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Article

The Impact of Supply Chain Network Position on Corporate Green Technology Innovation

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Abstract

As a critical form of social network in which firms are embedded, supply chain networks profoundly shape firms' strategic choices and the diversification of their innovation pathways. Drawing on a social network analysis framework, this study constructs firm-level supply chain networks using data on Chinese A-share listed companies from 2008 to 2023 and examines the impact of supply chain network position on corporate green technological innovation and its underlying mechanisms. The results show that both network centrality and structural hole advantages in supply chain networks significantly promote firms' green technological innovation. Mechanism tests further indicate that advantageous supply chain network positions foster green technological innovation through three channels: enhancing firms' absorptive capacity, increasing green investor attention, and strengthening supply chain stability. Heterogeneity analyses reveal that the promoting effect of supply chain network position is more pronounced in heavily polluting and highly competitive industries, as well as among state-owned enterprises and firms with higher asset specificity, stronger managerial green cognition, and lower financing constraints. Further analyses show that supply chain network position advantages significantly improve both environmental and economic performance by promoting green technological innovation, suggesting that such network advantages can be transformed into sustainable competitive advantages for firms.

Keywords: supply chain network position; absorptive capacity; green investor attention; supply chain stability; green technological innovation

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1. Introduction

The Report to the 20th National Congress of the Communist Party of China identified "promoting green development and fostering harmonious coexistence between humanity and nature" as a national strategy, and further emphasized that "promoting the green and low-carbon transformation of economic and social development is a key component of achieving high-quality development." This strategic orientation clarifies the fundamental direction of China's transition toward a comprehensive green and low-carbon development model and indicates that green transformation has become a core pathway and strategic choice for achieving high-quality development. As key actors in economic activities, firms are not only important practitioners of green transformation but also central drivers of this systemic change. With increasing resource and environmental constraints and rising public environmental awareness, firms' innovation activities have exhibited an increasingly green orientation. Through the systematic development and application of energy-saving, clean, and recyclable technologies and processes, green technological innovation can not only help firms reduce resource consumption and environmental costs and fulfill their environmental responsibilities, but also reshape production models and product structures, thereby fundamentally enhancing competitiveness. In particular, under increasingly stringent environmental regulations and the continuous expansion of green consumer markets, green technological innovation has become an important source of long-term competitive advantage for firms. Therefore, under the concept of green development, systematically promoting a green

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technological innovation system with firms as the core market actors is of great theoretical significance and strategic value.

In recent years, the determinants of corporate green technological innovation have mainly been examined from two dimensions: the external environment and the internal environment of the firm. With respect to the external environment, existing studies have primarily focused on environmental regulation, media attention, and policy instruments. First, the effect of environmental regulation on corporate green technological innovation remains contested. Some studies support the Porter hypothesis, arguing that environmental regulation encourages firms to shift toward environmentally friendly production and stimulates green innovation [1], whereas other studies contend that environmental regulation may crowd out firms' innovation space and thereby inhibit green technological innovation [2]. Second, media attention can promote corporate green technological innovation through channels such as improved corporate governance [3]. Both policy-oriented and market-oriented media attention have been found to exert significant positive effects on firms' green technological innovation [4]. Third, policy instruments such as green credit and fiscal subsidies can enhance green innovation by easing financing constraints and reducing R&D costs [5,6]. Regarding the internal environment, prior studies have mainly focused on executive teams, corporate capabilities, and governance structures. First, top managers' attention to environmental issues significantly affects firms' green innovation strategies [7], and executives with environmental backgrounds are better able to identify green innovation opportunities and make proactive investment decisions [8,9]. Second, firms' green governance structures and internal control mechanisms can promote green technological innovation by strengthening environmental awareness and reducing agency costs [10].

It can be seen that the existing literature has, to some extent, overlooked the influence of firms' network positions on green technological innovation from the perspective of network structure. As key actors in green technological innovation, firms do not innovate in isolation; rather, their innovation activities are embedded in supply chain networks composed of suppliers, customers, and business partners. Supply chain networks are not merely channels for the circulation of products and capital, but also important carriers for the transmission of information, technology, and even environmental governance pressure [11]. Differences in firms' positions within these networks may affect their abilities in information acquisition, resource integration, and interorganizational coordination, thereby influencing opportunity identification, risk taking, and the efficiency of transforming green innovation outcomes . Specifically, firms occupying central positions usually possess denser connections and stronger information access capabilities, which provide advantages in competitive position and risk-bearing capacity [12,13]. Firms occupying structural hole positions can connect otherwise disconnected groups and obtain non-redundant information. Their advantages in accessing heterogeneous resources and acting as intermediaries may generate differentiated innovation effects, but may also be accompanied by higher coordination costs and greater governance complexity, resulting in stronger contextual dependence [14–16]. Therefore, examining the determinants and mechanisms of corporate green technological innovation from the perspective of supply chain network structure is of important academic and practical significance for enriching green development theory and guiding firms' innovation practices.

Using non-financial A-share listed firms in Shanghai and Shenzhen from 2008 to 2023 as the research sample, this study constructs firm-level supply chain networks and systematically examines how firms' positions in these networks affect their green technological innovation and through what mechanisms. In particular, this study focuses on three channels—absorptive capacity, green investor attention, and supply chain relationship stability—to reveal the mechanisms through which network position influences green technological innovation. It also investigates heterogeneous effects across industry pollution intensity, competitive environment, ownership type, and financing constraints. The potential marginal contributions of this study are twofold. First, it extends the research perspective on the determinants of corporate green technological innovation. Existing studies have largely concentrated on drivers such as environmental regulation, policy incentives, and internal

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governance, while paying relatively limited attention to the role of supply chain network structure as a form of external embeddedness. To address this gap, this study adopts a supply chain network perspective and employs social network analysis to construct networks based on firms' top five suppliers and top five customers. It characterizes firms' network positions from the dimensions of centrality and structural holes, and systematically examines their effects on green technological innovation. In doing so, this study broadens the research boundary of green innovation determinants and enriches the empirical evidence in this field. This not only contributes theoretically to the literature on the relationship between supply chain networks and corporate green innovation, but also provides practical implications for firms seeking to leverage network position advantages to facilitate green transformation. Second, this study supplements the literature on the micro-level mechanisms through which supply chain network position affects corporate green technological innovation. Existing studies have mainly focused on the direct effects of supply chain networks on innovation, while discussions of intermediate transmission mechanisms remain fragmented. In particular, limited attention has been paid to the specific pathways through which network position advantages are converted into green innovation outcomes from the joint perspective of internal firm capabilities and external stakeholders. To fill this gap, this study systematically reveals that supply chain network position promotes green technological innovation through three channels: enhancing firms' absorptive capacity, increasing green investor attention, and strengthening supply chain relationship stability. This provides a more comprehensive theoretical perspective and empirical support for understanding the relationship between supply chain networks and corporate green innovation.

2. Theoretical Mechanisms and Research Hypotheses

2.1. Supply Chain Network Position and Corporate Green Technological Innovation

In a modern economic system characterized by a high degree of specialization and collaboration, firms are generally embedded in supply chain networks composed of suppliers and customers. Social network theory suggests that nodes in a network differ in the advantages conferred by their positions. Within supply chain networks, firms occupying more advantageous positions are more likely to obtain green technology-related knowledge, demand feedback, and complementary resources at lower information search costs and coordination frictions, thereby facilitating the implementation and diffusion of green technologies through upstream and downstream collaboration .

Specifically, on the one hand, firms located in central positions within supply chain networks possess more significant advantages in information acquisition, resource access, and relational coordination because they maintain direct or indirect connections with a larger number of upstream and downstream partners. Such firms can not only rapidly capture green-related knowledge, technologies, and market demand information through broad and efficient information channels, but can also rely on their resource acquisition capacity and relational coordination advantages to promote interorganizational collaborative innovation and accumulate social capital. In doing so, they effectively alleviate information asymmetry in the process of green innovation, reduce transaction and coordination costs, and mitigate uncertainties in the R&D and commercialization stages [17].

