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The Impact of Strategic Alliances on Corporate Green Innovation: Evidence from China

Yanming Chen [a], Kaiwen Peng [b,*], Kangjie Zhao [b]

[a] *College of Finance and Statistics of Hunan University, Changsha, China*

[b] *Institute of Resource-based Economy Transformation Development, Shanxi University of Finance and Economics, Taiyuan, China*

ABSTRACT

We investigate the impact of strategic alliances on corporate green innovation by collecting and collating announcements of Chinese A-share listed enterprises related to their participation in strategic alliances from 2007 to 2022, and yields three main findings: Strategic alliances significantly improve corporate green innovation, and it contributes more to symbolic green innovation than to substantive green innovation, using the proportion of other enterprises in the same industry and same province that participated in strategic alliances in the previous year as an instrumental variable, we find that this positive impact is likely to be causal. Mechanism analysis indicates that public attention and productivity play an important moderating role in this process. The research results also show that the impact of strategic alliances on corporate green innovation is heterogeneous in terms of industry competitiveness, enterprise categories and strategic alliances types. Our research sheds mechanisms of strategic alliances on corporate green innovation, and provides a theoretical reference for enterprises to improve their green innovation level and enhance their core competitiveness.

KEYWORDS

Strategic alliances; Green innovation; Public attention; Total factor productivity

* Corresponding author: Kaiwen Peng
E-mail address: kevinpeng_cn@163.com

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1. Introduction

The IPCC report points out that increasing global greenhouse gas emissions have led to climate warming and influenced the pattern of natural disaster outbreaks. As the carrying capacity of resources and environment is approaching its limit, the problem of environmental pollution is becoming more and more serious, how to reduce greenhouse gas emissions and realize a low-carbon green economy has become the focus of attention of the theoretical and practical circles. Green innovation, as the key to cracking the double constraints of resources and environment, has become a global trend in addressing environmental issues (Zhao & Ren, 2023). As claimed by numerous researchers, as environmental regulation and environmental enforcement becomes more stringent, enterprises with low productivity and high pollution control costs urgently need green innovation to change their predicament (Galinato & Chouinard, 2018). While improving environmental performance, the economic benefits of green innovation can compensate for, or even exceed, the costs of system compliance, thus creating more value (Liao, 2018). However, green innovation has a longer cycle and greater financial needs, which reduces the willingness of enterprises to green innovation to a certain extent. Meanwhile, with increasing inter-enterprises cooperation, the rise of strategic alliances seems to bring a new way for enterprises to green innovation.

The increasingly competitive external environment and the rapid development of technological links have further pushed the traditional boundaries of organizational governance, and strategic alliances are now a common business phenomenon (Malik & Yazar, 2016). Strategic alliance is a cooperative relationship established between two or more organizations aimed at achieving common strategic goals. This partnership is based on the principles of mutual benefit and interdependence, involves production, distribution, and R&D, which enable participants to gain strategic advantage in a competitive business environment through resource sharing, risk sharing, and concerted action (Gulati, 1998). Prior studies have recognized that forming strategic alliances can obtain resources from the alliance network: including resources, knowledge and information obtained directly from partners, sharing risks and costs (Jiang et al., 2016); obtaining intangible benefits such as power, reputation, and trust from the overall network, and increasing public awareness and visibility (Bellini et al., 2019). Alliance activities occur in various fields: alliances between technology companies and research institutions for knowledge sharing and innovation cooperation; alliances between manufacturers, suppliers, and distributors to reduce purchasing costs and improve production efficiency; alliances between financial institutions and investment enterprises for risk sharing and capital sharing; and enterprises expand into new international markets or further consolidate their existing market positions by establishing alliances with foreign companies. Enterprises establish strategic alliances with each other to improve their capabilities and expand their advantages by cooperating with partners with complementary resources and sharing their internal resources with partners of equal strength.

In the face of increasingly severe domestic and international economic situations, more and more enterprises are choosing to participate in or establish strategic alliances to strengthen cooperation with other organizations, acquire external resources and knowledge, and enhance their competitiveness. From 1987 to 2016, the growth rate of newly established strategic alliances between enterprises in the United States reached an astonishing average annual rate of 25% (Cabral & Pacheco-de-Almeida, 2019). The development of strategic alliances in China has also been rapid. From the data collected in this paper, the number of announcements of strategic alliances made by A-share listed companies was only 22 in 2007, and the number of announcements of corporate strategic alliances will rise to 580 by 2022. The booming development of strategic alliances has also attracted the attention of academics, and research on strategic alliances is increasing. However, studies using publicly available market and financial data to empirically analyze the business performance of listed companies participating in strategic alliances remain scarce. While some scholars have explored the impact of strategic alliances on earnings quality and firm performance (Demirkan & Demirkan, 2014; Cacciolatti et al., 2020), there is limited research examining how these alliances influence corporate green innovation. This gap in the literature highlights the need for further empirical

analysis to understand how strategic alliances can drive sustainability and foster green innovation within firms.

