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Supply chain stability and corporate green technology innovation

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ABSTRACT

The supply chain is a critical perspective that enables understanding a company's business decisions. This paper indicates that corporate green technology innovation activity has significantly improved supply chain stability, as evidenced by data from 2012 to 2022. Supply chain stability can effectively stimulate corporate green technology innovation, alleviating financing constraints and enhancing risk-taking ability. Further analysis confirms that the impacts of supply chain stability in non-state-owned enterprises and firms with higher competitive industries play multiplier effects. Providing empirical data and management insights for establishing a green innovation environment system that is concentrated on both the enterprise and the market, the findings contribute to the existing research on the influencing factors of corporate green innovation.

1. Introduction

Finding a way to achieve both economic development and ecological preservation is a pressing issue. It is crucial to enable small businesses to enhance the quality of economic growth through innovation while also utilizing innovation to drive the transition towards a greener industrial structure and promote sustainable development. Enterprises typically pursue green innovation by developing new or enhancing existing product designs, processes, and organizational management. This approach combines innovation and green development to achieve sustainable development, resulting in mutually beneficial economic and environmental outcomes (Barbieri et al., 2023; Chen et al., 2024). Green innovation enhances ecological efficiency and achieves integrated progress and peaceful cohabitation of the economy, society, and nature (He, Lu, et al., 2024; Yang, Zhu, & Albitar, 2024; Zhang et al., 2023). Thus, identifying the crucial factors that promote or impede green innovation has emerged as a significant topic of interest and discussion in both academic and practical spheres. Green innovation is vital in transforming the economic development model and achieving sustainable growth.

Existing research confirms that stakeholder pressure is a significant external element that compels corporations to adopt green innovation (Bai et al., 2024; He, Ribeiro-Navarrete, & Botella-Carrubi, 2024; Li et al.,. 2023). Firms, driven by cultural traditions and historical circumstances, tend to cultivate strong relationships with a select group of suppliers and customers in their day-to-day operations (Liu & Cao, 2024; Shi et al., 2022; Xu & Hu, 2024). This approach allows them to build a business model centered around a network of familiar and trustworthy connections. Specifically, this is demonstrated by the fact that companies rely heavily on crucial suppliers and customers for their daily procurement and sales operations (Chen, 2023; Liu & Zheng, 2024), which contributes

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to the supply chain stability (Shi et al., 2024; Sun et al., 2024). Institutional economics posits that the transaction model, functioning as an informal system, impacts the behavioral decisions of the individuals involved in the transaction (Ivanov, 2024; Mao & Yang, 2024). Can supply chain stability serve as a significant external stakeholder influence on corporate green innovation? Existing literature does not offer a definitive response.

To address the research gap, this paper utilizes data from A-share listed firms spanning 2011 to 2022 to analyze how supply chain stability affects corporate green innovation. This paper contributes significantly to the existing literature in two dimensions. First, this paper broadens the investigation into the determinants of corporate green innovation, focusing specifically on the viewpoint of well-established clients within the supply chain(Hu et al., 2023; Wang et al., 2024). However, there is a lack of study literature that offers empirical proof of the connection between the stability of corporate supply chain customers and the decisions made by corporations regarding green innovation. Second, limited research investigates the economic effects of corporate customer stability. This research focuses on several aspects, such as the accuracy of analyst surplus forecasts, the volatility of stock prices, the constraints on supplier credit, the quality of accounting information, and collaborative innovation (He, Zhang, & Wang, 2024; Jiang et al., 2024). This study examines the relationship between a firm's supply chain customer stability and its decisions on corporate green innovation from a corporate green innovation perspective and investigates the mechanism that connects these two factors.

The subsequent sections of this study are organized as follows: the theoretical background and hypotheses are presented in Section 2, the discussion of the methodology and data sources in Section 3, and the presentation of empirical findings and tests of robustness in Section 4. Section 5 synthesizes the study and evaluates the potential policy ramifications.