On the other hand, firms occupying structural hole positions play a bridging role by connecting relatively disconnected network groups, which enables them to access more heterogeneous information and resources. Such information is typically less redundant and can provide firms with new ideas and novel opportunities required for innovation. Accordingly, these firms are better able to integrate dispersed technological experience from upstream and downstream partners as well as market demand signals, thereby enhancing the flexibility and success rate of green technology development and application [18,19].

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Based on the above analysis, the following hypothesis is proposed:

H1. *Advantageous supply chain network positions, including network centrality and structural hole richness, contribute to the promotion of corporate green technological innovation.*

2.2. Supply Chain Network Position, Knowledge Absorptive Capacity, and Corporate Green Technology Innovation

Firms occupying advantageous positions within supply chain networks can more readily access rich, timely, and high-quality green-related information, while simultaneously operating in environments characterized by frequent inter-organizational interaction and learning. This facilitates greater efficiency in identifying, assimilating, and exploiting external knowledge, thereby enhancing knowledge absorptive capacity [20,21]. Li Guihua et al. (2020) [22] interpreted this dynamic from the perspective of knowledge acquisition and absorption, arguing that firms holding central positions in supply chain networks are better positioned to acquire and absorb valuable external knowledge elements, which in turn improves innovation performance. From the perspective of knowledge transformation and exploitation, they further noted that abundant structural holes enable firms to access heterogeneous resources, which can subsequently be transformed and leveraged to strengthen innovation capability.

Green technology innovation is fundamentally dependent on firms' capacity to acquire, assimilate, and exploit external knowledge—particularly the ability to translate technical information, application experience, and demand feedback from upstream and downstream supply chain partners and collaborative entities into actionable research and development (R&D) plans and deployable technological outcomes. In this process, knowledge absorptive capacity reflects a firm's ability to recognize the value of external knowledge, internalize it through organizational learning, and generate further innovations. It thus constitutes a critical mechanism through which external knowledge enters the firm's innovation process and is ultimately converted into innovation outputs [23]. As knowledge absorptive capacity improves, firms become increasingly capable of transforming external green knowledge into tangible innovation outcomes—including green patents, green process improvements, and green product development—thereby elevating the level of green technology innovation [24].

Based on the foregoing analysis, the following hypothesis is proposed:

H2: *A firm's supply chain network position advantage contributes to the enhancement of knowledge absorptive capacity, which in turn promotes corporate green technology innovation.*

2.3. Supply Chain Network Position, Green Investor Attention, and Corporate Green Technology Innovation

Firms occupying advantageous positions within the supply chain network are more likely to have their green behaviors and green capabilities recognized by capital markets, thereby attracting sustained attention from green investors. Firms with higher network centrality typically possess greater market visibility and more efficient information dissemination, making their green actions more easily identifiable to investors and enabling investors to form more stable patterns of attention and oversight toward them [25,26]. Firms with greater structural hole richness can leverage their cross-network resource integration capabilities to build a more differentiated green technology portfolio advantage, thereby helping investors more clearly identify their long-term growth potential and ultimately enhancing investor attention and willingness to hold shares in such firms [27,28].

Green investor attention reflects the capital market's preferences for identifying, monitoring, and allocating resources toward firms' green strategies and green behaviors. An increase in green investor attention influences corporate green technology innovation through two primary pathways: on the one hand, heightened green attention helps firms secure more stable financial support, alleviating the funding pressures associated with green R&D; on the other hand, the strengthening of external oversight further reinforces firms' intrinsic incentives and external constraints to pursue green

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innovation, driving firms to channel more resources toward green R&D activities and thereby affecting green innovation output [29]. As green investor attention increases, firms are more likely to raise their green R&D investment and ultimately improve green innovation output [30].

Based on the foregoing analysis, the following hypothesis is proposed:

H$_3$: *An advantageous supply chain network position helps enhance green investor attention, which in turn promotes corporate green technology innovation.*

2.4. Supply Chain Network Position, Supply Chain Stability, and Corporate Green Technology Innovation

Firms occupying advantageous positions in the supply chain network typically possess stronger reputations, greater bargaining power, and higher resource-matching efficiency, which enables them to establish long-term, stable cooperative relationships with upstream and downstream partners, thereby effectively reducing transactional uncertainty and improving supply chain stability [31]. Higher supply chain stability implies clearer cooperative expectations between firms and their key suppliers and core customers, lower risks of opportunistic behavior, and more sufficient information sharing, all of which contribute to advancing green technology innovation. This stability provides a guarantee for long-term cooperation, enabling firms to promote green material substitution, clean process transformation, and the implementation of green standards within enduring partnerships, and offering more reliable organizational and transactional safeguards for high-investment, long-cycle green R&D activities [32].

Supply chain stability not only strengthens the sustained interaction between firms and their upstream and downstream partners, but also enhances firms' capacity for continuous investment and risk tolerance in green technology innovation by reducing transactional uncertainty and improving cooperative expectations. In green technology innovation activities, higher supply chain stability more effectively promotes green innovation output, alleviates the financing and technological risks faced by firms, and strengthens the continuity and probability of success of innovation pathways [33,34].

Based on the foregoing analysis, the following hypothesis is proposed:

H$_4$: *An advantageous supply chain network position helps reinforce the stability of supply chain relationships, which in turn promotes corporate green technology innovation.*

3. Research Design

3.1. Model Specification

Using Chinese A-share non-financial listed companies over the period 2008–2023 as the research sample, this paper constructs the following model to examine the relationship between supply chain network position and corporate green technology innovation:

$$AGreen_{it}=\beta_0+\beta_1 Position_{it}+Controls_{it}+u_{ind}+v_t+\varepsilon_{it} \quad (1)$$

where AGreen denotes corporate green technology innovation; Position represents the firm's supply chain network position, measured by network centrality (Degree) and structural holes (SH) respectively; Controls denotes control variables; i indexes firms; t indexes years;μ_i denotes industry fixed effects; λ_t denotes year fixed effects; and ε_{it} is the error term.

3.2. Variable Selection

(1) Dependent Variable: Corporate Green Technology Innovation (AGreen). Corporate green technology innovation refers to the process by which firms, guided by the principles of ecological and economic development, pursue the coordinated goals of green technology advancement and pollution control, and continuously reduce pollutant emissions through technological innovation. Existing research widely holds that the number of green patent applications can directly and

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accurately reflect a firm's green technology innovation achievements and effectiveness. Accordingly, following Wang Yue et al. (2025) [35], this paper measures corporate green technology innovation by the number of green invention patent applications filed by firms, with a logarithmic transformation applied to the raw values.

(2) Core Explanatory Variable: Supply Chain Network Position (Position). This paper focuses on firms' central and bridging positions within the supply chain network. Following Shi Jinyan et al. (2019) [36], two widely used indicators are selected to measure supply chain network position: network centrality (Degree) and structural hole richness (SH). The specific construction process for these two indicators is as follows: ① Information on the names of the top five suppliers and customers disclosed by listed firms from 2009 to 2023 is extracted from the CSMAR database, retaining only those firms whose suppliers and customers are also domestically listed companies. ② The unified social credit codes of firms are matched to the listed firms and their top five suppliers and customers at the enterprise level. A network relationship list for each sample year is constructed using text editing software, and the relationship list is converted into a .net file using txt2pajek software, which is then imported into Pajek software to calculate supply chain network position data—namely network centrality and structural hole richness—for each year. Network centrality represents the degree to which a firm is positioned close to the core of the supply chain network, calculated as: Network Centrality = Number of network nodes directly connected to the firm / (Total number of nodes in the entire supply chain network − 1). A higher value indicates that more firms are linked to the focal firm, implying a more central position within the supply chain. Structural hole richness (SH) represents the gaps formed by firms that are not directly connected to one another, calculated as: Structural Hole Richness = 1 − Network Constraint Index. A lower value indicates more structural holes—that is, fewer direct business relationships—implying that the firm occupies a relatively dispersed network position; conversely, a higher value implies that the firm occupies a relatively dense network position.

