***	
SOE	0.09*	0.32*	0.28*	0.40*	0.06*	0.18*	-0.13*	-0.03*	-0.46*	0.21*	1.00***

4. Benchmark empirical results

4.1. Analysis of benchmark regression results

The benchmark regression results of empirical model (1) above are shown in Table 4. Table 4 shows the step-up regression results, and the explained variables are all the natural logarithms of the number of patents applied by listed companies in current year. Among them, column (1) does not control any fixed effects and control variables, column (2) adds year fixed effects and industry fixed effects, and column (3) adds control variables at the enterprise level. It can be seen that, under what kind of control, the estimated coefficients of SCT_Ratio of enterprise supply chain transparency of all the model's core explanatory variables are significantly negative at the statistical level of 1%. This indicates that the transparency of enterprise supply chain significantly reduces the output of enterprise innovation. To sum up, the above theories are proven.

4.2. Robustness test

In order to verify the robustness of the core results in this paper, it is necessary to conduct multi-dimensional robustness tests for detailed verification.

First, change the explained variable. Investigate the influence of supply chain transparency on the number of patents obtained by enterprises. The results are shown in Table 5, and the explained variables in Table 5 are the natural logarithm of the number of patents obtained by the listed company in the year. Column (1) did not control any fixed effects and control variables; column (2) added year fixed effects and firm fixed effects; and column (3) added control variables at the enterprise level. It can be seen that, under any kind of control, the estimated coefficients of SCT_Ratio of core explanatory variables of all models are significantly negative at the statistical level of 1%, consistent with the conclusions in Table 4. Therefore, when the number of patents obtained by an enterprise is used as a measure of innovation output, the transparency of the supply chain still significantly reduces the innovation performance of an enterprise.

Second, change the measuring of the core explanatory variable supply chain transparency. SCT_Num, the number of large suppliers and customers whose specific names were disclosed by the listed company in that year, was used as the core explanatory variable for analysis, and the results were shown in Table 6: Similarly, column (1) does not control any fixed effects and control variables, column (2) adds year fixed effects and firm fixed effects, and column (3) adds firm level control variables. It can be seen that, under what kind of control, the estimated coefficients of core explanatory variables SCT_Num of all models are -1.633, -1.386 and -0.827, respectively. The statistical level of 1% is significantly negative, which is consistent with the conclusion in Table 4. Therefore, the core conclusions of this paper are highly robust.

The third robustness test in this paper is to change the

estimation model. There may be systematic differences in the transparency of enterprise supply chain among different enterprises. Since propensity value score matching (PSM) has played an important role in reducing the correlation between processing variables and observable variables, this paper intends to use PSM to make the causal inference of this paper more accurate. In PSM matching, treat variable was used to perform Logit regression on control variables to obtain the propensity score. The control group with the closest propensity score is the paired sample of the experimental group. This method can minimize the systematic differences between the experimental group and the control group, so as to reduce the estimation bias. Therefore, before estimation, it is also necessary to test the equilibrium hypothesis of covariables, that is, whether the variables become balanced between the experimental group and the control group after matching, that is, whether the mean values of the covariables of the experimental group and the control group are significantly different after matching. If no significant differences exist, further model estimates are supported.

In the empirical analysis framework of this paper, according to Gong Xiaoyun et al. (2022), samples are divided into two groups according to whether the supply chain transparency index is higher than the sample mean. The treatment group was listed companies with high supply chain transparency index, while the control group was listed companies with low supply chain transparency index. Figure 1 shows the difference of covariates between the treatment group and the control group. It can be seen that the difference between the two types of enterprises is significantly reduced after matching, satisfying the assumption of balance.