Our paper makes the following possible contributions. First, while previous research has focused on the impact of strategic alliances on firm performance and value (Jiang et al., 2016; Ko et al., 2020), little is known about how these alliances affect corporate green innovation. We address this gap by exploring the positive relationship between strategic alliances and both symbolic and substantive green innovation, enriching the literature on sustainability and innovation. Second, we expand the concept of strategic alliances to include partnerships not only between firms but also with entities such as universities, research institutions, governments, and financial institutions. This broadens the understanding of how different types of collaborations drive corporate innovation, particularly in the context of sustainability. Third, we examine the moderating roles of public attention and productivity—two factors often overlooked in previous studies. Our analysis reveals how these variables influence the effectiveness of strategic alliances in fostering green innovation, offering new insights into the external factors that enhance innovation outcomes. Finally, we uncover the heterogeneous impact of strategic alliances on corporate green innovation, highlighting how industry competitiveness, firm type, and alliance characteristics influence their effectiveness. This nuanced analysis adds depth to the literature by showing that the impact of strategic alliances varies across contexts. In summary, our research provides practical insights for firms to leverage strategic alliances to enhance their green innovation capabilities, gaining a sustainable competitive advantage. By exploring new moderating factors and expanding the scope of strategic alliances, we contribute to both theoretical and practical understanding in the fields of green innovation and strategic management.

2. Theoretical Analysis and Hypothesis

2.1. Strategic Alliances and Green Innovation

According to the characteristic facts of enterprise growth, enterprises usually choose to develop in the local market initially, and the strategic alliance, as a kind of agreement and institutionalized cooperation arrangement between enterprises and organizations, can help to establish a more solid, long-term, and regular cooperation relationship between alliance enterprises, and help to reduce the transaction costs, reduce opportunistic behaviors, improve the learning efficiency and obtain additional external resources (Niesten & Jolink,2018; Mikami & Bird, 2022; Caner & Tyler, 2015). Different organizations have different proprietary technological knowledge and resources, and inter-organizational cooperation can promote the intermingling of knowledge and resources of different organizations, so as to fill the deficiencies of their own technology and capabilities, and achieve complementarity of advantages, after the establishment of the strategic alliance, the intensive interaction in the strategic alliance provides an opportunity to access each other's knowledge, and also effectively improves the learning efficiency (Schildt et al., 2012).

Value chain theory suggests that enterprises can improve their customer relationship management and supply chain management capabilities by learning from other enterprises in strategic alliances and improving information asymmetry with upstream suppliers or downstream customers (Bai et al., 2024).Organizational capabilities theory suggests that enterprises can access the complementary assets (including corporate resources, core competencies and knowledge resources) of their partners, expanding the boundaries of the enterprise's ability to utilize external resources (Windsperger et al., 2018).As the boundaries of enterprises utilizing external resources expand, and their own knowledge and technological capabilities improve, strategic alliances make a positive contribution to green innovation.

In addition, small and medium-sized enterprises (SMEs) in China generally face the "financing difficulties", "high cost of financing" dilemma in the external capital market, enterprises can build internal capital markets and optimize resource allocation through strategic alliances and cooperation, thus replacing external capital markets to

a certain ex-tent (Matvos & Seru, 2014).Internal capital markets have significant functional substitution effects on regional financial markets and can effectively reduce financing costs (Tan et al., 2023).The degree of information asymmetry between capital providers and capital demanders in the internal capital market is much lower than that in the external capital market, thus effectively avoiding the problems of high financing costs and insufficient financing caused by in-formation asymmetry. The high cost and uncertainty of innovative activity makes it more vulnerable to financing constraints (Guariglia & Liu, 2014; Xu, 2020). Based on the above literature, this paper argues that internal capital markets are constructed with the help of strategic alliances, which leads to lower financing costs and easier access to financial support, which in turn promotes green innovation. Accordingly, this paper hypothesizes that:

H1: Strategic alliances have a positive impact on corporate green innovation.