(3) Control Variables. Firm size (Size), measured by the natural logarithm of total assets; leverage ratio (Lev), measured by the ratio of total liabilities to total assets; return on equity (ROE), measured by the ratio of net profit to average net assets; board size (Board), measured by the natural logarithm of the number of board members; operating cash flow ratio (CashFlow), measured by the ratio of net cash flows from operating activities to current liabilities; revenue growth rate (Growth), measured by (current period operating revenue − prior period operating revenue) / prior period operating revenue; proportion of independent directors (Indep), measured by the ratio of independent directors to total board members; CEO-Chairman duality (Dual), taking the value of 1 if the chairman and CEO are the same person, and 0 otherwise; and Tobin's Q (TobinQ), measured by (enterprise value + total liabilities) / total assets.

3.3. Data Sources

The data used in this study are sourced from the CSMAR Supply Chain Database, the China Innovation Patent Research Database (CIRD) under the China Research Data Service Platform (CNRDS), and the CSMAR Listed Companies Database. The sample covers A-share non-financial listed firms on the Shanghai and Shenzhen exchanges over the period 2008–2023. Based on the CSRC secondary industry classification, observations involving ST and ST* firms, firms listed for fewer than three years, and observations with missing values for key variables are excluded. Extreme values are addressed by winsorizing all variables at the 1% level. Missing values in control variables are also removed and winsorizing is applied to ensure continuous variables fall within reasonable ranges. The final dataset comprises an unbalanced panel of 11,948 firm-year observations. Descriptive statistics for all variables are presented in Table 1. The maximum value of green technology innovation is 3.912, the minimum is 0, the mean is 0.398, and the standard deviation is 0.841, indicating substantial variation in green technology innovation levels across firms. The maximum value of supply chain network centrality is 12, the minimum is 1, the mean is 4.421, and the standard deviation is 3.218, reflecting significant heterogeneity in network centrality. The maximum value of

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structural hole richness is 0.900, the minimum is 0, the mean is 0.551, and the standard deviation is 0.353, indicating considerable variation in structural hole richness. These results provide the empirical foundation for the subsequent analysis.

Table 1. Descriptive Statistics.

Variable	N	Mean	Sd	Min	p25	p50	p75	Max
AGreen	11948	0.398	0.841	0	0	0	0	3.912
Degree	11948	4.421	3.218	1	1	4	7	12
SH	11948	0.551	0.353	0	0	0.720	0.842	0.900
Size	11948	22.28	1.447	19.81	21.21	22.04	23.11	26.26
ROE	11948	0.0740	0.112	-0.479	0.0320	0.0770	0.127	0.343
Board	11948	2.157	0.198	1.609	2.079	2.197	2.197	2.708
Cashflow	11948	0.0470	0.0690	-0.155	0.00800	0.0460	0.0880	0.230
Growth	11948	0.159	0.342	-0.493	-0.0240	0.107	0.263	1.824
Indep	11948	37.12	5.154	30.77	33.33	33.33	40	57.14
Dual	11948	0.234	0.424	0	0	0	0	1
AC	11948	0.0440	0.0640	0	0.00900	0.0390	0.0430	0.464
Attention	11948	0.0650	0.123	0	0.00100	0.0170	0.0590	0.601
Cus	11948	0.509	0.274	-0.176	0.188	0.556	0.752	0.944
Sup	11948	0.614	0.270	-0.511	0.597	0.634	0.799	0.964

4. Results Analysis

4.1. Baseline Regression

Table 2 presents the regression results for the effect of supply chain network position on corporate green technology innovation. Columns (1) and (2) report results without control variables and without controlling for industry and year fixed effects. Columns (3) and (4) report results with control variables included and with both industry and year fixed effects controlled for. The results show that the estimated coefficients for network centrality (Degree) and structural hole richness (SH) are 0.0091 and 0.1189, respectively, and are statistically significant at the 5% and 1% significance levels, respectively. This indicates that when firms occupy a central position or a structural hole position within the supply chain network, their level of green technology innovation is higher. Hypothesis H1 is thus supported. When a firm's supply chain network centrality is higher, it indicates that the firm holds the advantage of being at the relational center of the supply chain network—that is, a greater number of network members are directly connected to the firm—which provides broader channels for the firm to exchange and acquire information and resources. When a firm occupies a greater abundance of structural holes, it indicates that the firm plays a more prominent bridging role, enabling it to access diverse types of knowledge and facilitating the acquisition of the knowledge and resources it needs. Both of these factors contribute to promoting corporate green technology innovation.

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Table 2. Baseline Regression Results.

	(1)	(2)	(3)	(4)
Degree	0.0207***		0.0091**	
	(9.80)		(2.07)	
SH		0.0954***		0.1189***
		(5.04)		(3.99)
Size			0.2031***	0.2044***
			(10.84)	(10.72)
ROE			0.2255***	0.2291***
			(2.59)	(2.63)
Board			0.1513	0.1521
			(1.54)	(1.56)
Cashflow			0.2555*	0.2670**
			(1.95)	(2.04)
Growth			-0.0521**	-0.0527**
			(-2.43)	(-2.46)
Indep			0.0020	0.0021
			(0.70)	(0.74)
Dual			0.0590**	0.0595**
			(2.00)	(2.02)
TobinQ			0.0183**	0.0185**
			(2.16)	(2.17)
_cons	0.2857***	0.3189***	-4.6401***	-4.6997***
	(18.49)	(19.84)	(-10.24)	(-10.07)
N	11948	11948	11948	11948
R^2	0.0127	0.0029	0.2394	0.2407
YearFE	No	No	YES	YES
IndustryFE	No	No	YES	YES

4.2. Robustness Checks

4.2.1. Replacing the Dependent Variable

Since the quality of green technology innovation more effectively reflects the external influence and knowledge spillover intensity of technological outcomes, this paper draws on Hall et al. (2005) [37] and employs the number of green patent citations (GPC) to measure the quality of corporate green technology innovation. Furthermore, to reduce potential estimation bias arising from self-citations, this paper follows Jaffe and Trajtenberg (2002) [38] and excludes firms' citations of their own patents from the calculation, so as to more accurately capture the true external influence of their green technologies. The regression results reported in Columns (1) and (2) of Table 3-1 show that the coefficients for network centrality (Degree) and structural hole richness (SH) are 0.1489 and 2.7743, respectively, and are statistically significant at the 5% and 1% levels, respectively, confirming the robustness of the baseline regression results.

4.2.2. Replacing the Explanatory Variables

Drawing on the studies of Guan Yujuan (2015) and Guo Jianjie et al. (2024) [39,40], this paper employs two additional widely used indicators of supply chain network position—closeness centrality (Closeness) and betweenness centrality (Betweenness)—to conduct robustness checks on the core explanatory variables. Closeness centrality measures the average distance between a firm and all other nodes in the network; a higher value indicates that the firm can reach other entities via shorter paths. Betweenness centrality measures the extent to which a firm lies on the shortest paths between other nodes; a higher value indicates that the firm plays a stronger role in information transmission and network connectivity. The regression results reported in Columns (3) and (4) of Table 3-1 show that the coefficients of closeness centrality (Closeness) and betweenness centrality (Betweenness) on green technology innovation (AGreen) are 2.1370 and 11.7632, respectively, both

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statistically significant at the 1% level, thereby confirming the robustness of the baseline regression results.

Table 3-1. Robustness Checks: Replacing Variables.