2. Theoretical hypothesis

2.1. The direct impact of supply chain stability on corporate green technology innovation

Enhanced supply chain stability can bolster organizations' inclination to innovate, that is, to augment their investment in innovation (Colon & Hochrainer-Stigler, 2023). With the changing competitive market environment, businesses have progressively transitioned their business model from focusing on products to customers. This move has resulted in significant expenditures in research and development tailored to meet customers' individual demands. When an enterprise frequently changes its relationship with suppliers, the innovation activities it undertakes to meet the needs of its existing customers are at risk of being disrupted (Ersahin et al., 2024). This is because applying these innovations to new customers becomes difficult, which can result in significant economic losses for the enterprise. Consequently, companies are inclined to allocate resources to research and development (R&D) exclusively when their supply chain connections are secure and reliable.

Furthermore, investing in research and development (R&D) indicates a firm's commitment to a long-term strategic partnership with a dependable supply chain (Feng et al., 2023). R&D investment is a specific type of investment firms make to support and solidify this distinctive business transaction model. This investment encourages loyal customers to offer valuable innovation resources, such as information, knowledge, and technology, to the firms. Consequently, it enhances the firms' confidence in investing in innovation. Increased supply chain stability improves the ability of enterprises to innovate in environmentally friendly ways (Zhang et al., 2024). Firstly, supplier enterprises can establish regular, prompt, and precise communication with stable customers downstream. This facilitates the acquisition of novel ideas, product usage feedback, and end-market demand information from customers. Consequently, enterprises can expedite the process of product research and development (R&D) and design, reduce the duration of the product R&D cycle, and ultimately enhance the speed at which new products are brought to market. Furthermore, the strong bond between the company and its loyal customers facilitates the acquisition of essential and undisclosed knowledge and expertise in innovation from these customers. This, in turn, enhances the company's ability to innovate and speeds up the company's output of innovative solutions (Farooq et al., 2024). Simultaneously, clients may hold technical information acquired from other suppliers, allowing enterprises to tap into technology spillovers within the same sector through trade networks of loyal customers tightly connected to their economic interests. Establishing solid ties between enterprises and customers can facilitate the complete exchange of innovation resources and elements, leading to collaborative innovation. This, in turn, reduces the time spent on research and development for firms and increases the output of collaborative innovation. Therefore, this paper proposals the following hypothesis:

Hypothesis 1. Supply chain stability can effectively stimulate corporate green technology innovation.

2.2. The mechanisms of supply chain stability on corporate green technology innovation

Enhancing a firm's reputation can improve its credit borrowing ability through increased supply chain customer stability. Reputation is a significant and enduring intangible asset that businesses cultivate over time via long-term development. It is difficult for others to replicate or mimic. Reputation is crucial in establishing trust and influencing the actions of business stakeholders. Providing credit demonstrates a strong belief in the bank's capacity and willingness to return the loan. A positive reputation of a firm further boosts the bank's assurance that it can lend money to the borrower and get timely repayment. Establishing a reliable customer connection inside the supply chain may effectively deter unlawful action by the firm and enhance the development of a positive reputation. First and foremost, loyal consumers are motivated to observe and restrict any non-compliant conduct exhibited by businesses closely. Enterprises that have established long-term business connections with steady customers have a stronger bond of interest. This increased supply relationship adhesion effect makes it more difficult and costly for large customers to depart from their initial supplier relationship. Furthermore, to ensure a durable strategic alliance with a company, reliable and established major clients

typically make investments that are tailored to the unique needs of their supply chain partners. Consequently, if the upstream company incurs multiple penalties due to non-compliance and cannot sustain its operations, it will significantly jeopardize the economic interests of the significant customer. This includes the interruption of raw material procurement, a decline in stock price, and a decrease in the value of the investment made in the previous period that is specific to the relationship between the two parties. From this perspective, establishing a strategic cooperative partnership with reliable major customers provides a solid motivation to monitor and enforce limitations on various infractions by upstream and downstream firms in the supply chain. Furthermore, due to the extensive and trustworthy information gathered over time from ongoing procurement and sales transactions with enterprises and their economic significance to these enterprises, stable large customers possess a significant advantage in information and bargaining power. As a result, they can effectively monitor and regulate any opportunistic actions undertaken by these enterprises. In other words, stable large customers can supervise and restrict any non-compliant behaviors enterprises exhibit. Higher supply chain customer stability can improve corporate reputation by reducing corporate violations. Additionally, reputation serves as a signal that helps companies establish credit cooperation with banks, enhancing their ability to borrow credit and ultimately easing corporate financing constraints.