Table 4. Results of benchmark step-up regression

Explained variable	(1) lnpatent_ apply	(2) lnpatent_ apply	(3) lnpatent_ apply
SCT_Ratio	-0.140***	-0.100***	-0.059***
	(0.013)	(0.014)	(0.013)
Size			0.213***
			(0.009)
Leverage			-0.305***
			(0.040)
Age			-0.004***
			(0.001)
ROA			0.066***
			(0.017)
Fix			-0.216***
			(0.045)
Cash			-0.014***
			(0.003)
Indratio			0.001
			(0.001)
Boardsize			0.000
			(0.000)
Top1			-0.182***
			(0.048)
SOE			0.048***
			(0.015)
Constant	0.357***	0.344***	-4.192***
	(0.009)	(0.008)	(0.193)
Industry FE	No	Yes	Yes
Year FE	No	Yes	Yes
Observations	16,146	16,146	16,146
R-squared	0.006	0.043	0.121

Note: The observed values are at the enterprise level. ***, ** and * are statistically significant at 1%, 5% and 10% respectively. The values in brackets are heteroscedasticity robust standard error. Industry FE and Year FE are fixed effects of industry and year respectively. "Yes" indicates that the fixed effect is controlled, and "No" indicates that the fixed effect is not controlled.

Table 5. Robustness test 1: Change explained variables

Explained variable	(1) lnpatent_ get	(2) lnpatent_ get	(3) lnpatent_ get
SCT_Ratio	-0.319***	-0.206***	-0.147***
	(0.015)	(0.015)	(0.015)
Size			0.210***
			(0.010)
Leverage			-0.143***
			(0.046)
Age			-0.021***
			(0.001)
ROA			0.081***
			(0.018)
Fix			-0.383***
			(0.052)
Cash			-0.015***
			(0.003)
Indratio			0.002***
			(0.001)
Boardsize			0.000
			(0.000)
Top1			-0.293***
			(0.053)
SOE			0.108***
			(0.018)
Constant	0.724***	0.688***	-3.697***
	(0.010)	(0.010)	(0.208)
Industry FE	No	Yes	Yes
Year FE	No	Yes	Yes
Observations	16,146	16,146	16,146
R-squared	0.021	0.132	0.193

Note: The observed values are at the enterprise level. ***, ** and * are statistically significant at 1%, 5% and 10% respectively. The values in brackets are heteroscedasticity robust standard error. Industry FE and Year FE are fixed effects of industry and year respectively. "Yes" indicates that the fixed effect is controlled, and "No" indicates that the fixed effect is not controlled.

The estimated results of PSM are shown in Table 7, where the explained variable of column (1) is lnpatent_apply, and the explained variable of column (2) is lnpatent_get. All columns controlled for all control variables and bidirectional fixed effects. The transparency degree of enterprise supply chain of the core explanatory variable is still significantly negative at the statistical level of 1%, which conforms to the basic conclusion above. Therefore, after using PSM for estimation, the conclusion still exists.

Fourth, further change the estimation model. The benchmark model in this paper adopts the bi-directional fixed-effect model, but because of the core explained variable, the distribution of enterprise innovation performance indicators cannot be negative, that is, there is truncation. Therefore, the robustness test is further conducted based on the Tobit panel of the constrained dependent variable model.

The results of panel Tobit estimation are shown in Table 8. All columns have fixed effects on enterprise dimension

control variables, year and industry. The explained variable of column (1) is lnpatent_apply, and the explained variable of column (2) is lnpatent_get. As can be seen from the results in Table 8, the estimated coefficients of SCT_Ratio are still significantly negative, which indicates that the conclusion of this paper is still robust after the model is changed: that is, the transparency of enterprise supply chain significantly inhibits enterprise innovation.

Table 6. Robustness Test 2: Measurement of transparency of replacement supply chain

Explained variable	(1) lnpatent_ apply	(2) lnpatent_ apply	(3) lnpatent_ apply
SCT_Num	-1.633***	-1.386***	-0.827***
	(0.151)	(0.156)	(0.148)
Size			0.212***
			(0.009)
Leverage			-0.305***
			(0.040)
Age			-0.004***
			(0.001)
ROA			0.066***
			(0.017)
Fix			-0.215***
			(0.045)
Cash			-0.014***
			(0.003)
Indratio			0.001
			(0.001)
Boardsize			0.000
			(0.000)
Top1			-0.182***
			(0.048)
SOE			0.047***
			(0.015)
Constant	0.353***	0.347***	-4.176***
	(0.008)	(0.008)	(0.193)
Industry FE	No	Yes	Yes
Year FE	No	Yes	Yes
Observations	16,146	16,146	16,146
R-squared	0.006	0.044	0.121

