Green Innovation Spillover Effect of Supplier Firms: from the Perspective of Supply Chain

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Abstract. This research studies the impact of supplier companies' green innovation efforts on customer firms' environmental innovation initiatives in supply chains. It illustrates through empirical study that the green innovation activities of supplier firms significantly enhance the green innovation activities of customer firms. Furthermore, it confirms that the level of closeness and effectiveness of collaboration between consumer and supplier firms directly influences the degree to which client firms acquire and exchange green innovation capabilities from the supplier firms, leading to a more pronounced translational impact. Additional research has demonstrated that the influence of supplier companies' efforts to develop environmentally friendly innovations on the environmental innovation activities of client companies is more noticeable when suppliers rely less on their primary customers and customers rely more on their primary suppliers. Green innovation spillovers are more probable when the supply firm is situated in an industry that has lower levels of pollution and fewer restrictions. In conclusion, this study increases comprehension the dynamics underpinning the transfer of green innovation from supplier firms to consumer firms. Furthermore, it offers legislative suggestions for the creation of sustainable supply chains and an economy that is efficient in reducing carbon emissions.

Keywords: Green Innovation; Supplier Firms; Spillover Effect

1 Introduction

Recently, environmental issues have become an increasingly important proposition in enterprise production and development due to the mounting pressures from governments, consumers, and competitors[1][2]. Firms need to employ green innovation approaches to achieve both environmental preservation and commercial growth. Green innovation demands a substantial allocation of financial resources and time from the organization, as well as a collaborative endeavor between the organization and its supply chain partners. Businesses, particularly those seeking to achieve ecologically sustainable transformation and growth, have recognized the significance of implementing green supply chains.

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An optimal condition for the operation of a green supply chain is when every firm in the chain collaborates and engages in green innovation activities to advance the overall development of the supply chain towards low-carbonization and greening[3]. Previous research on corporate green innovation spillovers from a logistical perspective primarily focuses on the influence of a consumer enterprises's green innovation activities on its upstream supplier firms[4][5]. These studies have demonstrated that in green innovation aspect, supplier companies tend to enhance their production collaboration with the consumer firms. As a result, suppliers invest more of their assets or engage in joint investments with the consumer firms, leading to an increased reliance on the consumer firms[6][7]. However, this reliance on consumer firms might lead to more significant repercussions for suppliers in the event of operational challenges faced by these organizations[8][9]. Multiple studies have demonstrated that the presence of diverse technologies within supplier networks plays a crucial role in fostering innovation within consumer firms[10][11][12]. Nevertheless, the full recognition of the innovation spillover effect resulting from the impact of green innovation activities conducted by supplier firms on the green innovation activities of consumer enterprises is still lacking.

This paper utilizes CSMAR supply chain relationship data and CNIPA green innovation patent data from the A-share listed companies in Shanghai and Shenzhen, China between 2010 and 2021. The objective of this research is to conduct an empirical study of the spillover effect of green innovation from supplier enterprises to customer firms in the context of the green supply chain. Additionally, the study investigates the key factors influencing this spillover effect and differs depending on the features of the firm and industry. The significance of this paper is to boost the comprehension of innovation spillovers in the realm of green supply chains among business and academic communities. It also seeks to address the research gap regarding the influence of supplier firms' innovation activities on the innovation of their downstream customer firms.

2 Theoretical Hypothesis

Faced with intense market competition, companies are increasingly depending on external partners to gain new information given to a paucity of internal innovation[11][13][14]. The supply chain network is of utmost importance in enabling enterprises to obtain new external elements for restructuring and development[15][16]. Establishing strong cooperative relationships and exchanging knowledge with other enterprises in the supply chain is beneficial for increasing mutual reliance, reducing economic risks, and achieving sustainable development for the enterprise itself[17]. Trade and cooperation between different business entities is a mutually beneficial undertaking. Suppliers' green innovation activities can motivate organizations to develop their own green innovation strategies. Specifically, suppliers' green innovation activities can drive enterprises to produce environmentally friendly products that fulfill consumer demands, improve their reputation for social responsibility, and eventually advance sustainable development. Therefore, suppliers' green innovation activities may have a beneficial impact on customer firms. This study presents the following hypotheses:

H1: Supplier firms' environmentally friendly innovation has a beneficial impact on the green innovation of consumers.