Risk-taking pertains to the specific attributes involved in making investing decisions. Initially, the level of risk is considerable, although the potential return is also quite substantial. Furthermore, it highlights the enduring worth of the organization, characterized by an extended duration of recouping investments, elevated immediate expenses, and a comparatively reduced likelihood of achieving success. The company's investment decisions demonstrate a preference for hazardous investment initiatives, as seen by its willingness to take on risk. Executives with a higher propensity for risk-taking are more inclined to engage in adventurous behavior. They are less likely to abandon investment initiatives with positive net present value (NPV) that include some level of risk. When evaluating a company's risk-taking behavior, the volatility of stock returns is more reliable than financial indicators. Unlike financial statements, stock returns are not limited to assessing a company's risk-taking. Therefore, the volatility of stock returns is often employed to measure a company's risk-taking. Therefore, this paper proposals the following hypothesis:

Hypothesis 2. Supply chain stability can effectively stimulate corporate green technology innovation by alleviating financing constraints and enhancing risk-taking ability.

3. Research design

3.1. Methodology

This study adopts the two-way fixed model to investigate supply chain stability and corporate green technology innovation as follows:

$$Y_{it} = \alpha + \beta \cdot stable_{it} + \sum \gamma \cdot X + year_t + firm_i + \varepsilon_{it} \tag{1}$$

$$\mathrm{M_{it}} = \alpha + \beta \cdot stable_{it} + \sum \gamma \cdot \mathrm{X} + \mathrm{year_t} + \mathrm{firm_i} + \varepsilon_{it} \tag{2}$$

$$Y_{it} = \alpha + \xi \cdot stable_{it} + \theta^{*} M_{it} + \sum \gamma \cdot X + year_t + firm_i + \varepsilon_{it} \tag{3}$$

The primary focus centers on the coefficient β, which measures the impact of supply chain stability on corporate green technology innovation and is theoretically expected to be positive.

3.2. Variable selection

3.2.1. Measuring corporate green innovation

Green patents, the International Patent and Trademark Office (IPC Green Inventory), were first introduced by the International Intellectual Property Office (IPO) this year (2010). The natural logarithm of the number of green invention patent applications (*green*) is utilized in this study to measure green innovation in corporations and to address concerns related to right-skewed distribution.

According to the definition of Chinese patent law and the research material that is currently available, this paper distinguishes between two distinct types of innovation motives. Businesses' application of green utility model patents is considered symbolic innovation. In contrast, businesses applying high-quality green invention patents are considered substantive innovations. Design patents are distinguished by their fundamental nature and relatively low level of technical complexity, which should be considered. It is more like an independent method because the application process for design patents does not require submitting reports or passing through substantive reviews, in contrast to the application process for other types of patents. Therefore, the quantity of patent applications for environmentally friendly designs is not considered. Then, the natural logarithm of the number of patents for inventions and utility models is utilized to quantify both the substantive (*invention*) and symbolic (*utility*) aspects of green innovation.

3.2.2. Measuring supply chain stability

This paper employs customer relationship stability (*customer*) and supplier relationship stability(*supply*) as metrics. The stability of customer relationships is evaluated by determining the percentage of repeat customers among the firm's top five clients in the current year to those in the previous year, divided by 5. A higher proportion of repeat customers in the current year indicates greater consistency in customer relationships. The stability of supplier relationships is measured by the percentage of overlapping suppliers

between the top five suppliers of the current year and those of the prior year, divided by five. This year, an increased quantity of repeated suppliers signifies enhanced consistency in supplier relationships.

3.2.3. Control variables

This study chooses three control variables from three dimensions: the financial, governance and characteristics. The detailed definition are shown in Table 1.