According to the Chinese Patent Law, patents can be categorized into three types: invention patents, utility model patents, and design patents. Depending on the motivation for the innovation, scholars tend to define green invention patents as substantive innovations, green utility model patents and green design patents as strategic or symbolic innovations (Liao et al., 2023; Wang et al., 2024). Substantive green innovations aim at promoting the progress of green technology and striving for real solutions; symbolic green innovation attaches importance to the quantity and speed of innovation to cater to government policies and regulations (Huang & Ma, 2024). The substantive green innovation is obviously more valuable for enterprises' farsighted future and is also identical to original intention of government (Zhang et al., 2024).

Regarding the differential impact of strategic alliances on enterprises' substantive and symbolic green innovation, it can be analyzed in terms of both enterprises' own and alliance characteristics. On the one hand, in the early stages of strategic cooperation, enterprises often choose to share knowledge with low technological content, most of which involves only marginal innovations and does not effectively contribute to green technological advances. Moreover, the advantaged enterprises in a strategic alliance may deliberately conceal the relevant technology, and due to information asymmetry, the disadvantaged enterprises do not have access to all the rich information on the evolution and development of the technology, which adversely affects substantive green innovation. One the other hand, the theoretical analysis above mentions strategic alliances can help enterprises obtain more internal innovation resources, change the dilemma of financing constraints, and enhance green innovation. However, due to the rent-seeking mechanism, enterprises may use innovation resources for non-substantive R&D activities to improve their profits rather than carry out high-risk and long-term substantive green innovation activities, thus crowding out substantial green innovation (Roychowdhury, 2006; Wang et al., 2022). Therefore, this article puts forward the second hypothesis:

H2: The promoting effect of strategic alliances on corporate substantial green invention is lower than that on symbolic green innovation.

2.2. Moderating Effects of Public Attention and Productivity

Based on the media governance theory, as an effective information intermediary, the media plays an important positive role in improving market information asymmetry, regulating corporate governance behavior, and improving corporate operational efficiency by reporting corporate events or behaviors and lowering the cost of stake-holders' access to corporate information (Miller, 2006; Bushee et al., 2010).As a special kind of enterprise social network, the establishment and development of strategic alliance will attract strong attention from the market and the media. In this process, enterprises increase the publicity and disclosure of alliance partners, alliance methods, as well as the results and performance achieved by the alliance, which can help to shape the enterprise image of mutual benefit and win-win cooperation and friendly cooperation, which can alleviate enterprise's financial constraints and deterring agency costs, enabling enterprises to allocate re-sources more rationally and

thereby increasing corporate green innovation (Hao, 2023).Therefore, this paper puts forward the following hypotheses:

Resource base theory suggests that strategic alliances can facilitate communication and interaction between enterprises and horizontal two-way flows of factors of production (Gulati, 1995) and have a value-creating effect on enterprises through efficient allocation of resources (Das & Teng, 2000).According to transaction cost theory, the establishment of strategic alliance can make full use of the stability of the alliance organization to offset the uncertainty in the external market environment, thus reducing the transaction costs caused by uncertainty, and the establishment of strategic alliance with upstream and downstream distributors and suppliers can stabilize the transaction relationship, increase the frequency of transactions, and save transaction costs. It can be seen that the formation of strategic alliances can bring more external resources and learning opportunities for enterprises, enhance the position of enterprises in the global value chain, and reduce transaction costs, all of which contribute to the improvement of enterprise productivity, increased productivity in turn allows for more effective utilization of factor advantages resulting from strategic alliances. Based on the above theories and literature, this paper argues that:

H3: Public attention can positively strengthen the promoting of strategic alliances on corporate green innovation.

H4: Strategic alliances can synergize with productivity to promote corporate green innovation.

3. Experimental

3.1. Sample Selection and Data Sources

The sample includes Chinese A-share listed companies from 2007 to 2022.We obtain green innovation data of all A-share listed companies from the China Stock Market & Accounting Research Database(CSMAR). And the control variables date also from CSMAR. After removing enterprise-year observations for financial industry enterprises and ST enterprises, we obtain 21324 enterprise-year observations in our final sample. In order to eliminate the influence of extreme values, the main continuous variables are subjected to tail reduction at the 1% level.

3.2. Variable Definition

3.2.1. Dependent Variables

Green innovation is our primary dependent variable, measured by green patent application data (Acharya & Xu, 2017; Sunder et al., 2017). The patent application, although not granted, still represents the inventor's creative work achievement (Cai et al., 2020), thus we use the application of green patents to proxy for green innovation. And we use the application of green invention patents to proxy for substantial green invention and non-invention patents for symbolic green innovation.