Supplier firms' green innovation activities exert a substantial influence on the activities related to green innovation of consumer firms. A range of current research suggests that firms can utilize supply chain networks to access and share information. Access to valuable knowledge is often tacit, specialized, public, and difficult to achieve through business interactions. Supply chain networks facilitate effective information communication, increasing direct and regular access to corporate expertise. At the same time, supply chain networks reduce the probability of potential opportunistic behaviours, thus significantly increasing the efficiency of organizational knowledge transfer and absorption[10]. Prior studies have demonstrated that the development and exchange of knowledge among entities involved in innovation is closely correlated with the distance between them, and that increasing geographic distance significantly reduces the impact of sharing of knowledge[18][19][20]. The degree of collaboration link among firms in the identical supply chain significantly influences the significance of firms' actions[7]. Based on these two aspects, the following hypotheses are proposed in this study:

H2a: The distance between enterprise subjects has an impact on the spillover effect of suppliers' green innovation activities on customer firms.

H2b: The level of collaboration between businesses directly influences the extent to which suppliers' green innovation activities benefit customer firms.

3 Research Design

3.1 Data Source

This study used a sample of CSMAR supply chain relationship data encompassing the information of the most significant five clients of A-share listed enterprises in Shanghai and Shenzhen, spanning from 2010 to 2021. The financial data, supply chain data, and green innovation patent data for the listed organizations were sourced from the CSMAR database, CNRDS database, and CNIPA database. The initial data underwent the following processing: (1) Financial listed companies were excluded because of the distinctive attributes of firms in the financial industry. (2) The sample excluded ST, PT, and ST corporations. (3) Samples with inadequate financial data and green innovation patent data were removed. Following the methods outlined above, the paper gathered a grand total of 1,435 observations for supply chain-year. To mitigate the potential impact of extreme values, the primary continuous variables were winsorized at the 1st and 99th percentiles.

3.2 Model Construction and Variable Selection

This article employed a two-way fixed effects model to examine the influence of supplier firms' green innovation on customer firms' green innovation.

$$\boldsymbol{Patent^{C}_{i,t}/InvPatent^{C}_{i,t}/UPatent^{C}_{i,t} = \alpha_0 + \beta_1 Patent^{S}_{i,t} + \beta_i \sum Controls_{i,t} + Year_i + Industry_{i\_} + \varepsilon_{i,t}} \quad (1)$$

The explanatory variable $\mathbf{Patent}_{i,t}^{s}$ showed the number of patent applications related to green technology submitted by supplier companies in supply chain $\mathbf{i}$ in year $\mathbf{t}$. Similarly, $\mathbf{Patent}_{i,t}^{c}$ represented the aggregate count of patent applications specifically related to environmentally friendly inventions filed by client enterprises in supply chain $\mathbf{i}$ during year $\mathbf{t}$. The control variables were denoted by $\mathbf{Controls}_{i,t}$. $\mathbf{Year}_{i}$ and $\mathbf{Industry}_{i\_}$ indicated the control year and industry fixed effects specific to the firm. The random disturbance term was denoted as $\boldsymbol{\varepsilon}_{i,t}$. Refer to the former research, the assessment of green innovation in supply chain firms was conducted based on the number of green patent applications [4]. This paper divided green innovation of customer firms ($\mathbf{Patent}_{i,t}^{c}$) into green invention innovation of customers ($\mathbf{InvPatent}_{i,t}^{c}$), and the number of green utility model innovations of customer firms ($\mathbf{UPatent}_{i,t}^{c}$) to evaluate the spillover effect of green innovation of supplier enterprises on green innovation of customer firms. The logarithm of the total number of green patent applications, increased by one was computed.