3.3. Data sources

Given that 2011 has been treated as the digital era's starting point and excludes the financial crisis's global economic consequences. The final sample comprises Chinese A-share listed companies from 2012 to 2022, consisting of 4479 observations. Table 1 describes the variables statistics.

4. Empirical analysis

4.1. Benchmark regression analysis

The results of the benchmark regression are presented in Table 2. The estimated coefficients have positive effects at the 5% significance level, demonstrating that increasing supply chain stability can promote corporate green technology innovation, regardless of whether or not the control variable was included in the analysis. Specifically, customer relationship stability has more pronounced positive effects on corporate green technology innovation, as demonstrated by the coefficients' values.

In addition, columns (2) and (3) present the results of regressions that incorporate control variables accordingly. Notably, the estimated coefficient for firms' age (*AGE*) has no relationship with corporate green technology innovation. However, the coefficient of the largest shareholders (*TOP1*) has a negative impact, suggesting that higher equity concentration hinders corporate engagement in green innovation activity.

Further, this paper explores the relationship between supply chain stability and heterogeneous green innovation activity from an innovation motivation perspective. Table 3 reports the results. All estimated coefficients are significantly positive at the 1% level, indicating that supply chain stability can effectively promote corporate green innovation. From the innovation motivation perspective, the positive impacts are more significant for green invention applications than the utility mode. From the different types of supply chain perspective, customer relationship stability has better stimulating effects than the supplier. The findings emphasize the importance of supply chain stability, especially customer relationships.

4.2. Robustness tests

First, adopting alternative measure for supply chain stability. The supply chain stability is determined by dividing the total occurrences of a company's top five customers in the year prior or the year before by 10 (*concentration*). Column (1) of Table 4 reports the results. The estimated coefficient is positive at the 10% level, confirming the baseline regression result.

Second, adopting alternative measure for corporate green technology innovation. This study employs a further analysis to examine the relationship between supply chain stability and the ratio of green innovation (*green_ratio*) on tota technology patents. Columns (2) and (3) report the results, verifying the baseline regression results.

Third, the instrumental variables (IV) approach. This paper employs a two-stage regression analysis to investigate potential causal relationships between explanatory and interpreted variables. Specifically, this paper employs the peer effect of supply chain stability of other companies in the same industry and year as an instrumental variable.Acknowledging that the enterprises under analysis operate within the same industry and year as other firms, satisfying the requisite requirement for correlation in instrumental variables is crucial. Conversely, it is difficult for the supply chain stability of other firms within the same industry during the same year to directly

Table 1
Descriptive statistics.

Variables	Definition	Obs	Mean	Std.	Min	Max
green	Green innovation	4328	0.645	1.007	0.000	6.040
supp;y	Suppliers relationship stability	4479	0.322	0.299	0.000	1.000
customer	Customer relationship stability	4479	0.247	0.239	0.000	1.000
SIZE	The natural logarithm of total assets	4479	22.096	1.307	18.219	26.864
AGE	The age of the firm	4455	2.263	0.869	0.000	3.434
ROE	Return on equity	4456	0.037	0.156	−0.894	0.303
LEV	The proportion of liabilities to total assets	4479	0.446	0.216	0.055	0.904
FIX	Fixed assets ratio	4479	0.224	0.175	0.002	0.689
GROWTH	The rate of revenue growth	4456	0.436	1.134	−0.740	6.766
SOE	Enterprises' ownership	4479	0.418	0.493	0.00	1.000
DUAL	Combined title of board Chair and CEO	4338	0.478	0.076	0.001	0.348
TOP1	The ratio of the largest shareholder	4479	0.339	0.151	0.003	0.888

Table 2
Baseline regression results.