3.2.2. Independent Variables

Strategic alliance is our independent variable, it is a dummy variable equal to one if enterprise was involved in at least one strategic alliance during the year and zero otherwise.

And the process of organizing data and information on strategic alliances is as follows: Firstly, this paper collects announcements released by A-share listed companies from 2007-2022 from the China Research Data Service (CNRDS), and extracts all the announcements containing the words "strategic alliance", "strategic cooperation", "strategic agreement" and so on in the title. Second, we read the announcements of the strategic alliance enterprises one by one, and manually organized the information such as the starting time, the cooperation

object, the duration of the cooperation, the goal of the cooperation, the amount of cooperation, etc., and judged whether there was an equity type of cooperation, and identified whether the object of the cooperation was an enterprise, a school, a hospital, a research institution, a financial institution, or a government; Third, this paper removes all strategic alliances that have subsequently announced their termination, failure, or cessation of implementation based on the subsequent progress of the alliance. Finally, this paper has screened the announcements containing the words "strategic alliance", "strategic cooperation" and " strategic agreement" in the full text of annual and quarterly reports of listed companies to ensure that the information collection and organization of listed companies' development of strategic alliances in this paper is complete.

3.2.3. Control Variables

In alignment with closely related literature (Chemmanur et al., 2023; Li and Gao, 2022; Yasmeen et al., 2020; Testa et al., 2011), this study incorporates a set of firm-level control variables, including enterprise age (Age), total assets (Size), number of employees (Staff), leverage ratio (Lev), fixed assets ratio (PPE), growth ability (Growth), investment value (TobinQ), board size (Board), independent director ratio (Indep), ownership (SOE), and whether the chairman and managing director hold concurrent positions (Duality). Definitions of these control variables are presented in Table 1.

3.2.4. Moderating Variables

Our moderating variables in this paper are public attention and productivity. First, to explore the impact of public attention on the relationship between strategic alliances and corporate green innovation, we refer to Abramova et al. (2020) and Das et al. (2006), using analyst attention (Ana) and research report attention (Rep) as proxies for the level of public attention, where a higher value indicates greater attention. Second, we follow Levinsohn & Petrin (2003) and Olley & Pakes (1996), employing the LP and OP methods to calculate the total factor productivity of enterprises as the productivity variable (TFP_LP, TFP_OP), where a higher value indicates higher total factor productivity. The data for analyst attention (Ana) and research report attention (Rep), as well as the data for calculating total factor productivity (TFP_LP and TFP_OP), are all sourced from the China Stock Market & Accounting Research Database (CSMAR).

3.3. Model Design

First, we use model (1) examine the relationship between strategic alliance and green innovation:

$$GI_{i,t} = \alpha_0 + \alpha_1 Alliance_{i,t} + \lambda Controls_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (1)$$

Second, we use model (2) - (3) examine the moderating effects of public attention and productivity:

$$GI_{i,t} = \beta_0 + \beta_1 Alliance_{i,t} + \beta_2 Alliance_{i,t} \times PA_{i,t} + \beta_3 PA_{i,t} + \lambda Controls_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (2)$$

$$GI_{i,t} = \gamma_0 + \gamma_1 Alliance_{i,t} + \gamma_2 Alliance_{i,t} \times PR_{i,t} + \gamma_3 PR_{i,t} + \lambda Controls_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (3)$$

Here, $GI_{i,t}$ is green innovation, among them, $Gipat_{i,t}$ represents substantive green innovation and $Gudpat_{i,t}$ is symbolic green innovation. $Alliance_{i,t}$ represents the participating strategic alliance of enterprise i in year t. $Controls_{i,t}$ represents a series of control variables. μ_i is the corporate fixed effect, δ_t is the time fixed effect, $\varepsilon_{i,t}$ is the error term. $PA_{i,t}$ represents public attention of enterprises and $PR_{i,t}$ is productivity of enterprises.

4. Base Results

4.1. Descriptive Statistics

Table 1 reports the descriptive statistics, the mean value of Alliance is 0.180, which means relatively a small number of Chinese A-listed companies form strategic alliances during the sample period. the mean value of GI, Gipat and Gudpat are 2.276, 1.814 and 1.611. But green innovation is unevenly distributed among enterprises, many listed companies do not have green patents.

Table 1. Descriptive statistics.