Note: The observed values are at the enterprise level. ***, ** and * are statistically significant at 1%, 5% and 10% respectively. The values in brackets are heteroscedasticity robust standard error. Industry FE and Year FE are fixed effects of industry and year respectively. "Yes" indicates that the fixed effect is controlled, and "No" indicates that the fixed effect is not controlled.

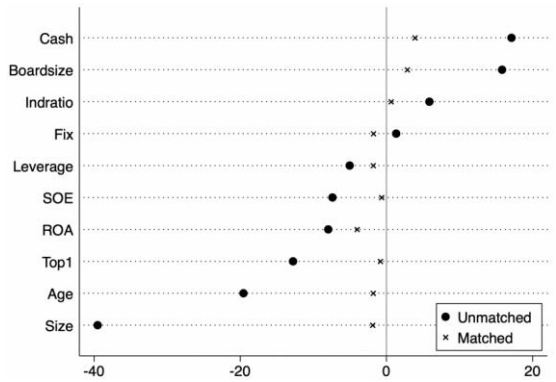


Figure 1. Covariate differences before and after PSM matching

Table 7. Robustness Test 3: PSM estimation results

Explained variable	(1) lnpatent_apply	(2) lnpatent_get
SCT_Ratio	-0.028***	-0.032***
	(0.009)	(0.011)
Size	0.164***	0.169***
	(0.006)	(0.007)
Leverage	-0.244***	-0.153***
	(0.027)	(0.035)
Age	-0.005***	-0.023***
	(0.001)	(0.001)
ROA	0.073***	0.061***
	(0.013)	(0.014)
Fix	-0.166***	-0.417***
	(0.030)	(0.037)
Cash	-0.010***	-0.013***
	(0.002)	(0.003)
Indratio	0.000	0.001
	(0.000)	(0.001)
Boardsize	-0.000	0.000
	(0.000)	(0.000)
Top1	-0.106***	-0.216***
	(0.034)	(0.042)
SOE	0.032***	0.074***
	(0.011)	(0.015)
Constant	-3.142***	-2.742***
	(0.125)	(0.148)
Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	24,062	24,062
R-squared	0.089	0.185

Note: The observed values are at the enterprise level. ***, ** and * are statistically significant at 1%, 5% and 10% respectively. The values in brackets are heteroscedasticity robust standard error. Industry FE and Year FE are fixed effects of industry and year respectively. "Yes" indicates that the fixed effect is controlled, and "No" indicates that the fixed effect is not controlled.

4.3. Adjustment effect analysis

From the perspective of enterprises, political connection builds a channel for government's help by establishing a close relationship with the government. Therefore, this paper first examines the moderating effect of political relevance, which is an important factor.

How to identify the relationship between enterprises and government has been discussed in the relevant literature. Literature usually takes the political identity of corporate executives as the proxy variable of corporate political association. Referring to the standard practice of existing literature (Yu Wei et al., 2012), this paper identifies the relationship between enterprises and the government from the working experience of senior executives of listed companies: if any one of the chairman and general manager of listed companies is or used to work in a government department, specifically: If the chairman or general manager of the enterprise has been or is currently a section-level cadre, the value is 1, the department level cadre is 2, the department level cadre is 3, the ministry level cadre is 4, and the value is 0 without political connection.

Table 9 reports the moderating effects of corporate political relevance. The explained variable of column (1) is

lnpatent_apply, and the explained variable of column (2) is lnpatent_get. According to the estimation coefficient of core interaction term SCT_Ratio*PCLevel, all of them are significantly negative. Therefore, political relevance has a significant moderating effect: the higher the level of political relevance, the greater the negative inhibitory effect of supply chain transparency on enterprise innovation performance.