	(1)	(2)	(3)	(4)
	green	green	green	green
supply	0.136*** (0.052)		0.199** (0.047)	
customer		0.153** (0.068)		0.252*** (0.062)
SIZE			0.340*** (0.016)	0.340*** (0.015)
AGE			0.022 (0.021)	0.022 (0.023)
ROE			0.281*** (0.023)	0.288*** (0.020)
LEV			−0.017** (0.007)	−0.018*** (0.006)
FIX			−0.360*** (0.105)	−0.351*** (0.104)
GROWTH			0.016** (0.008)	0.015*** (0.004)
SOE			0.077** (0.033)	0.078** (0.033)
DUAL			0.348*** (0.025)	0.351*** (0.026)
TOP1			−0.094*** (0.013)	−0.092*** (0.010)
cons	0.689*** (0.023)	0.683*** (0.022)	−6.539*** (0.347)	−6.553*** (0.347)
controls	No	No	YES	YES
FE	YES	YES	YES	YES
N	4322	4322	4310	4310
R^2	0.2154	0.2151	0.3383	0.3382

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 3
Baseline regression results: Heterogeneous innovation motivation.

	(1)	(2)	(3)	(4)
	invention	invention	utility	utility
supply	0.180*** (0.037)		0.147*** (0.039)	
customer		0.239*** (0.050)		0.176*** (0.051)
cons	−4.890*** (0.293)	−4.902*** (0.290)	−4.796*** (0.291)	−4.806*** (0.292)
controls	YES	YES	YES	YES
FE	YES	YES	YES	YES
N	4310	4310	4310	4310
R^2	0.2895	0.2898	0.3190	0.3186

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.

influence the examined corporate green innovation, which corresponds with the homogeneity of instrumental variables. Columns (4) and (5) of Table 4 report the results. The Kleibergen-Paap rk LM statistic shows significance at the 1% level, leading to the rejection of the initial hypothesis that the instrumental variables are not identifiable. The Cragg-Donald Wald F-statistic exceeds the crucial value of the Stock-Yogo F-test for identifying weak instrumental variables at a significance level of 10%. Consequently, this paper rejects the null hypothesis of weak instrumental variables. The results confirms the benchmark regression results.

Fourth, excluding the effect of COVID-19 pandemic. This analysis excludes the period from 2020 to 2022 to mitigate the effects of the COVID-19 pandemic, which has caused significant interruptions to businesses' operations. Columns (6) and (7) of Table 4 displays the results and confirms the accuracy of the benchmark findings.

Fifth, considering that endogeneity problem may caused by omitted variables, this paper further introduce firm-year fixed effects, and the regression results are shown in columns (8) and (9) of Table 4. The estimated coefficient is significantly positive at the 1% level, confirming the baseline regression results.

Finally, a firm with a good historical supply chain stability is more likely to improve supply chain stability. With this consideration, it would be better to run a dynamic panel model for a robustness check, which incorporates lagged values of supply chain stability as the independent variable. Columns (10) and (11) in Table 4 reports the result, consistent with the baseline estimation findings.

4.3. Mechanism test

First, this paper employs the logarithm of the standard deviation of annualized monthly returns (*risk*) as metrics to assess corporate risk-taking. Standard deviation functions as a statistical measure to assess the variability of asset returns. By annualizing monthly results, the standard deviation of monthly annualized returns can more precisely represent a company's risk tolerance over various timeframes. This methodology is not limited by the restrictions of financial statements and more accurately represents a company's genuine risk-taking behavior. Table 5 reports the risk-taking mechanism. The estimated coefficients for supply chain stability on corporate stock returns volatility in columns (1) and (3) are positive at the 1% level, indicating that supply chain stability can effectively enhance corporate risk-taking ability. The estimated coefficients in columns (2) and (4) are statistically positive at the 1%