Variable	Definition	N	Mean	p50	SD	Min	Max
GI	Ln (green patent +1)	21324	2.276	2.303	1.973	0.000	7.248
Gipat	Ln (green invention patent +1)	21324	1.814	1.609	1.781	0.000	6.848
Gudpat	Ln (green utility patent +green design patent+1)	21324	1.611	1.099	1.700	0.000	6.009
Alliance	Strategic alliance dummy	21324	0.180	0.000	0.384	0.000	1.000
Age	Ln(Year-year of establishment+1)	21324	2.877	2.944	0.355	1.792	3.526
Size	Ln(Total assets)	21324	22.377	22.225	1.385	19.435	26.435
Staff	Ln(number of employees)	21324	7.869	7.860	1.345	3.989	11.353
Lev	Total liabilities/total assets	21324	0.474	0.473	0.208	0.070	0.987
PPE	Net fixed assets/total assets	21324	0.222	0.193	0.161	0.002	0.691
Growth	Operating income/last year's operating income-1	21324	0.160	0.080	0.455	-0.624	3.188
TobinQ	The Q value of James Tobin	21324	2.025	1.571	1.403	0.849	9.499
Board	Ln(number of board members)	21324	2.150	2.197	0.197	1.609	2.708
Indep	Independent directors/ board members	21324	0.372	0.333	0.053	0.300	0.571
SOE	The dummy variable equals one if the shareholder is SOE and zero for non-SOE	21324	0.509	1.000	0.500	0.000	1.000
Duality	The dummy variable equals one if the chairman and general manager are the same person and zero otherwise	21324	0.237	0.000	0.425	0.000	1.000

4.2. Descriptive Statistics

Table 2 tested the effect of strategic alliances on corporate green innovation, the coefficient of Alliance in columns (1) is 0.071, and the p-value is less than 0.01. The results show that strategic alliances can significantly promote corporate green innovation. The regression results of substantive green invention (Gipat) and symbolic green innovation (Gudpat) are reported in columns (2) and (3), with the coefficients of the Alliance being 0.045 and 0.063, and significant at the level of 5% and 1%, respectively. Consistent with our expectations, the results prove that strategic alliance can have a positive impact on green innovation. Therefore, the H1 was supported. And the difference in coefficients indicates a greater promoting effect on substantive green innovation than symbolic green innovation, which means H2 is verified. The following reasons may have caused the differences: firstly, due to the difficulty and long research cycles of green invention patents, it is difficult to achieve a large number of high-quality innovations in a short time of strategic alliances; secondly, at the beginning of a strategic alliance, enterprises do not share their core technologies with each other; thirdly, enterprises are inclined to apply symbolic green patents for other benefits based on the psychology of chasing short-term profits.

Table 2. Baseline regression.

	(1)	(2)	(3)
Variable	GI	Gipat	Gudpat
Alliance	0.071***	0.045**	0.063***
	(3.082)	(1.993)	(2.663)
Age	1.200***	1.218***	0.926***
	(6.183)	(6.627)	(5.203)
Size	0.153***	0.148***	0.150***
	(4.661)	(4.661)	(5.248)
Staff	0.078***	0.065***	0.072***

	(3.168)	(2.748)	(3.425)
Lev	-0.029	0.007	-0.050
	(-0.330)	(0.091)	(-0.605)
PPE	0.382***	0.338***	0.410***
	(2.961)	(2.813)	(3.534)
Growth	-0.032**	-0.027**	-0.032***
	(-2.496)	(-2.331)	(-2.692)
TobinQ	0.034***	0.035***	0.029***
	(3.946)	(4.245)	(3.552)
Board	0.105	0.136	0.023
	(1.013)	(1.407)	(0.233)
Indep	0.178	0.114	0.024
	(0.623)	(0.433)	(0.088)
SOE	-0.006	0.007	0.017
	(-0.115)	(0.129)	(0.348)
Duality	0.013	0.004	0.017
	(0.444)	(0.141)	(0.626)
Constant	-5.980***	-6.210***	-5.434***
	(-7.187)	(-8.148)	(-7.049)
Firm FE	YES	YES	YES
Year FE	YES	YES	YES
N	21324	21324	21324
Adj. R^2	0.301	0.268	0.247

*Note: T statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01.*

4.3. Robust Test

We conduct several tests to check the robustness of our benchmark regression, the results are given as follows:

4.3.1. Alternative Measures for Strategic Alliances

Our dependent variable, Alliance, is a dummy variable which captures only the incidence of strategic alliances; however, the use of this dichotomous variable fails to account for the frequency of strategic alliance activities. To further examine the impact of strategic alliances on corporate green innovation, we replace Alliance with a discrete variable that captures the number of strategic alliance activities undertaken by an enterprise (Allinum). The results are shown in panel A of table 3. The estimated coefficients of Allinum are 0.031, 0.018 and 0.023, respectively, which are all significant. Our results remain robust to an alternative measure of strategic alliance.