This research identified and selected control variables that have been demonstrated. In prior literature, the concept of consumer firms' green innovation has been discussed. These control variables encompassed consumer firms' age at listing (AgeC), firms' size (SIZEC), firms' gearing ratio (LevC), firms' return on assets (ROAC), firms' return on equity (ROEC), firms' proportion of ownership by its first largest shareholder (TOP1C), firms' institutional investor shareholding (InstC), firms' book-to-market ratio (BMC) and firms' Tobin Q (TobinQC). The natural logarithm of the current year minus the year of listing plus one was used to calculate AgeC. The natural logarithm of the total assets of the consumer firms was used to measure SIZEC. Furthermore, this research added the interaction element into equation (2) and equation (3) to test the processes (the effect of distance and firm collaboration) that drive green innovation diffusion from supplier businesses to customer firms along the supply chain[21]:

$$\boldsymbol{Patent_{i,t}^{C}/InvPatent_{i,t}^{C}/UPatent_{i,t}^{C} = \alpha_0 + \beta_1 Patent_{i,t}^{S} + \beta_2 Distance \times Patent_{i,t}^{S} + \beta_3 Distance + \beta_i \sum Controls_{i,t} + Year_i + Industry_{i\_} + \varepsilon_{i,t}} \tag{2}$$

$$\boldsymbol{Patent_{i,t}^{C}/InvPatent_{i,t}^{C}/UPatent_{i,t}^{C} = \alpha_0 + \beta_1 Patent_{i,t}^{S} + \beta_2 Link \times Patent_{i,t}^{S} + \beta_3 Link + \beta_i \sum Controls_{i,t} + + Industry_{i\_} + \varepsilon_{i,t}} \tag{3}$$

Where the interaction element represented moderating variables, including the effect of distance and firm collaboration. According to the previous analysis, this study with the base of the spatial distance between the supplier and its clients, adds one, and then takes the opposite value. This is used as a measure of the distance between the two sides of the index. The greater figure suggests that the geographic distance between the major body of the organization is less, resulting in faster information transportation. Suppliers can use the ratio of their sales to customers to their total sales as a measure to quantify the level of collaboration between suppliers and consumer enterprises[7]. As the value rises, the degree of link between commercial organizations intensifies. The remaining variables were held constant at the values specified in equation (1), while accounting for industry and year fixed effects.

3.3 Descriptive Statistics

Table 1 presents the quantitative summary of the primary variables. The results indicate that the average value of green innovation among supplier firms is 0.574, with a standard deviation of 0.939. The average value of green innovation among customer firm is 2.275, means that enterprises apply for an average of 2.275 green innovation patents per year using a measure of variability known as standard deviation of 1.987. Customer firms' average green invention innovation score is 1.819, with a standard deviation of 1.864. Customer firms' green utility model innovation has a mean value of 1.685 and a standard deviation of 1.662. Compared to supplier organizations, there is a distinct difference in green innovation among customer enterprises.

Table 1. Summary Statistics of Main Variables.

variable	N	mean	sd	min	p50	max
$Patent^{C}$	1435	2.275	1.987	0.000	2.079	7.290
$InvPatent^{C}$	1435	1.819	1.864	0.000	1.386	7.116
$UPatent^{C}$	1435	1.685	1.662	0.000	1.386	5.700
$Patent^{S}$	1435	0.574	0.939	0.000	0.000	3.871
AgeC	1435	12.293	6.808	0.000	13.000	27.000
LevC	1435	0.560	0.169	0.099	0.582	0.854
ROAC	1435	0.043	0.043	-0.088	0.037	0.188
ROEC	1435	0.093	0.097	-0.329	0.089	0.334
TOP1C	1435	40.559	18.498	9.270	39.520	86.200
InstC	1435	106.776	131.523	5.476	74.203	956.844
BMC	1435	0.779	0.246	0.189	0.818	1.221
SIZEC	1435	24.063	1.903	20.682	23.876	28.509
TobinQC	1435	1.499	0.782	0.819	1.223	5.287