Table 8. Robustness test 4: Panel Tobit estimation

Explained variable	(1) lnpatent_apply	(2) lnpatent_get
SCT_Ratio	-0.020*	-0.039***
	(0.012)	(0.014)
Size	0.138***	0.113***
	(0.009)	(0.010)
Leverage	-0.026	0.035
	(0.043)	(0.051)
Age	-0.002	-0.016***
	(0.002)	(0.002)
ROA	0.049***	0.003
	(0.017)	(0.020)
Fix	0.095*	0.150**
	(0.050)	(0.059)
Cash	0.000	-0.005
	(0.003)	(0.004)
Indratio	0.001*	0.002***
	(0.000)	(0.001)
Boardsize	0.001	0.000
	(0.001)	(0.001)
Top1	-0.104*	-0.244***
	(0.057)	(0.067)
SOE	0.048**	0.054*
	(0.024)	(0.028)
Constant	-2.920***	-2.448***
	(0.210)	(0.251)
Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	16,146	16,146
Number of scode	2,613	2,613

Note: The observed values are at the enterprise level. ***, ** and * are statistically significant at 1%, 5% and 10% respectively. The values in brackets are heteroscedasticity robust standard error. Industry FE and Year FE are fixed effects of industry and year respectively. "Yes" indicates that the fixed effect is controlled, and "No" indicates that the fixed effect is not controlled.

Referring to the method of Lu Tong and Dang Yin (2014), this paper further divides the industries of enterprises into labor-intensive industries and capital-intensive industries to discuss the heterogeneity. Table 10 shows the empirical results of the adjustment effect analysis of enterprises and industries. Similarly, the explained variable of column (1) is lnpatent_apply, and the explained variable of column (2) is lnpatent_get. As can be seen from the estimated coefficients of the core interaction term SCT_Ratio* for capital and technology-intensive industries, all of them are significantly negative. Therefore, capital and technology-intensive industries also have a significant moderating effect: compared with labor-intensive industries, the supply chain transparency of enterprises in capital and technology-intensive industries has a greater negative inhibitory effect on their innovation performance.

Table 9. Analysis of the moderating effect of corporate political correlation

Explained variable	(1) lnpatent_ apply	(2) lnpatent_ get
SCT_Ratio	-0.039**	-0.118***
	(0.016)	(0.018)
PCLevel	0.009	0.020***
	(0.006)	(0.006)
SCT_Ratio*PCLevel	-0.016**	-0.024***
	(0.008)	(0.009)
Size	0.212***	0.207***
	(0.009)	(0.010)
Leverage	-0.303***	-0.136***
	(0.040)	(0.046)
Age	-0.004***	-0.021***
	(0.001)	(0.001)
ROA	0.065***	0.079***
	(0.017)	(0.018)
Fix	-0.218***	-0.389***
	(0.045)	(0.053)
Cash	-0.014***	-0.014***
	(0.003)	(0.003)
Indratio	0.001	0.002***
	(0.001)	(0.001)
Boardsize	0.000	0.000
	(0.000)	(0.000)
Top1	-0.182***	-0.290***
	(0.048)	(0.053)
SOE	0.049***	0.112***
	(0.015)	(0.018)
Constant	-4.184***	-3.662***
	(0.194)	(0.209)
Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	16,146	16,146
R-squared	0.121	0.194

Note: The observed values are at the enterprise level. ***, ** and * are statistically significant at 1%, 5% and 10% respectively. The values in brackets are heteroscedasticity robust standard error. Industry FE and Year FE are fixed effects of industry and year respectively. "Yes" indicates that the fixed effect is controlled, and "No" indicates that the fixed effect is not controlled.