	Replacing DV		Replacing IV	
	(1) GPC	(2)GPC	(3)Closeness	(4)Betweeness
Degree	0.1489**		2.1370***	
	(0.0749)		(3.31)	
SH		2.7743***		11.7632***
		(0.5780)		(2.97)
Size	2.6870***	2.7412***	0.1952***	0.1960***
	(0.3985)	(0.4060)	(10.34)	(10.34)
ROE	0.5442	0.8170	0.2075**	0.2100**
	(2.4782)	(2.4596)	(2.37)	(2.41)
Board	4.9374**	4.9737**	0.1534	0.1543
	(2.0228)	(2.0189)	(1.56)	(1.57)
Cashflow	-0.0775	0.2719	0.2594**	0.2580**
	(2.3161)	(2.3103)	(1.99)	(1.97)
Growth	-1.4022*	-1.4083*	-0.0520**	-0.0507**
	(0.7334)	(0.7327)	(-2.42)	(-2.37)
Indep	0.0849	0.0899	0.0018	0.0020
	(0.0627)	(0.0623)	(0.63)	(0.68)
Dual	0.1549	0.1767	0.0589**	0.0576*
	(0.3830)	(0.3825)	(2.00)	(1.95)
TobinQ	0.5954***	0.6083***	0.0176**	0.0170**
	(0.2103)	(0.2102)	(2.08)	(2.00)
_cons	-72.3598***	-74.7570***	-4.4498***	-4.4559***
	(11.0085)	(11.1910)	(-9.74)	(-9.71)
N	11948	11948	11948	11948
R2	0.2093	0.2099	0.2465	0.2466
YearFE	YES	YES	YES	YES
IndustryFE	YES	YES	YES	YES

4.2.3. Excluding Municipalities Directly Under Central Government

Given the political, economic, and cultural distinctiveness of the four municipalities directly under the central government—Beijing, Shanghai, Tianjin, and Chongqing—observations from these four municipalities are excluded and the regressions are re-estimated to ensure the robustness of the findings. The regression results reported in Columns (1) and (2) of Table 3-2 show that the coefficients of supply chain network centrality (Degree) and structural hole richness (SH) on corporate green technology innovation (AGreen) are both significantly positive, confirming the robustness of the baseline regression results.

4.2.4. Excluding Exogenous Shocks

Given that the COVID-19 pandemic may have exerted a potential influence on the relationship between supply chain network position and corporate green technology innovation, observations from 2020 to 2022 are excluded to eliminate the confounding effects of the pandemic, and the regressions are re-estimated accordingly. The regression results reported in Columns (3) and (4) of Table 3-2 show that the coefficients of supply chain network centrality (Degree) and structural hole richness (SH) on corporate green technology innovation (AGreen) are both significantly positive, confirming the robustness of the baseline regression results.

4.2.5. Adopting the Tobit Model

Since corporate green technology innovation contains a large number of zero values, the estimates obtained via ordinary least squares may be subject to bias. Accordingly, this paper re-

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estimates the baseline model using the Tobit model. The results, reported in Columns (5) and (6) of Table 3-2, show that the coefficients of supply chain network centrality (Degree) and structural hole richness (SH) on corporate green technology innovation (AGreen) are both significantly positive, confirming the robustness of the baseline regression results.

Table 3-2. Robustness Checks: Replacing Variables.

	Excl. Municipalities		Excl. COVID		Tobit	
	(1)	(2)	(3)	(4)	(5)	(6)
Degree	0.0090^{*}		0.0125^{***}		0.0469^{***}	
	(1.82)		(2.60)		(3.45)	
SH		0.0988^{***}		0.1098^{***}		0.3239^{***}
		(2.99)		(3.50)		(3.21)
Size	0.2135^{***}	0.2142^{***}	0.1969^{***}	0.1970^{***}	0.5817^{***}	0.5730^{***}
	(9.72)	(9.55)	(10.27)	(10.14)	(13.82)	(13.65)
ROE	0.3134^{***}	0.3150^{***}	0.2443^{***}	0.2479^{***}	1.0810^{***}	1.0674^{***}
	(3.35)	(3.35)	(2.60)	(2.64)	(3.34)	(3.32)
Board	0.0466	0.0483	0.1533	0.1527	0.5569^{**}	0.5518^{**}
	(0.44)	(0.46)	(1.53)	(1.54)	(1.97)	(1.96)
Cashflow	0.1454	0.1507	0.1802	0.1881	0.8096	0.8166
	(1.02)	(1.06)	(1.32)	(1.38)	(1.60)	(1.62)
Growth	-0.0620^{**}	-0.0629^{**}	-0.0535^{**}	-0.0544^{***}	-0.1243	-0.1280
	(-2.51)	(-2.56)	(-2.56)	(-2.60)	(-1.48)	(-1.53)
Indep	0.0022	0.0022	0.0012	0.0012	0.0002	-0.0005
	(0.66)	(0.67)	(0.43)	(0.42)	(0.03)	(-0.06)
Dual	0.0482	0.0483	0.0770^{**}	0.0765^{**}	0.1279	0.1239
	(1.48)	(1.48)	(2.57)	(2.56)	(1.43)	(1.39)
TobinQ	0.0183^{*}	0.0183^{*}	0.0162^{*}	0.0162^{*}	-0.0517	-0.0543
	(1.93)	(1.92)	(1.83)	(1.82)	(-1.54)	(-1.62)
_cons	-4.6423^{***}	-4.6760^{***}	-4.5099^{***}	-4.5160^{***}	-17.2129^{***}	-16.9837^{***}
	(-8.81)	(-8.59)	(-9.64)	(-9.40)	(-13.51)	(-13.34)
var(e.y)					3.8663^{***}	3.8630^{***}
					(25.00)	(25.01)
N	9658	9658	9531	9531	11948	11948
r^2	0.2248	0.2254	0.2347	0.2349		
Year	YES	YES	YES	YES	YES	YES
Ind	YES	YES	YES	YES	YES	YES
Company	NO	NO	NO	NO	NO	NO

4.3. Endogeneity Tests

To mitigate potential sample selection bias arising from differences in observable characteristics, this paper employs the Propensity Score Matching (PSM) method for this purpose. Specifically, firms are divided into a treatment group (treat = 1) and a control group (treat = 0) based on the sample median of supply chain network centrality (Degree), with control variables including Size, Lev, and ROE used as covariates to estimate propensity scores, and 1:1 nearest-neighbor matching applied to obtain the matched sample. The results of the balance test indicate that, after matching, the differences between the treatment group and the control group in terms of key covariates converge significantly, and the sample satisfies the common support condition. Model (1) is re-estimated using the matched sample, and the same procedure is applied to supply chain network structural hole richness (SH). The regression results reported in Columns (1) and (2) of Table 4 show that the coefficients of supply chain network centrality (Degree) and structural hole richness (SH) on corporate green technology innovation (AGreen) are both significantly positive, further confirming the robustness of the baseline regression results.

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Table 4. Endogeneity Tests (PSM).

	(1)	(2)
Degree	0.0168***	
	(3.15)	
SH		0.1358***
		(4.03)
Size	0.1895***	0.1938***
	(9.11)	(9.39)
ROE	0.1559	0.2493**
	(1.55)	(2.26)
Board	0.1161	0.1556
	(1.02)	(1.58)
Cashflow	0.2599	0.3159**
	(1.47)	(1.97)
Growth	-0.0542*	-0.1003***
	(-1.90)	(-3.55)
Indep	0.0026	0.0046
	(0.70)	(1.48)
Dual	0.0604*	0.0485
	(1.71)	(1.39)
TobinQ	0.0076	0.0183*
	(0.89)	(1.74)
_cons	-4.2961***	-4.5621***
	(-8.60)	(-9.38)
N	5686	6179
r^2	0.2328	0.2594
Year	YES	YES
Ind	YES	YES

4.4. Mechanism Tests

The preceding analysis has systematically demonstrated the promoting effect of supply chain network position on corporate green technology innovation, showing that firms occupying advantageous positions in the supply chain network can leverage their informational, resource, and relational advantages to enhance green technology innovation. But through what specific pathways is this effect realized? To address this question, this paper conducts mechanism tests along two dimensions—firms' internal capabilities and external stakeholders—focusing on three channels: knowledge absorptive capacity, green investor attention, and supply chain stability, so as to further illuminate the underlying mechanisms through which supply chain network position influences corporate green technology innovation.