4 Results and Discussion

4.1 Baseline Model Results

Table 2 displays the outcomes of the baseline regression. The regression analysis in column (1) reveals that supplier companies' green innovation activities can significantly improve customer firms' green innovation. The finding holds when firm-level control variables, industry-specific fixed effects and time-specific fixed effects are included. The coefficient for this variable is statistically significant at a 1% significance level. Means that supplier firms' green innovation activities have a 99 % confidence level of increasing the consumer firms' green innovation. The results shown in columns (3) and (4) indicate that the environmentally-friendly innovations implemented by supplier businesses make a substantial contribution to the progress of eco-friendly invention innovation and the establishment of eco-friendly utility models in consumer companies. These effects exhibit statistical significance at the 1% level. The comprehensive findings of the baseline regression provide evidence in favour of H1, which posits that the green innovation of supplier firms exerts a substantial influence on the green innovation of customer firms.

Table 2. Estimation Results of Baseline Regression.

	(1) $Patent^C$	(2) $InvPatent^C$	(3) $UPatent^C$
$Patent^S$	0.167***	0.146***	0.146***
	(3.68)	(3.33)	(3.72)
_cons	1.375***	0.958**	0.940**
	(3.01)	(2.41)	(2.53)
Control variables	YES	YES	YES
fixed effects	YES	YES	YES
N	1435	1435	1435
R^2	0.394	0.364	0.383

t statistics in parentheses.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.2 Empirical Specification

Customers firms' green innovation behaviors may spill over to suppliers in the opposite manner, creating the prospect of reverse causation. The instrumental variable approach and Heckman two-stage method[22] were used to mitigate the mentioned endogeneity problem[23].

The instrumental variable test in this paper employs the mean value of green innovation among listed companies in the same industry and year (mIndus_Patent), as well as the average value of green innovation among listed companies within the identical province and year (mPro_Patent), as instrumental variable for the green innovation of enterprises (Patent)[24]. Both mIndus_Patent and mPro_Patent are measured by the number of applications for green innovation. Generally, companies that are listed and operate within the same industry or geographical area encounter comparable industry characteristics and market conditions. Consequently, their efforts in green innovation are interconnected. Table 3 demonstrates that following a one-stage backward regression for column (1), the findings demonstrate a statistically significant positive correlation between the instrumental variables and the explanatory variables. Moreover, the instrumental variables have satisfactorily passed the test for weak instrumental variables, under-identification test, and over-identification test. The results of the second-stage regression in columns (2)-(4) indicate that, after considering the influence of endogeneity, the environmentally friendly progress achieved by supplier companies has a large impact on the green innovation of client firms, with a statistically significant level of 1%. Moreover, the level of consumer enterprises' green utility innovation has significantly improved.

Table 3. Instrumental Variable Test Results.

	(1) $Patent^S$	(2) $Patent^C$	(3) $InvPatent^C$	(4) $UPatent^C$
mIndus_Patent	0.646***			
	(20.75)			
mPro_Patent	0.278***			

	(9.31)			
Patent^S		0.203***	0.147**	0.197***
		(2.92)	(2.15)	(3.38)
Control variables	YES	YES	YES	YES
fixed effects	YES	YES	YES	YES
N	1435	1435	1435	1435
R^2	0.468	0.394	0.364	0.382

t statistics in parentheses.* **p** < 0.10, ** **p** < 0.05, *** **p** < 0.01

To tackle the problem of endogeneity caused by sample selection bias, this research employs the Heckman two-stage technique. During the initial phase of the analysis, the focus is to ascertain whether the dependent variable accurately represents comprehensive data regarding the top five customer firms. The inverse Mills ratio (IMR) is generated by applying the Probit model to this dataset. In the second stage, basic regression model includes the initial stage derived inverse Mills ratio (IMR) as a covariate. Table 4 displays the results of the regression analysis by using Heckman two-stage regression method. When given the inverse Mills ratio (IMR), the results indicate that the supplier firms continues to have a good influence on the creation of environmentally-friendly innovations in consumer enterprises. However, the extent of influence on green invention innovation and green utility model innovation has decreased compared to prior findings.