Table 4
Robustness tests.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	green	green_ratio	green_ratio	green	green	green	green	green	green	green	green
supply		0.014***		0.199***		0.142***		0.177***			
		(0.003)		(0.047)		(0.052)		(0.025)			
customer			0.050***		0.252***		0.178**		0.222***		
			(0.004)		(0.062)		(0.070)		(0.052)		
L.supply										0.176***	
										(0.050)	
L.customer											0.198***
											(0.066)
concentration	0.022* (0.012)										
cons	−4.074***	−4.293***	−5.296***	−5.998***	−5.167***	−6.168***	−6.179***				
	(0.241)	(0.227)	(0.174)	(0.647)	(0.584)	(0.382)	(0.382)				
controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Firm-year FE								YES	YES		
FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Kleibergen-Paap rk LM				82.364***	70.579***						
Kleibergen-Paap rk Wald F				81.900***	70.300***						
N	4310	4310	4310	3873	3873	3516	3516	4310	4310	3999	3999
R^2	0.2479	0.1524	0.1907	0.2572	0.2465	0.3011	0.2835	0.3517	0.3638	0.3571	0.3566

Note: The symbols ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Parentheses imply that the coefficients have high reliability regarding their standard errors.

Table 5
Mechanism channel tests: Enhancing corporate risk-taking ability.

	(1)	(2)	(3)	(4)
	risk	green	risk	green
supply	0.091*** (0.014)	0.194*** (0.054)		
customer			0.123*** (0.019)	0.250*** (0.079)
risk		0.038*** (0.005)		0.032*** (0.008)
cons	1.592*** (0.119)	−6.606*** (0.612)	1.597*** (0.120)	−6.620*** (0.612)
controls	YES	YES	YES	YES
FE	YES	YES	YES	YES
N	4437	4309	4437	4309
R^2	0.5156	0.3384	0.5161	0.3293

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.

level, indicating that supply chain stability can improve corporate green innovation through enhancing corporate risk-taking ability.

Second, this paper adopts the SA index (*SA*) as a measurement. Table 6 describe the financing constraint mechanism. The estimated coefficients for supply chain stability on the SA index in columns (1) and (3) are negative at the 5% level, indicating that supply chain stability can alleviate financing constraint. The estimated coefficients in columns (2) and (4) are statistically significant at the 1% level, indicating that supply chain stability can improve corporate green innovation through alleviating financing constraints.

4.4. Heterogeneous analysis

4.4.1. From the perspective of enterprises' ownership

The role of supply chain stability in supporting green innovation varies among firms with various property rights. State-owned enterprises, controlled by the government at all levels, benefit from national credibility and receive policy preferences and financial subsidies. This reduces concerns among supply chain actors regarding these enterprises' business reputation and sustained supply capacity. Consequently, supply chain actors are more willing to engage in business with them. Simultaneously, due to the implicit government guarantee, State-Owned Enterprises (SOEs) possess a distinct advantage in acquiring commercial and bank credit financing. Consequently, the financial status of state-owned firms is minimally affected by the stability of the supply chain, making it challenging to influence their green innovation efforts. However, even if state-owned enterprises (SOEs) experience financial losses due to inadequate management, the government will offer financial assistance for paternal reasons. Consequently, SOEs that face less pressure to ensure their survival are subjectively less inclined to pursue excessive profits through innovation. This, in turn, weakens the influence of supply chain stability on their efforts towards environmentally-friendly innovation. Conversely, non-state-owned enterprises (non-SOEs) without government support are fundamentally less likely to be preferred by customers. As a result, they allocate more resources into acquiring or retaining customer connections and have relative challenges in securing financing from suppliers and banks. Furthermore, private firms operating in a competitive market tend to be more inclined towards embracing change and fostering innovation. Thus, the financial benefits and favorable resource conditions resulting from supply chain stability are more favorable for enhancing green innovation capability. In conclusion, better supply chain stability has a more significant impact on improving environmentally friendly innovation in privately owned companies compared to government-owned companies.

Table 7 reports the results. All estimated coefficients are significantly positive at the 10% level, indicating that the existence of stimulating effects of supply chain stability, regardless of enterprises' ownership. However, the value of coefficients in non-state-owned enterprises are more pronounced than that of state-owned enterprises. The finding confirms the interference above.

4.4.2. From the perspective of industry competition

The level of rivalry within an industry can impact how successful supply chain stability is in encouraging enterprises to engage in

Table 6
Mechanism channel tests: Alleviating financing constraints.