4.3.2. Lag One Period Behind

The impact of strategic alliances on green innovation may have a lag effect, and it may take time for enterprises to digest, assimilate and practice the knowledge and technology acquired through strategic alliances, and it may take time to transform them into green patent outputs. Therefore, we use the lagged one-period independent variable to regress, the results in panel B of table 3 show that strategic alliances have a lag effect on corporate green innovation.

4.3.3. Considering the Impact of Green Finance Policies and Financial Crisis

1.Excluding policy impacts. In 2017, the country-selected provinces of Zhejiang, Jiangxi, Guangdong, Guizhou, and Xinjiang were selected as pilot areas to conduct green finance reform and innovation. Considering that the development of green finance will affect the financing conditions for enterprises and thus promote green innovation activities, this paper excludes the impact of this policy by eliminating these samples from the above provinces after 2017. The regression results in panel C of table 3 show that the coefficients all decrease slightly, and the regression

results are still significant. 2.Excluding financial crisis impacts. We run the regression by intercepting the sample after 2010 to exclude shocks from the financial crisis, and the coefficients of Alliance in panel D of table 3 remain significant, which verifying the robustness of the baseline regression.

Table 3. Robust test.

	Panel A: replace variable			Panel B: consider lag effect		
Variable	GI	Gipat	Gudpat	GI	Gipat	Gudpat
Allinum	0.031**	0.018*	0.023*			
	(2.357)	(1.764)	(1.842)			
L.Alliance				0.069***	0.044*	0.057**
				(2.857)	(1.815)	(2.277)
Control	YES	YES	YES	YES	YES	YES
Constant	-5.998***	-6.227***	-5.469***	-5.313***	-5.508***	-5.285***
	(-7.185)	(-8.150)	(-7.075)	(-5.984)	(-6.739)	(-6.387)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	21324	21324	21324	18705	18705	18705
Adj. R^2	0.301	0.268	0.247	0.264	0.228	0.224
	Panel C: excluding policy impacts			Panel D: excluding financial crisis impacts		
Variable	GI	Gipat	Gudpat	GI	Gipat	Gudpat
Alliance	0.080***	0.048*	0.077***	0.059***	0.037*	0.059***
	(2.880)	(1.734)	(2.691)	(2.868)	(1.834)	(2.591)
Control	YES	YES	YES	YES	YES	YES
Constant	-6.254***	-6.225***	-5.475***	-4.188***	-4.941***	-3.942***
	(-6.488)	(-7.015)	(-6.146)	(-4.751)	(-6.008)	(-4.797)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	14957	14957	14957	18535	18535	18535
Adj. R^2	0.286	0.252	0.234	0.199	0.168	0.178

*Note: T statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01.*

4.4. Endogenous Analysis

The decision of whether an enterprise participates in a strategic alliance is not exogenous, and to further exclude the impact of endogeneity on the results of our analysis, we adopts the 2SLS regression to further analyze the impact of strategic alliances on the corporate green innovation. Previous studies found that enterprises are affected by the business decisions of other enterprises in the same industry in the previous year in their operations (Srinidhi et al., 2011). Especially when other companies in the same industry have strategic partners, firms are more likely to engage in strategic alliance cooperation (Wassmer, 2010). Thus, we follow Wassmer (2010) and Chou et al. (2014) to construct the proportion of strategic alliance participation of other A-listed companies in the same industry and province in the previous year as an instrumental variable (Alliance Ratio). This ratio excludes the firm itself in the calculation, ensuring its exogeneity as an instrumental variable. It does not have a direct impact on the green innovation level of individual firms, making it a suitable instrumental variable. Table 4 shows the results of the instrumental variables test, in the first stage regression results in column (1), the coefficient of Alliance_Ratio is 0.727, which is significant at 1% level. The Cragg-Donald Wald F-test has a statistic of 1657.88, which passes the weak instrumental variable test and confirms that enterprises' decisions to engage in strategic alliances are significantly influenced by the participation of other enterprises in the same region and same industry. Columns (2) - (4) of table 4 show the results of the second-stage regression, where the coefficients of Alliance are 0.307, 0.277, 0.195, respectively, and are all significant, which further verifies the validity of hypothesis H1.

Table 4. 2SLS regression.