Table 4. Heckman Models Test Results.

	(1)	(2)	(3)
	Patent^C	**InvPatent^C**	**UPatent^C**
Patent^S	0.196***	0.163***	0.165***
	(3.43)	(2.96)	(3.32)
IMR	0.350	0.286	0.152
	(1.28)	(1.11)	(0.67)
_cons	1.687***	1.460***	1.038*
	(2.66)	(2.83)	(1.91)
Control variables	YES	YES	YES
fixed effects	YES	YES	YES
N	972	972	972
R^2	0.353	0.326	0.334

t statistics in parentheses.* **p** < 0.10, ** **p** < 0.05, *** **p** < 0.01

4.3 Robustness Tests

The green innovation of primary supplier enterprises has a beneficial impact on the green innovation of customer enterprises and remains consistent across various alternative specifications. This research incorporates supplementary control variables into the benchmark regression model to consider the influence of pertinent attributes of supplier businesses on the green innovation endeavors of client firms. These variables consist of the age of supplier firms (AgeS), the size of assets (SizeS), the gearing ratio (LevS), the return on assets (ROAS), the growth rate of operating income (GrowthS), and the proportion of shares held by the first largest shareholder (ShrHolder1S). This paper employs the logarithmic value of the number of green innovation patent applications from the buyer, with lags of one year and two years plus one, to measure the explanatory variables of the benchmark regression. Like the previous article, this research will employ the logarithmic value of the number of green innovation patent applications, increased by one, with a time lag of one year and two years, to measure the explanatory variables, similar to the previous article. The regression results presented above demonstrate that the green innovation activities of the supplier have a considerable positive impact on the green innovation activities of the buyer. The data suggest that the benchmark regression results of this research are dependable and coherent.

4.4 Effect of Distance

Table 5 displays the impact of geographical distance on the diffusion of innovation. The data in column (1) demonstrates that as the distance between supplier firms and customer firms decreases, the effectiveness of information transmission in promoting green innovation activities is enhanced. Additionally, the spillover effect of supplier firms' green innovations on customer firms' green innovations also increases. The coefficient in question exhibits statistical significance at 5% level. It analyses the impact of customer green invention innovation and customer-centric green utility model innovation on this effect, using them as independent variables in columns (2) and (3) accordingly. The results indicate that the distance between sites have a stronger influence on the dissemination of supplier firms' green invention innovation efforts compared to green utility model innovation activities. This discrepancy is statistically significant with a significance level of 5%. The close distance between supplier and customer firms directly influences the extent of spillover effects resulting from supplier companies' green innovation activities, particularly about green invention innovations. The previous results provide evidence in favor of hypothesis H2a, which suggests that geographical distance has an impact on how the spillover effect of green innovation is experienced by supply enterprises.

Table 5. Effect of Distance.

	(1) $\boldsymbol{Patent}^{C}$	(2) $\boldsymbol{InvPatent}^{C}$	(3) $\boldsymbol{UPatent}^{C}$
$\boldsymbol{Patent}^{S}$	0.447^{***}	0.404^{***}	0.304^{**}
	(3.29)	(3.01)	(2.41)
Distance	-0.148^{***}	-0.128^{***}	-0.122^{***}
	(-5.17)	(-4.86)	(-5.06)
$\boldsymbol{Patent}^{S}$ *Distance	0.0469^{**}	0.0431^{**}	0.0260
	(2.12)	(1.97)	(1.29)
_cons	0.450	0.152	0.174