	(1)	(2)	(3)	(4)
	SA	green	SA	green
supply	−0.004** (0.002)	0.198*** (0.050)		
customer			−0.005** (0.002)	0.249*** (0.079)
SA		−0.368*** (0.127)		−0.367*** (0.126)
cons	−4.044*** (0.199)	−5.017*** (0.621)	−4.044*** (0.199)	−5.017*** (0.621)
controls	YES	YES	YES	YES
FE	YES	YES	YES	YES
N	4438	4310	4438	4310
R^2	0.4680	0.3428	0.4567	0.3284

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
Further analysis:From the perspective of enterprises' ownership.

	State-owned enterprises		Non state-owned enterprises	
	green	green	green	green
supply	0.115* (0.059)		0.313*** (0.079)	
customer		0.120* (0.055)		0.411*** (0.098)
cons	−4.479*** (0.042)	−4.485*** (0.423)	−8.426*** (0.593)	−8.415*** (0.563)
controls	YES	YES	YES	YES
FE	YES	YES	YES	YES
N	1837	1837	2468	2468
R^2	0.465	0.405	0.316	0.315

Note: The robustness standard errors of the coefficients are in parentheses; ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

environmentally friendly innovation. Increased rivalry in the business can lead to reduced profits, greater cash flow instability, and an elevated chance of bankruptcy. These financial concerns make it difficult to get external financing. Simultaneously, a rise in competition within the industry leads to increased rivals vying with the organization for scarce consumer resources. Consequently, the enterprise incurs significant expenses to acquire, create, and sustain customer connections. Consequently, companies operating in fiercely competitive sectors often face a shortage of funds and experience significant fluctuations in cash flow, which poses challenges for them in making essential and continuous expenditures. In this scenario, the substantial influx of stable money facilitated by a reliable supply chain is more favorable for promoting and advancing green innovation. Conversely, a highly competitive environment prompts firms to enhance their innovation efforts to boost their profit margins and outperform other companies in the industry. Additionally, a more stable supply chain, coupled with increased capital and innovation conditions, facilitates firms in improving their green innovation capabilities more efficiently. In contrast, in industries with minimal competition, corporations can generate substantial monopoly profits, contributing to their solid operational performance and enabling them to get external funding. Simultaneously, the limited number of enterprises in the industry confers a favorable position to the enterprise regarding business collaboration with customers. Even if the existing customer relationships deteriorate, other customers will proactively seek collaboration, significantly reducing expenses associated with customer relationships. In this scenario, the companies have more financial resources, which could challenge the effectiveness of supply chain stability. Simultaneously, these enterprises experience reduced survival pressure, resulting in a subjective lack of motivation to pursue excessive profits through innovation. Additionally, the innovation resources provided by higher customer stability are challenging to utilize effectively, hindering customer stability's benefits. Thus, compared to firms facing less competition in the sector, enterprises experiencing intense competition in the industry are more significantly impacted by a higher level of supply chain stability in enhancing green innovation.

Table 8 reports the results. All estimated coefficients are significantly positive at the 10% level, indicating that the existence of stimulating effects of supply chain stability, regardless of industry competition. However, the value of coefficients in firms with higher HHI index are more pronounced than that of firms with lower HHI index. The finding confirms the interference above.

4.4.3. From the perspective of industry nature

Due to its significant environmental impact, heavily polluting firms encounter increased pressure for environmental protection from public attention and government supervisors, making promoting green transformation essential for sustainable development. Thus, enterprises in heavy polluting have more possibility to conduct green innovation. The identification of heavily polluting industries primarily relies on the 2012 revision of the Guidelines for Industry Classification of Listed Companies by the China Securities Regulatory Commission, encompassing 16 sectors, including coal, mining, textiles, tanneries, paper production, petrochemicals, pharmaceuticals, chemicals, metallurgy, and thermal power, among others. This article assesses whether a publicly traded company qualifies as a significantly polluting enterprise based on the industry classification of its primary income source. Heavily polluting firms (pollute) are valued at 1, otherwise 0.