Variable	(1) Alliance	(2) GI	(3) Gipat	(4) Gudpat
Alliance_Ratio	0.727***			
	(40.717)			
Alliance		0.307***	0.277***	0.195**
		(2.783)	(2.722)	(1.964)
Constant	-0.562***	0.444	-2.008***	1.032***
	(-6.971)	(1.135)	(-5.558)	(2.935)
Control Variables	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
N	18705	18705	18705	18705
Adj. R^2	0.171	0.342	0.314	0.287

*Note: T statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01.*

5. Further Analysis

5.1. Moderating Analysis

Public attention can expand the visibility of the enterprises and its products, and provide support for the enterprises' innovative activities. And strategic alliances can promote the communication and interaction between enterprises and the flow of factors of production, and through the effective allocation of resources to improve the total factor productivity of enterprises, which is an important factor affecting the innovation of enterprises, and enterprises with higher productivity can afford the long-term cost of innovation.

Table 5 reports the regression results of moderating effects, verifying hypothesis H3 and H4. The results in panel A indicate that public attention significantly promote corporate green innovation. The results in panel B indicate that total factor productivity measured by the LP method reinforces the positive effect of strategic alliances on total, substantive and symbolic green innovation, the regression of total factor productivity measured by the OP method also have a significant effect on total and substantive green innovation, possibly because enterprises with high productivity can afford the capacity and capital to undertake green innovation activities.

Table 5. Moderating effect tests.

Panel A: public attention						
Variable	GI	Gipat	Gudpat	GI	Gipat	Gudpat
Alliance	0.065***	0.038*	0.056**	0.065***	0.038*	0.056**
	(2.774)	(1.668)	(2.362)	(2.765)	(1.665)	(2.354)
Alliance*Ana	0.059***	0.069***	0.070***			
	(3.442)	(4.078)	(4.024)			
Alliance*Rep				0.043***	0.049***	0.052***
				(3.162)	(3.639)	(3.757)
Control	YES	YES	YES	YES	YES	YES
Constant	-2.901***	-2.961***	-3.481***	-2.902***	-2.930***	-3.497***
	(-3.684)	(-3.922)	(-4.735)	(-3.692)	(-3.888)	(-4.764)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	21324	21324	21324	21324	21324	21324
Adj. R^2	0.295	0.260	0.244	0.294	0.260	0.244
Panel B: productivity						
Variable	GI	Gipat	Gudpat	GI	Gipat	Gudpat
Alliance	0.068***	0.042*	0.061***	0.069***	0.044*	0.063***

	(2.972)	(1.889)	(2.594)	(3.003)	(1.955)	(2.642)
Alliance*TFP_LP	0.025**	0.024**	0.022**			
	(2.448)	(2.377)	(2.160)			
Alliance*TFP_OP				0.026**	0.022*	0.020
				(2.048)	(1.777)	(1.646)
Control	YES	YES	YES	YES	YES	YES
Constant	-3.533***	-3.486***	-3.968***	-3.538***	-3.500***	-3.968***
	(-4.436)	(-4.560)	(-5.404)	(-4.437)	(-4.574)	(-5.402)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	21324	21324	21324	21324	21324	21324
Adj. R^2	0.294	0.259	0.243	0.294	0.259	0.243

*Note: T statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01.*

5.2. Heterogeneity Analysis

In order to provide a more comprehensive analysis and understanding about the impact of strategic alliances on corporate green innovation, this paper examines the heterogeneity from multiple perspectives, including the degree of industry competition, different enterprise categories and different strategic alliances types.

5.2.1. Heterogeneity of Industry Competition

Competitive conditions in product markets can create uncertainty in corporate strategic decision-making. A competitive market environment requires enterprises to compete and fight for market share with competitors, which can lead to price wars and pressure on profits. In this situation, enterprises face an existential threat and need to actively seek opportunities to enhance product competitiveness, especially considering green innovation activities. On the contrary when the industry in which a enterprise operates has a low level of competition, the enterprise may be satisfied with the status quo, believing that its existing products or services are sufficient to meet users' needs, and thus lack incentives for green innovation. In this paper, the Herfindahl Index is used to measure the intensity of competition in the industry in which a enterprise operates. The larger the value reflects the high degree of market concentration and the smaller the competitive intensity of the industry, and conversely the smaller the value indicates the low degree of market concentration and the larger the competitive intensity of the industry. In this paper, the median HHI index of listed companies is calculated according to the year, and the sample are divided into low industry competition enterprises and high industry competition enterprises. The regress results are in panel A of table 6. Although strategic alliances have a significant effect on total and symbolic green innovation in both groups of enterprises, strategic alliances have a greater and more significant contribution to substantive green innovation of enterprises with higher industry competition.