4.4.1. Enhancing Knowledge Absorptive Capacity

Knowledge absorptive capacity reflects a firm's ability to identify, absorb, utilize, and deploy available external knowledge (Cohen and Levinthal, 1990). Following Jia Huiying et al. (2018) [41], this paper measures corporate knowledge absorptive capacity (Absorptive Capacity, AC) by the ratio of R&D expenditure to operating revenue; a higher value of this indicator represents stronger knowledge absorptive capacity. Columns (1) and (2) of Table 5 report the effects of supply chain network position on corporate knowledge absorptive capacity. The regression results show that the estimated coefficients of supply chain network centrality (Degree) and structural hole richness (SH) on knowledge absorptive capacity (AC) are 0.0037 and 0.0099, respectively, both statistically significant at the 1% level, indicating that firms occupying advantageous positions in the supply chain network exhibit significantly stronger knowledge absorptive capacity. Meanwhile, existing research has shown that knowledge absorptive capacity constitutes an important internal foundation for driving corporate green technology innovation; firms with stronger absorptive capacity are better able to identify and assimilate external green technology knowledge, environmental regulatory

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information, and advanced production processes, and to convert these into green patents and process improvements, thereby significantly enhancing green technology innovation performance [42–44]. Therefore, the advantages of supply chain network centrality and structural holes promote corporate green technology innovation by enhancing firms' knowledge absorptive capacity, and Hypothesis H2 is supported.

Table 5. Mechanism Test Results.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	AC		Attention		Sup		Cus	
Degree	0.0037***		0.0115***		0.0212***		0.0222***	
	(6.71)		(15.28)		(20.18)		(20.34)	
SH		0.0099***		0.0456***		0.1685***		0.2005***
		(4.25)		(11.78)		(18.69)		(20.23)
Size	0.0014*	0.0004	0.0090***	0.0065***	0.0095***	0.0081***	-0.0118***	-0.0123***
	(1.71)	(0.51)	(7.28)	(4.97)	(3.23)	(2.74)	(-3.88)	(-3.97)
ROE	-0.0118*	-0.0146**	0.0600***	0.0529***	0.0450*	0.0412	0.1064***	0.1052***
	(-1.71)	(-2.12)	(5.64)	(4.84)	(1.78)	(1.62)	(3.73)	(3.68)
Board	0.0007	-0.0001	-0.0108	-0.0127	-0.0024	-0.0036	-0.0147	-0.0153
	(0.15)	(-0.01)	(-1.33)	(-1.54)	(-0.13)	(-0.20)	(-0.81)	(-0.83)
Cashflow	-0.0119	-0.0151	0.0087	0.0018	0.1000***	0.1044***	0.0403	0.0499
	(-1.07)	(-1.34)	(0.50)	(0.10)	(2.63)	(2.73)	(0.94)	(1.17)
Growth	-0.0054***	-0.0057***	0.0094***	0.0086**	-0.0182***	-0.0196***	-0.0651***	-0.0665***
	(-3.21)	(-3.33)	(2.88)	(2.55)	(-2.67)	(-2.85)	(-7.29)	(-7.47)
Indep	-0.0002	-0.0003**	-0.0001	-0.0004	0.0000	-0.0002	-0.0005	-0.0007
	(-1.43)	(-2.13)	(-0.25)	(-1.39)	(0.02)	(-0.32)	(-0.80)	(-1.01)
Dual	0.0059***	0.0054***	0.0076**	0.0063**	0.0055	0.0047	-0.0034	-0.0038
	(3.05)	(2.76)	(2.48)	(2.02)	(0.79)	(0.68)	(-0.48)	(-0.54)
TobinQ	0.0035***	0.0031***	0.0036***	0.0027**	0.0018	0.0011	-0.0020	-0.0025
	(3.94)	(3.57)	(3.01)	(2.30)	(0.67)	(0.40)	(-0.74)	(-0.92)
_cons	-0.0023	0.0381**	-0.1748***	-0.0741**	0.1987***	0.2428***	0.8360***	0.8410***
	(-0.12)	(2.15)	(-5.48)	(-2.28)	(2.68)	(3.29)	(10.94)	(10.84)
N	11948	11948	11948	11948	11948	11948	11948	11948
r^2	0.2025	0.1782	0.2255	0.1694	0.2592	0.2525	0.1323	0.1389
Year	YES	YES	YES	YES	YES	YES	YES	YES
Ind	YES	YES	YES	YES	YES	YES	YES	YES

4.4.2. Strengthening Green Investor Attention

Green investor attention reflects the capital market's tendency to identify and allocate resources toward firms' green behaviors, and may influence firms' green R&D investment and innovation incentives through channels such as financing support and external monitoring. Following Jiang Guangsheng et al. (2021) [29], this paper uses green investment funds as representatives of green institutional investors, aggregates the shareholding ratios of green funds in a given firm at the quarterly level, and computes the arithmetic mean of quarterly values at the annual level to measure the green investor attention received by each firm (Attention). Columns (3) and (4) of Table 5 report the effects of supply chain network position on green investor attention. The regression results show that the estimated coefficients of supply chain network centrality (Degree) and structural hole richness (SH) on green investor attention (Attention) are 0.0115 and 0.0456, respectively, both statistically significant at the 1% level, indicating that firms occupying advantageous positions in the supply chain network are more likely to receive sustained attention from green investors. Meanwhile, existing research has shown that green investor attention constitutes an important external governance mechanism for driving corporate green technology innovation. On the one hand, institutional investors with environmental preferences exert external constraints and incentives on firms' environmental behavior through capital allocation and exit mechanisms, combined with ongoing monitoring [26][44]; on the other hand, the entry of green institutional investors helps alleviate the financing constraints faced by firms in pursuing green innovation, reduces the

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uncertainty risks associated with green R&D activities, and thereby improves both the quantity and quality of green technology innovation [27,28]. Therefore, the advantages of supply chain network centrality and structural holes strengthen the external incentive and constraint mechanisms of capital markets toward firms' green behaviors by enhancing green investor attention, and in so doing promote corporate green technology innovation. Hypothesis H3 is supported.

4.4.3. Reinforcing Supply Chain Stability

Supply chain stability characterizes the continuity and predictability of a firm's cooperative relationships with its major suppliers and customers, helps reduce transactional uncertainty, and strengthens cross-organizational coordination, thereby providing more stable organizational and transactional conditions for green R&D activities that require high investment and long development cycles [45]. Drawing on the measurement approach for customer stability proposed by Pan Hongbo and Zhang Zhe (2020) [46], this paper uses the lists of a firm's top five customers and top five suppliers to calculate, for each year, the number of top five customers (suppliers) that overlap with those of the previous year, divided by 5 to obtain customer stability (Cus) and supplier stability (Sup). These two indicators are further standardized at the firm-year level to represent the firm's overall supply chain stability. The regression results reported in Columns (5) through (8) of Table 5 show that the coefficients of network centrality (Degree) and structural holes (SH) on supplier stability (Sup) and customer stability (Cus) are all significantly positive, indicating that firms occupying advantageous positions in the supply chain network are able to form more stable upstream and downstream cooperative relationships. Meanwhile, existing research has shown that customer relationship stability can significantly promote firms' technological innovation activities, while supplier relationship stability also affects firms' innovation output [47]; furthermore, from the perspective of green transformation, supply chain stability can effectively promote corporate green technology innovation [48]. Therefore, the advantages of supply chain network centrality and structural holes promote corporate green technology innovation by reinforcing the stability of firms' cooperative relationships with their major customers and suppliers, thereby providing more stable external conditions for green R&D investment and sustained innovation activities. Hypothesis H4 is supported.

4.5. Heterogeneity Analysis

Although the preceding analysis has examined in considerable detail the effect of supply chain network position on corporate green technology innovation and its underlying mechanisms, the heterogeneity of this effect across different contexts has not yet been fully explored. Given the differences in industry characteristics and firm characteristics, the effect of supply chain network position on green technology innovation may vary substantially. Accordingly, this paper further conducts heterogeneity analysis along two dimensions: the industry dimension and the firm dimension.