Table 9 reports the results. All estimated coefficients are significantly positive at the 5% level, indicating that the existence of stimulating effects of supply chain stability, regardless of industry nature. However, the value of coefficients in heavy-polluting firms are more pronounced than that of firms in non-heavy-polluting industry. The finding confirms the interference above.

5. Conclusion

In contrast to existing research focusing on external elements of corporate green innovation, this paper centers on stakeholders' influence. Based on a sample of Chinese listed companies from 2012 to 2022, this paper reveals a significant enhancement of supply chain stability in corporate green technology innovation activity. The findings point out that supply chain stability can effectively stimulate corporate green technology innovation through enhancing risk-taking ability and alleviating financing constraint. The findings contribute to the existing research on the elements influencing corporate green innovation. It offers empirical data and management insights for establishing a green innovation environment system focused on both the enterprise and the market. Further analysis confirms that the impacts of supply chain stability in non-state-owned enterprises and firms with higher competitive industries play multiplier effects.

Table 8
Further analysis:From the perspective of industry competition.

	Higher HHI		Lower HHI	
	green	green	green	green
supply	0.392*** (0.085)		0.103* (0.057)	
customer		0.497*** (0.113)		0.124* (0.072)
cons	−7.166*** (0.691)	−7.187*** (0.689)	−6.459*** (0.410)	−6.464*** (0.400)
controls	YES	YES	YES	YES
FE	YES	YES	YES	YES
N	1546	1545	2761	2761
R^2	0.426	0.395	0.329	0.329

Note: The robustness standard errors of the coefficients are in parentheses; ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 9
Further analysis:From the perspective of industry nature.

	Pollute = 0		Pollute = 1	
	green	green	green	green
supply	0.172** (0.081)		0.215*** (0.059)	
customer		0.246** (0.108)		0.255*** (0.079)
cons	−7.367*** (0.527)	−7.393*** (0.529)	−5.886*** (0.459)	−5.890*** (0.459)
controls	YES	YES	YES	YES
FE	YES	YES	YES	YES
N	1323	1323	2805	2805
R^2	0.354	0.336	0.343	0.325

Note: The robustness standard errors of the coefficients are in parentheses; ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

The following policy implications are a direct result of the relevant research findings. First, enterprises have a crucial role in rejuvenating the real economy and achieving green transformation as a significant component of the market economy. Hence, to ensure consistent supply and sales, businesses should reduce their reliance on critical suppliers, adapt the level of supply chain consolidation based on market conditions, and establish wider collaborations with suppliers upstream and downstream in the supply chain. Enterprises should enhance the visibility of the supply chain and the accuracy of information sharing while also managing operational risks and asset specialization at a reasonable level, achieved by increasing the speed of capital turnover and establishing financial flexibility. Second, the government must prioritize promoting an efficient market by actively participating and using the incentives and regulations to encourage businesses to adopt green innovation. Governments at all levels must enhance regional marketization, legalization, and financialization based on the specific regional development conditions, eliminate transactions based on supply chain relationships, promote market-based transactions, and reinforce the market-oriented impact of green innovation in transitioning towards sustainability. Implement a regulatory framework tailored to the unique characteristics of the Chinese capital market. Take into account the effect of informal systems on businesses' environmental practices. Strengthen the oversight of supply chain relationships and promote the disclosure of information regarding transactions between upstream and downstream entities. Establish an early warning system for supply chain relationships to guide businesses in maintaining suitable and sustainable partnerships. Given the current high risk of disruption in the global supply chain, it is crucial for enterprise managers to engage in effective key account management proactively. This involves undertaking additional activities that recognize customers' economic significance, such as assigning dedicated personnel or even restructuring the organization to provide special treatment to large customers. By delivering superior products and services, they may establish enduring business connections, enhance their overall productivity, and ultimately increase corporate value.

While this study offers valuable information, specific limitations necessitate more investigation. The sample consists solely of listed Chinese enterprises, which may present a potential bias in the selection process. Therefore, future research should utilize sophisticated econometric methods to address these difficulties and explore the possibility of including more emerging economies.

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Declaration of competing interest

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Data availability

The authors do not have permission to share data.

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