Table 10. Analysis of the adjustment effect of enterprises and industries

Explained variable	(1) lnpatent_apply	(2) lnpatent_get
SCT_Ratio	-0.019	-0.014
	(0.019)	(0.018)
Capital and technology intensive industries	0.200***	0.473***
	(0.018)	(0.021)
SCT_Ratio*Capital and technology intensive industries	-0.058**	-0.196***
	(0.024)	(0.026)
Size	0.213***	0.211***
	(0.009)	(0.010)
Leverage	-0.326***	-0.188***
	(0.041)	(0.046)
Age	-0.004***	-0.021***
	(0.001)	(0.001)

ROA	0.076***	0.106***
	(0.017)	(0.018)
Fix	-0.200***	-0.347***
	(0.045)	(0.052)
Cash	-0.014***	-0.016***
	(0.003)	(0.003)
Indratio	0.001	0.003***
	(0.001)	(0.001)
Boardsize	0.000	-0.000
	(0.000)	(0.000)
Top1	-0.171***	-0.266***
	(0.048)	(0.053)
SOE	0.047***	0.106***
	(0.015)	(0.018)
Constant	-4.346***	-4.061***
	(0.195)	(0.208)
Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	16,146	16,146
R-squared	0.126	0.212

Note: The observed values are at the enterprise level. ***, ** and * are statistically significant at 1%, 5% and 10% respectively. The values in brackets are heteroscedasticity robust standard error. Industry FE and Year FE are fixed effects of industry and year respectively. "Yes" indicates that the fixed effect is controlled, and "No" indicates that the fixed effect is not controlled.

4.4. Intermediate effect test

Why can the transparency of enterprise supply chain produce significant inhibitory effect on enterprise innovation? In order to verify the influencing mechanism, the following mediation effect model is set up in this paper for analysis:

$$Z_{it} = \gamma_0 + \gamma_1 STC_{it} + \gamma_2 X_{it} + +Year_{FE} + Industry_{FE} + \varepsilon_{it}$$

$$Innovation_{it} = \delta_0 + \delta_1 STC_{it} + \rho Z_{it} + \delta_2 X_{it} + +Year_{FE} + Industry_{FE} + \varepsilon_{it}$$

Where, $Z_{it}$is the intermediary variable. If the model meets both the significance in Equation (3) that γ_1 is most pronounced and in equation (4) that δ_1 and ρ are most pronounced, it indicates that there is a mediating effect. Based on the theoretical analysis above, this paper makes a detailed empirical discussion from the perspectives of R&D expenditure and internal control quality.

4.4.1. R&D expenditure

Firstly, the factors of innovation input are investigated. This paper uses RDexp, the natural logarithm of R&D expenditure of listed companies in the current year, to measure and test the intermediary effect. Similarly, all control variables and bidirectional fixed effects are controlled by the model. Firstly, it can be seen from Table 11 column (1) that the estimated coefficient of SCT_Ratio's impact on R&D expenditure is -0.175, which is significantly negative at the statistical level of 1%, that is, the transparency of the enterprise supply chain significantly inhibits the innovation input of the enterprise. Further, the estimation results in column (2) of Table 13 show that the estimated coefficient of RDexp is 0.140, which is significantly positive, that is, the innovation input of the firm significantly improves the patent output of the firm. This conclusion indicates that there is an intermediary mechanism for innovation input: the transparency of supply chain inhibits innovation output by inhibiting innovation input.

Table 11. Intermediate effect test: R&D expenditure

Explained variable	(1) RDexp	(2) lnpatent_apply
RDexp		0.140***
		(0.006)
SCT_Ratio	-0.175***	-0.038**
	(0.027)	(0.017)
Size	0.881***	0.132***
	(0.012)	(0.012)
Leverage	-0.819***	-0.227***
	(0.079)	(0.052)
Age	-0.025***	-0.002
	(0.002)	(0.002)
ROA	0.504***	-0.013
	(0.035)	(0.023)
Fix	-0.778***	-0.101*
	(0.089)	(0.060)
Cash	-0.021***	-0.013***
	(0.005)	(0.003)
Indratio	0.001	0.001
	(0.001)	(0.001)
Boardsize	0.000	0.000
	(0.001)	(0.000)
Top1	-0.363***	-0.183***
	(0.076)	(0.061)
SOE	0.015	0.051**
	(0.029)	(0.020)
Constant	-1.305***	-4.824***
	(0.245)	(0.244)
Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	12,356	12,356
R-squared	0.502	0.139

Note: The observed values are at the enterprise level. ***, ** and * are statistically significant at 1%, 5% and 10% respectively. The values in brackets are heteroscedasticity robust standard error. Industry FE and Year FE are fixed effects of industry and year respectively. "Yes" indicates that the fixed effect is controlled, and "No" indicates that the fixed effect is not controlled.