4.5.1. Industry-Level Heterogeneity

(1) Degree of Industry Competition

Given that firms operating in industries with different levels of competition occupy different roles and positions within the supply chain network, the effect of supply chain network position on corporate green technology innovation may vary accordingly. Compared with firms in less competitive industries, firms in highly competitive industries tend to rely more heavily on green technology innovation to maintain market share and competitive advantage, thereby achieving differentiated development and improvements in cost efficiency [49]. Accordingly, following Liu Liya et al. (2017) [50], this paper adopts the Lerner Index (L) to measure the degree of industry competition, calculated as: (firm operating revenue − operating costs − selling expenses − administrative expenses) / operating revenue. Using the sample median as the threshold, firms are

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divided into high-competition and low-competition industry groups. The results, reported in Columns (1) through (4) of Table 6, show that among firms in high-competition industries, the coefficients of supply chain network centrality (Degree) and structural hole richness (SH) are 0.0164 and 0.1848, respectively, both statistically significant at the 1% level, whereas among firms in low-competition industries, the coefficients are both insignificant. This indicates that in highly competitive industries, the positional advantage of supply chain network structural holes has a significantly positive effect on corporate green technology innovation.

Table 6. Industry-level heterogeneity analysis.

	High Competition		Low Competition		Heavy Pollution		Low Pollution	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Degree	0.0164***		0.0023		0.0313***		-0.0023	
	(2.70)		(0.41)		(4.80)		(-0.42)	
SH		0.1848***		0.0601		0.2097***		0.0801**
		(4.42)		(1.63)		(4.60)		(2.09)
Size	0.2246***	0.2247***	0.1880***	0.1899***	0.1563***	0.1560***	0.2179***	0.2230***
	(9.05)	(9.01)	(8.75)	(8.64)	(6.66)	(6.53)	(8.99)	(8.94)
ROE	0.2553**	0.2611**	0.1779	0.1835	0.0704	0.0547	0.3510***	0.3607***
	(2.44)	(2.50)	(0.99)	(1.02)	(0.70)	(0.54)	(2.80)	(2.86)
Board	0.1596	0.1603	0.1504	0.1510	0.0611	0.0551	0.2076	0.2109
	(1.11)	(1.13)	(1.48)	(1.48)	(0.53)	(0.48)	(1.52)	(1.55)
Cashflow	0.4489**	0.4602**	0.1214	0.1301	0.5220***	0.5278***	0.1411	0.1655
	(2.42)	(2.49)	(0.67)	(0.72)	(2.99)	(3.00)	(0.82)	(0.96)
Growth	-0.0789***	-0.0797***	-0.0323	-0.0326	-0.0753**	-0.0788**	-0.0387	-0.0382
	(-2.81)	(-2.84)	(-1.08)	(-1.09)	(-2.36)	(-2.44)	(-1.41)	(-1.40)
Indep	0.0023	0.0022	0.0030	0.0031	0.0022	0.0014	0.0019	0.0024
	(0.58)	(0.57)	(0.83)	(0.87)	(0.53)	(0.34)	(0.48)	(0.60)
Dual	0.0709*	0.0720*	0.0539	0.0547	0.0362	0.0355	0.0674*	0.0688*
	(1.75)	(1.79)	(1.55)	(1.57)	(1.05)	(1.02)	(1.76)	(1.80)
TobinQ	0.0265**	0.0258**	0.0150	0.0157	-0.0027	-0.0055	0.0307***	0.0316***
	(2.33)	(2.30)	(1.24)	(1.30)	(-0.26)	(-0.53)	(2.78)	(2.86)
_cons	-5.1951***	-5.2261***	-4.2937***	-4.3678***	-3.5608***	-3.4784***	-5.0103***	-5.2056***
	(-8.06)	(-7.97)	(-8.55)	(-8.47)	(-5.82)	(-5.64)	(-8.52)	(-8.53)
N	5974	5974	5974	5974	4003	4003	7945	7945
r^2	0.2593	0.2614	0.2572	0.2577	0.2967	0.2905	0.2342	0.2350
Year	YES	YES	YES	YES	YES	YES	YES	YES
Ind	YES	YES	YES	YES	YES	YES	YES	YES

(2) Degree of Industry Pollution

Given that firms in industries with different levels of pollution face significantly different environmental regulatory constraints and pressures for green transformation, the effect of supply chain network position on corporate green technology innovation may exhibit heterogeneity across industries with varying degrees of pollution. Compared with firms in less polluting industries, firms in heavily polluting industries typically face more stringent environmental regulations and social scrutiny; in order to meet emission constraints and reduce compliance costs, their production processes and product structures rely more heavily on green technology innovation as a key response mechanism. Accordingly, following Qian Xianhang et al. (2025) [51], this paper classifies the industries to which sample firms belong according to their pollution emission intensity and environmental regulatory standards, dividing the sample into a heavily polluting industry group and a non-heavily polluting industry group. The results, reported in Columns (5) through (8) of Table 6, show that among firms in heavily polluting industries, the coefficients of supply chain network centrality (Degree) and structural hole richness (SH) are 0.0313 and 0.2097, respectively, both statistically significant at the 1% level. In the low-pollution industry group, the coefficient of network centrality (Degree) is insignificant, while the coefficient of structural hole richness (SH) is 0.0801, statistically significant at the 5% level, but lower than the corresponding coefficient in the heavily

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polluting industry group. This indicates that when firms belong to heavily polluting industries, the positional advantage of supply chain network position has a significantly stronger promoting effect on corporate green technology innovation.

4.5.2. Firm-Level Heterogeneity

(1) Firm Ownership Type

Given that differences in firm ownership affect the incentive structures and resource allocation mechanisms for corporate green technology innovation, the effect of supply chain network position on green technology innovation may differ between state-owned and non-state-owned enterprises. Compared with non-state-owned enterprises, state-owned enterprises typically bear stronger policy objectives and social responsibility constraints, and enjoy relative advantages in resource acquisition, financing support, and external coordination, enabling them to more effectively translate their positional advantages in the supply chain network into green technology innovation outcomes [52,53]. Accordingly, this paper divides the sample into a state-owned enterprise group and a non-state-owned enterprise group based on ownership type. The results, reported in Columns (1) through (4) of Table 7, show that among state-owned enterprises, the coefficients of supply chain network centrality (Degree) and structural hole richness (SH) are 0.0210 and 0.1921, respectively, both statistically significant at the 1% level. Among non-state-owned enterprises, the coefficient of network centrality (Degree) is insignificant, while the coefficient of structural hole richness (SH) is 0.0645, significant at the 10% level, but lower than the corresponding coefficient in the state-owned enterprise group. This indicates that among state-owned enterprises, supply chain network centrality and structural hole position have a significantly positive promoting effect on corporate green technology innovation.

(2) Firm Asset Specificity

Given that differences in asset specificity affect firms' flexibility in resource allocation, the costs of technological adjustment, and their degree of dependence on external collaborative resources, the effect of supply chain network position on corporate green technology innovation may be heterogeneous across firms with different levels of asset specificity. Firms with higher asset specificity typically have committed greater amounts of non-redeployable specialized assets to particular technological trajectories and transactional relationships; their production systems thus face higher technological adjustment costs and stronger path dependencies, making them more reliant on upstream and downstream coordination as well as external knowledge and resource support during the process of technological upgrading and green transformation [54,55]. In this context, firms occupying advantageous positions in the supply chain network are better able to obtain the critical inputs required for green technology innovation through cross-organizational coordination, information sharing, and resource integration, thereby amplifying the promoting effect of supply chain network position on green technology innovation [56]. Accordingly, drawing on Williamson's (1985) [33] theoretical definition of the non-redeployability of specialized assets, this paper measures firm asset specificity by the degree of renewal of assets with specialized characteristics among non-current assets and intangible assets, and divides firms into a high asset specificity group and a low asset specificity group based on the sample median. The results, reported in Columns (5) through (8) of Table 7, show that among firms with high asset specificity, the estimated coefficients of supply chain network centrality (Degree) and structural holes (SH) are 0.0149 and 0.1311, statistically significant at the 5% and 1% levels, respectively. Among firms with low asset specificity, the coefficient of network centrality (Degree) is insignificant, while the coefficient of structural hole richness (SH) is 0.1107, significant at the 1% level, but lower than the corresponding coefficient in the high asset specificity group. This indicates that among firms with high asset specificity, the positional advantages of supply chain network centrality and structural holes have a significantly positive promoting effect on corporate green technology innovation.