	(0.88)	(0.34)	(0.43)
Control variables	YES	YES	YES
fixed effects	YES	YES	YES
N	1432	1432	1432
R^2	0.405	0.374	0.394

t statistics in parentheses.* ***p*** < 0.10, ** ***p*** < 0.05, *** ***p*** < 0.01

4.5 Effect of Firm Collaboration

The degree of collaboration between suppliers and customers has a considerable moderating impact on the transfer of green innovation from supplier to customer firms. The magnitude of a consumer firms' significance to a supplier directly correlates with the extent to which they will be impacted by the suppliers' green innovation initiatives and the level of cooperation in their relationship. The results in column (1) of Table 6 indicate that there is a positive correlation between the intensity relationship between supplier enterprises and client firms and the influence of suppliers' green innovation initiatives on customer firms. The coefficients exhibit statistical significance at a 5% level of confidence. Columns (2) and (3) indicate that the impact of enterprise collaboration on the innovation of green utility models in customer enterprises is more pronounced compared to green invention innovation. This suggests that the level of connectedness among companies is a significant factor in the occurrence of the spillover impact of suppliers' green innovation, hence providing support for hypothesis H2b.

Table 6. Effect of Firm Collaboration.

	(1) **Patent**^{C}	(2) **InvPatent**^{C}	(3) **UPatent**^{C}
Patent^S	0.115**	0.0939*	0.0949**
	(2.10)	(1.76)	(2.01)
Link	0.0211***	0.0215***	0.0124**
	(4.20)	(4.41)	(2.48)
PatentS *Link	0.00960**	0.00973**	0.00867***
	(2.46)	(2.35)	(2.66)
_cons	1.271***	0.853**	0.876**
	(2.85)	(2.22)	(2.39)
Control variables	YES	YES	YES
fixed effects	YES	YES	YES
N	1435	1435	1435
R^2	0.409	0.382	0.393

t statistics in parentheses.* **p** < 0.10, ** **p** < 0.05, *** **p** < 0.01

5 Heterogeneity Test

Supplier and customer firms have different internal organizational characteristics and face various external industry conditions, which might affect how supplier firms' actions impact customers' efforts towards green innovation. This section aims to investigate potential variations in the spillover effects of supplier firms' green innovation activities on consumer firms, while considering the various internal and external circumstances of different organizations and industries.

5.1 Enterprise Heterogeneity Test

Table 7 presents the heterogeneity study that examines the supplier concentration of the customer firms. As the customers' reliance on the supplier enterprise increases, this places the client organization in an unfavorable position within the supply chain relationship. To address the green innovation initiatives undertaken by its suppliers, the client organization needs to promptly adapt its green innovation strategy. This study employed the ratio of the purchasing amount from the top five suppliers to the overall annual purchasing amount as a statistic to analyze the extent of supplier concentration for client companies. The level of supplier concentration is classified as either low or high, based on the average value of supplier concentration. The regression results, displayed in Table 7, there is a clear and significant impact of suppliers' green innovation activities on customer firms. Especially, when there is a higher concentration of suppliers. This impact exhibits statistical significance at a significance level of 1%.

Table 7. Enterprise Heterogeneity Test Results-- Supplier Concentration.

	(1)	(2)	(3)	(4)	(5)	(6)
	Patent^C	**Patent**^{C}	**InvPatent**^{C}	**InvPatent**^{C}	**UPatent**^{C}	**UPatent**^{C}
	Low	High	Low	High	Low	High
Patent^S	0.121	0.186***	0.118	0.156***	0.111	0.159***
	(1.54)	(3.50)	(1.58)	(2.98)	(1.47)	(3.57)
Control variables	YES	YES	YES	YES	YES	YES
fixed effects	YES	YES	YES	YES	YES	YES
N	554	881	554	881	554	554
R^2	0.423	0.460	0.368	0.445	0.413	0.423