4.4.2. Enterprise internal control

Table 12 further tests the mediating effect of internal control. All control variables and bidirectional fixed effects are controlled by the model. Firstly, it can be seen from column (1) that the estimated coefficient of SCT_Ratio is significantly negative at the statistical level of 1%, that is, the higher the transparency of the enterprise supply chain, the worse the quality of the enterprise internal control. Further observation of column (2) shows that the estimated coefficient of ICI of enterprise internal control index is 0.026, which is significantly positive at the statistical level of 1%, indicating that the higher the enterprise's internal control and governance, the higher the enterprise's innovation level. Therefore, the mediating effect of enterprise internal control level can also be verified: enterprise supply chain transparency inhibits enterprise innovation output by reducing the quality of enterprise internal control.

Table 12. Intermediate effect test: enterprise internal control

Explained variable	(1) ICI	(2) lnpatent_apply
ICI		0.026***
		(0.005)
SCT_Ratio	-0.132***	-0.058***
	(0.024)	(0.014)
Size	0.384***	0.207***
	(0.011)	(0.010)
Leverage	-1.197***	-0.339***
	(0.088)	(0.045)
Age	-0.019***	-0.004***
	(0.002)	(0.001)
ROA	0.230***	0.060***
	(0.030)	(0.018)
Fix	-0.555***	-0.216***
	(0.079)	(0.048)
Cash	-0.029***	-0.019***
	(0.008)	(0.005)
Indratio	0.003***	0.001
	(0.001)	(0.001)
Boardsize	0.002**	0.000
	(0.001)	(0.001)
Top1	0.051	-0.164***
	(0.071)	(0.053)
SOE	0.066***	0.046***
	(0.025)	(0.016)
Constant	-1.337***	-4.238***
	(0.242)	(0.208)
Industry FE	Yes	Yes
Year FE	Yes	Yes
Observations	14,002	14,002
R-squared	0.166	0.127

Note: The observed values are at the enterprise level. ***, ** and * are statistically significant at 1%, 5% and 10% respectively. The values in brackets are heteroscedasticity robust standard error. Industry FE and Year FE are fixed effects of industry and year respectively. "Yes" indicates that the fixed effect is controlled, and "No" indicates that the fixed effect is not controlled.

5. Conclusion

Relying on government support and enterprise advantages, the transparent supply chain has gradually walked in the era of enterprise transformation and upgrading, attracting the attention of many scholars. This direction has an important theoretical and practical significance. Based on this, this paper takes all the A-share listed companies in Shanghai and Shenzhen as the original samples as the research object, and empirically tests the relationship between supply chain transparency and enterprise innovation, the moderating effect of political correlation and capital-intensive industries in the above relationship, and the mediating effect of enterprise innovation input and internal control level in the above relationship. The results of this paper not only enrich the research results of supply chain transparency on enterprise economic behavior, but also have a certain practical significance for scientific evaluation of supply chain transparency on the inhibition of enterprise innovation ability.

Based on the above conclusions, this paper draws the following enlightenments: First, coordinate the relationship between supply chain transparency and innovation behavior. The government should continue to play the leading role of policy guidance and innovation support, and actively promote supply chain transparency around core enterprises in the industry. Second, improve the transparent and full chain control and information disclosure of the supply chain, establishing an early warning system and reducing the safety of the supply chain. Finally, the transparency of supply chain should be refined according to the different characteristics of enterprises to improve the innovation ability of enterprises.

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