(3) Executive Green Cognition

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Given that the cognitive structures of top managers influence firms' strategic decision-making orientations and the manner in which external resources are allocated, the effect of supply chain network position on corporate green technology innovation is moderated by differences in executives' level of green cognition. Executive green cognition refers to the degree to which top managers understand and attach importance to green technology innovation and its long-term strategic value. Existing research has shown that executives with higher levels of green cognition are more capable of recognizing the latent value embedded in green technology innovation and are more proactive in strategically driving firms' green innovation activities . Following the research approaches of Duriau, Reger and Pfarrer (2007) [57] and Gamache et al. (2015) [58], this paper selects keywords along three dimensions—cognition of green competitive advantage, cognition of corporate social responsibility, and perception of external environmental pressure—and measures executive green cognition based on word frequency analysis of annual report texts. The results, reported in Columns (9) through (12) of Table 7, show that among firms with higher executive green cognition, the estimated coefficients of supply chain network centrality (Degree) and structural holes (SH) are 0.0140 and 0.2539, statistically significant at the 5% and 1% levels, respectively. Among firms with lower executive green cognition, both the coefficients of network centrality (Degree) and structural hole richness (SH) are insignificant. This indicates that among firms with higher executive green cognition, the positional advantages of supply chain network centrality and structural holes have a significantly positive promoting effect on corporate green technology innovation.

(4) Financing Constraints

Given that financing constraints affect firms' resource availability and risk tolerance for green technology innovation, the effect of supply chain network position on corporate green technology innovation may be heterogeneous across firms with different levels of financing constraints. Green technology R&D is typically characterized by high investment requirements, high risk, and long development cycles; firms with lower financing constraints are better equipped with the financial foundation and risk-buffering capacity needed to sustain green technology innovation activities on an ongoing basis [59]. Accordingly, following Yu Mingui (2019) [60], this paper adopts the SA index to measure firms' financing constraint levels, and divides firms into a high financing constraint group and a low financing constraint group based on the sample median. The results, reported in Columns (13) through (16) of Table 7, show that among firms with lower financing constraints, the estimated coefficients of supply chain network centrality (Degree) and structural hole richness (SH) are 0.0181 and 0.1719, respectively, both statistically significant at the 1% level. Among firms with higher financing constraints, both the coefficients of network centrality (Degree) and structural hole richness (SH) are insignificant. This indicates that among firms with lower financing constraints, the positional advantages of supply chain network centrality and structural holes have a significantly positive promoting effect on corporate green technology innovation.

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Table 7-1. Heterogeneity Analysis at the Firm Level.

	SOE		Non-SOE		High Asset Specificity		Low Asset Specificity	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Degree	0.0210***		-0.0019		0.0149**		0.0041	
	(2.98)		(-0.38)		(2.48)		(0.72)	
SH		0.1921***		0.0645*		0.1311***		0.1107***
		(4.04)		(1.66)		(3.18)		(2.81)
Size	0.1767***	0.1757***	0.2125***	0.2171***	0.2048***	0.2037***	0.2004***	0.2030***
	(7.38)	(7.30)	(6.51)	(6.44)	(8.25)	(8.03)	(8.42)	(8.43)
ROE	0.0699	0.0728	0.4231***	0.4364***	0.2219**	0.2267**	0.2559**	0.2625**
	(0.57)	(0.60)	(3.67)	(3.79)	(2.04)	(2.09)	(2.08)	(2.12)
Board	0.2332	0.2329*	0.0432	0.0433	0.1828	0.1809	0.0744	0.0810
	(1.64)	(1.65)	(0.37)	(0.37)	(1.25)	(1.25)	(0.70)	(0.77)
Cashflow	0.3875*	0.3889*	0.1240	0.1432	0.0643	0.0704	0.4302***	0.4503***
	(1.81)	(1.82)	(0.79)	(0.91)	(0.31)	(0.34)	(2.68)	(2.80)
Growth	-0.0212	-0.0226	-0.0725**	-0.0716**	-0.1030***	-0.1043***	-0.0124	-0.0127
	(-0.75)	(-0.80)	(-2.26)	(-2.23)	(-3.89)	(-3.95)	(-0.39)	(-0.40)
Indep	0.0004	0.0003	0.0040	0.0042	0.0039	0.0038	0.0004	0.0008
	(0.11)	(0.08)	(1.04)	(1.11)	(0.92)	(0.89)	(0.11)	(0.24)
Dual	0.1009*	0.1030*	0.0699**	0.0706**	0.0433	0.0420	0.0604	0.0621
	(1.73)	(1.78)	(2.14)	(2.16)	(1.14)	(1.11)	(1.57)	(1.61)
TobinQ	0.0104	0.0105	0.0172*	0.0182**	-0.0036	-0.0044	0.0397***	0.0407***
	(0.60)	(0.60)	(1.88)	(1.96)	(-0.38)	(-0.47)	(3.00)	(3.07)
_cons	-4.2511***	-4.2378***	-4.6050***	-4.7632***	-4.7683***	-4.7389***	-4.3963***	-4.5286***
	(-6.87)	(-6.78)	(-6.08)	(-6.00)	(-8.07)	(-7.77)	(-7.74)	(-7.77)
N	5663	5663	6285	6285	5974	5974	5974	5974
r^2	0.3140	0.3145	0.2101	0.2108	0.2585	0.2585	0.2723	0.2741
Year	YES	YES	YES	YES	YES	YES	YES	YES
Ind	YES	YES	YES	YES	YES	YES	YES	YES

Table 7-2. Heterogeneity Analysis at the Firm Level.

	High Green Cognition		Low Green Cognition		Low Financing Constraints		High Financing Constraints	
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Degree	0.0140**		0.0076		0.0181***		0.0013	
	(2.27)		(1.39)		(2.81)		(0.23)	
SH		0.2539***		0.0251		0.1719***		0.0354
		(5.36)		(0.74)		(4.07)		(0.93)
Size	0.2256***	0.2282***	0.1772***	0.1753***	0.2390***	0.2382***	0.1428***	0.1442***
	(7.94)	(8.02)	(9.74)	(9.46)	(9.51)	(9.41)	(7.46)	(7.32)
ROE	0.2519	0.2578*	0.2369**	0.2320**	0.1377	0.1441	0.2816***	0.2838***
	(1.65)	(1.70)	(2.48)	(2.43)	(1.00)	(1.05)	(2.73)	(2.76)
Board	0.2287	0.2288	0.1159	0.1147	0.1333	0.1308	0.1685	0.1703
	(1.52)	(1.55)	(1.12)	(1.11)	(1.03)	(1.02)	(1.53)	(1.55)
Cashflow	0.1951	0.2393	0.2839**	0.2787**	0.2946	0.3041*	0.1887	0.1940
	(0.77)	(0.95)	(2.04)	(2.00)	(1.62)	(1.67)	(1.13)	(1.16)
Growth	-0.1064**	-0.1045**	-0.0230	-0.0242	-0.0289	-0.0303	-0.0563**	-0.0567**
	(-2.48)	(-2.44)	(-1.04)	(-1.10)	(-0.86)	(-0.91)	(-2.30)	(-2.32)
Indep	0.0043	0.0044	0.0009	0.0006	0.0009	0.0009	0.0021	0.0022
	(0.95)	(0.99)	(0.27)	(0.20)	(0.23)	(0.23)	(0.61)	(0.63)
Dual	0.0933*	0.0958*	0.0461	0.0455	0.0668*	0.0664*	0.0182	0.0181
	(1.82)	(1.89)	(1.59)	(1.57)	(1.68)	(1.67)	(0.52)	(0.52)
TobinQ	0.0037	0.0041	0.0213***	0.0207**	0.0165	0.0162	0.0164	0.0168
	(0.21)	(0.23)	(2.66)	(2.56)	(1.30)	(1.27)	(1.61)	(1.64)
_cons	-5.3600***	-5.5037***	-3.9784***	-3.9043***	-5.3037***	-5.3011***	-3.3603***	-3.4125***
	(-7.83)	(-7.91)	(-8.87)	(-8.55)	(-9.15)	(-8.90)	(-6.96)	(-6.83)
N	4766	4766	7182	7182	5974	5974	5974	5974
r^2	0.3010	0.3073	0.1990	0.1983	0.3201	0.3211	0.1923	0.1925
Year	YES	YES	YES	YES	YES	YES	YES	YES
Ind	YES	YES	YES	YES	YES	YES	YES	YES