t statistics in parentheses.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8 displays the heterogeneity study, which is conducted by examining the client concentration of supplier firms. Greater customer concentration results in increased economic reliance on a single or a small number of clients, which hinders the ability to distribute risk among supplier businesses, hence restricting strategic choices and reducing market adaptability. Reducing client concentration allows suppliers to have greater flexibility in their decision-making on innovation and to be more innovative in experimenting with environmentally friendly technology or products. This, in turn, encourages the adoption of green innovation practices across the supply chain. This article quantifies the level of customer concentration in supplier firms by calculating the ratio of sales contributed by the top five clients to the total annual sales. Subsequently, the obtained value is utilized to classify the firms into low and high customer concentration categories, depending on the mean value of consumer concentration. The regression results, presented in Table 8, show that supplier firms that have a lower level of customer concentration have a more significant positive effect on customer enterprises in relation to their green innovation activities. The coefficients for these effects are statistically significant at a significance level of 1%. On the other side, supplier firms with higher customer concentration have large positive spillover effects regarding the patents for green inventions and green utility model patents of customer enterprises.

Table 8. Enterprise Heterogeneity Test Results-- Customer Concentration.

	(1) **Patent**^{C} Low	(2) **Patent**^{C} High	(3) **InvPatent**^{C} Low	(4) **InvPatent**^{C} High	(5) **UPatent**^{C} Low	(6) **UPatent**^{C} High
Patent^S	0.198***	0.110	0.170***	0.0901	0.176***	0.0769
	(3.47)	(1.44)	(3.10)	(1.17)	(3.56)	(1.14)
Control variables	YES	YES	YES	YES	YES	YES
fixed effects	YES	YES	YES	YES	YES	YES
N	818	617	818	617	818	617
R^2	0.659	0.656	0.645	0.636	0.622	0.638

t statistics in parentheses.* **p** < 0.10, ** **p** < 0.05, *** **p** < 0.01

5.2 Industry Heterogeneity Test

Suppliers in industries with high levels of pollution are more prone to facing more stringent environmental rules and greater financial constraints. As a result, these suppliers may dedicate additional resources to improving their environmental performance, which can have a detrimental effect on the overall efficiency of the supply chain. This article classifies the samples into two groups based on whether the supplier firms are part of the heavy pollution industry or not[25]. The results presented that the positive impact of supplier enterprises on the green innovation of client firms is stronger when the suppliers are not affiliated with the heavily polluting industry. This effect is mostly shown in the amount of green utility model patents obtained by the customer enterprises. Meanwhile, it is evident that the positive effects of active green innovation activities and the resulting spillovers from suppliers in heavy polluting industries to their client firms are greater than the spillovers from non-heavy polluting suppliers to their consumer firms.

6 Conclusions

This research examines the impact of suppliers' green innovation initiatives on customers' environmental innovation efforts in the supply chain. It empirically demonstrates that supplier firms' green innovation activities have a substantial positive impact on customers firms' green innovation activities. Furthermore, it determines that the geographic proximity and degree of collaboration between the organizations directly affect the magnitude of this influence. The proximity of the customer and supplier enterprises, coupled with the strength of their collaborative relationship, directly determines the amount to which the customer organization may gain and share green innovation skills from the supplier enterprise, resulting in a stronger transformation effect. Additional research suggests that when the supplier has low reliance on the primary customer while the customer has significant reliance on the primary supplier, the influence of the supply company's environmentally-friendly innovation efforts on the customer firm's green innovation activities becomes more visible. The occurrence of the green innovation spillover effect is more probable when the supplier firm operates in an industry with low levels of pollution and is relatively less constrained. To summarize, this study improves the comprehension of the mechanism behind the transfer of green innovation from supplier to consumer enterprises. Additionally, it offers legislative recommendations for the establishment of an environmentally friendly supply chain and a carbon-efficient economy.

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