5. Further Analysis

Firm performance is a core indicator for measuring the effectiveness of green transformation strategies, and serves as a key basis for evaluating whether the positional advantages of supply chain

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networks can be effectively converted into actual value creation. Having established that supply chain network position significantly promotes corporate green technology innovation, this section further incorporates firm performance into the analytical framework to explore whether supply chain network position can ultimately achieve substantial improvements in firm performance by driving corporate green technology innovation. Firm performance is disaggregated into two dimensions: environmental performance and economic performance. Corporate environmental performance (EP) is measured following Qu Yuxiao (2023) [61], drawing on the CSMAR Environmental Research Database to construct a comprehensive scoring index system encompassing pollutant emission control, pollution abatement investment, cleaner production measures, and environmental management system development. Corporate economic performance (ROA) is measured by return on assets, with the ratio of net profit to total assets serving as the proxy variable. To further examine the economic consequences of the effect of supply chain network position on corporate green technology innovation, this paper constructs the following model for empirical analysis:

$$\begin{gathered} Performance_{it} = \alpha_0 + \alpha_1 Position_{it} \times AGreen_{it} + \alpha_2 AGreen_{it} \\ +\alpha_3 Position_{it} + \ Controls_{it} + u_{ind} + v_t + \varepsilon_{it} \end{gathered} \tag{2}$$

where Performance denotes firm performance, comprising environmental performance (EP) and economic performance (ROA). All remaining variables are defined consistently with Model (1).

The regression results, reported in Table 8, show that the coefficients of supply chain network centrality (Degree) and structural hole richness (SH) on environmental performance (EP) are 0.0249 and 0.2520, respectively, both statistically significant at the 1% level; the corresponding coefficients on economic performance (ROA) are 0.0034 and 0.0260, statistically significant at the 5% and 10% levels, respectively. These results indicate that the positional advantages of supply chain networks can indeed promote improvements in both firms' environmental performance and economic performance through driving green innovation.

Table 8. Supply Chain Network Location, Green Technology Innovation and Corporate Performance.

	EP		**ROA**	
	(1)	(2)	(3)	(4)
AGreen	0.1178***	0.0824*	0.0063	0.0039
	(0.0375)	(0.0437)	(0.0082)	(0.0097)
Degree	0.0175**		0.0041**	
	(0.0076)		(0.0018)	
Degree*AGreen	0.0249***		0.0034**	
	(0.0077)		(0.0015)	
SH		0.2520***		0.0236*
		(0.0565)		(0.0143)
SH*AGreen		0.2180***		0.0260*
		(0.0687)		(0.0140)
Size	0.6459***	0.6521***	-0.0036	-0.0042
	(0.0161)	(0.0161)	(0.0048)	(0.0048)
Board	0.5877***	0.6032***	-0.0746**	-0.0734**
	(0.1109)	(0.1106)	(0.0324)	(0.0324)
Cashflow	2.2538***	2.3297***	3.1023***	3.1031***
	(0.2556)	(0.2554)	(0.0925)	(0.0926)
Growth	-0.1313***	-0.1304***	0.3450***	0.3443***
	(0.0480)	(0.0480)	(0.0189)	(0.0189)
Indep	0.0025	0.0035	-0.0031***	-0.0031***
	(0.0041)	(0.0040)	(0.0011)	(0.0011)
Dual	-0.1015**	-0.0976**	0.0495***	0.0493***
	(0.0401)	(0.0401)	(0.0125)	(0.0125)
_cons	-14.1311***	-14.4015***	0.5219***	0.5349***
	(0.4347)	(0.4348)	(0.1145)	(0.1150)
N	10320	10320	10320	10320
r^2	0.3947	0.3961	0.2507	0.2503
Year	YES	YES	YES	YES
Ind	YES	YES	YES	YES

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6. Conclusions and Policy Implications

6.1. Conclusions

Using Chinese A-share non-financial listed firms from 2008 to 2023 as the research sample, this study constructs firm-level supply chain networks based on the top five customers and top five suppliers disclosed by listed companies and systematically examines the impact of firms’ supply chain network positions on green technological innovation from the perspective of network structure. The main conclusions are as follows. First, both supply chain network centrality and structural hole advantages significantly promote corporate green technological innovation. This conclusion remains robust after replacing variable measures, adjusting the sample, and changing estimation methods. Second, mechanism tests show that supply chain network position advantages enhance green technological innovation through two broad dimensions—internal firm capabilities and external stakeholders. Specifically, advantageous supply chain network positions promote green technological innovation by improving firms’ absorptive capacity, increasing green investor attention, and strengthening supply chain relationship stability. Third, heterogeneity analyses indicate that the promoting effect of supply chain network position advantages on green technological innovation is more pronounced in heavily polluting and highly competitive industries, as well as among firms with higher asset specificity, stronger managerial green cognition, lower financing constraints, and state ownership. Fourth, further analyses show that supply chain network position advantages significantly improve firms’ environmental and economic performance by promoting green technological innovation. This implies that advantageous supply chain network positions can be further transformed into competitive advantages that support firms’ sustainable development.

6.2. Policy Implications

Based on the above findings, this study proposes the following policy implications. First, a firm’s position in the supply chain network directly affects its ability to acquire green technology information, collaborative resources, and innovation opportunities. Therefore, firms should strengthen collaborative relationships with key suppliers and core customers in order to improve their central positions and information access capabilities within the network. Subject to adequate organizational coordination capacity, firms should also proactively establish cross-group linkages, introduce diversified green knowledge, and enhance the matching and integration of green innovation factors. For firms located at the periphery of the network, priority should be given to consolidating basic transactional relationships and improving cooperation stability, thereby gradually deepening network embeddedness and improving the conditions for green innovation.

Second, firms should systematically strengthen the internal capability base, external governance environment, and long-term collaborative foundation for green innovation, with particular attention to absorptive capacity, green investor attention, and supply chain stability. Absorptive capacity determines the efficiency with which firms transform external green knowledge into actual innovation outcomes, and it can be continuously enhanced through increased green R&D investment, improvements in cross-departmental coordination and R&D management systems, and deeper university–industry–research collaboration. Green investor attention helps optimize the external governance environment for green innovation; accordingly, firms should improve the quality of green information disclosure and enhance the credibility of their sustainability strategies so as to gain recognition and support from capital markets. Supply chain stability, in turn, provides an important foundation for long-term green innovation collaboration. Firms may reduce the uncertainty and coordination costs associated with high-input and long-cycle green R&D activities by signing long-term agreements, engaging in joint R&D, implementing green procurement, and jointly setting emission reduction targets with supply chain partners.

Third, the promoting effect of supply chain network position on green technological innovation varies across firms. Firms should adopt differentiated green innovation and network governance

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strategies according to their ownership type, industry environment, and resource conditions so as to improve the fit and utilization efficiency of their network position advantages.

Fourth, at the policy level, greater efforts should be made to improve the institutional systems for green finance and green supply chains and to strengthen the incentive and spillover effects of network-based collaborative innovation. On the one hand, the government can reduce the financing costs and risks of firms' green R&D through instruments such as green credit, green bonds, fiscal subsidies, and tax incentives, with particular support directed toward firms in heavily polluting industries and those facing greater pressure for green transformation, thereby alleviating financial constraints. On the other hand, efforts should be accelerated to establish green supply chain standards and environmental information disclosure systems in order to improve the availability and comparability of green information, reduce the information costs faced by capital markets and supply chain participants in identifying green behavior, and encourage core firms to play the role of "chain leaders" in driving coordinated upstream and downstream emission reduction and the diffusion of green technologies, thereby improving the overall efficiency of green innovation and the transmission effect of relevant policies.

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