5.2.2. Heterogeneity of Enterprise Categories

According to the Guidelines on Industry Classification of Listed Companies (2012) issued by the China Securities Regulatory Commission (CSRC) and the Guidelines on Environmental Information Disclosure of Listed Companies (2010) issued by the Ministry of Environmental Protection (MEP), we classify sample into heavy-polluting enterprises and non-heavy-polluting enterprises. The results in panel B of table 6 show that strategic alliances can promote total green innovation in both groups of enterprises, but have non-significant effect on symbolic green innovation of heavy-polluting enterprises and non-significant effect on substantive green innovation of non-heavy-polluting enterprises. The reason is possible that heavy-polluting enterprises must invest in substantial innovation in order to minimize legal penalties and reduce the cost of pollution control, and non-heavy-polluting enterprises incline to choose symbolic green innovation which requires less investment.

Table 6. Heterogeneity of enterprise characters.

Panel A: industry competition						
	High industry competition			Low industry competition		
Variable	GI	Gipat	Gudpat	GI	Gipat	Gudpat
Alliance	0.078**	0.058*	0.072**	0.076**	0.042	0.069**
	(2.526)	(1.878)	(2.287)	(2.257)	(1.321)	(1.983)
Control	YES	YES	YES	YES	YES	YES
Constant	-7.346***	-7.149***	-7.088***	-3.393***	-4.242***	-2.873**
	(-6.718)	(-7.304)	(-6.693)	(-2.796)	(-3.755)	(-2.577)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	10407	10407	10407	10917	10917	10917
Adj. R^2	0.289	0.260	0.236	0.291	0.254	0.240
Panel B: enterprises categories						
	Heavy-polluting enterprises			Non-heavy-polluting enterprises		
Variable	GI	Gipat	Gudpat	GI	Gipat	Gudpat
Alliance	0.088**	0.071*	0.061	0.075***	0.043	0.069**
	(2.106)	(1.737)	(1.383)	(2.760)	(1.603)	(2.462)
Control	YES	YES	YES	YES	YES	YES
Constant	-5.315***	-5.188***	-5.680***	-6.785***	-7.127***	-5.860***
	(-3.864)	(-4.343)	(-4.059)	(-6.740)	(-7.511)	(-6.360)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	6497	6497	6497	14827	14827	14827
Adj. R^2	0.317	0.251	0.290	0.292	0.273	0.230
Panel C: enterprise ownership structure						
	State-owned			Non-state-owned		
Variable	GI	Gipat	Gudpat	GI	Gipat	Gudpat
Alliance	0.055	0.042	0.035	0.079***	0.042*	0.079**
	(1.583)	(1.225)	(0.974)	(2.642)	(1.765)	(2.442)
Control	YES	YES	YES	YES	YES	YES
Constant	-6.608***	-7.300***	-5.546***	-4.989***	-5.163***	-4.865***
	(-5.221)	(-6.240)	(-4.678)	(-4.240)	(-4.866)	(-4.431)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	10859	10859	10859	10465	10465	10465
Adj. R^2	0.294	0.272	0.231	0.299	0.259	0.254

*Note: T statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01.*

5.2.3. Heterogeneity of Enterprise Ownership Structure

We classify our sample into state-owned and non-state-owned enterprises. The results in Panel C of Table 6 show that strategic alliances have different effects on green innovation in the two groups of enterprises. For state-owned enterprises, strategic alliances do not have a significant impact on any type of green innovation. In contrast, the situation for non-state-owned enterprises is different. Strategic alliances have a significant positive effect on all

types of green innovation. This indicates that non-state-owned enterprises are more inclined to use strategic alliances to promote green innovation, especially in the area of substantive green innovation, which requires higher investment. The possible reason for this difference lies in the fact that state-owned enterprises are typically more influenced by government policies and regulations and may rely on government-driven policies to achieve green innovation rather than relying on market-based strategic alliances. As a result, strategic alliances have a smaller impact on innovation in state-owned enterprises. On the other hand, non-state-owned enterprises are generally more market-oriented and are more dependent on external strategic alliances to drive innovation, particularly in green innovation.

5.2.4. Heterogeneity of strategic alliances types

The targets of strategic cooperation by enterprises can be organizations or institutions such as universities, financial institutions, governments and other enterprises. Strategic cooperation between enterprises and universities and other research institutions can obtain diversified knowledge from high-quality research to promote green innovation; while strategic cooperation with financial institutions can reduce the degree of information asymmetry and alleviate the financing pressure by utilizing their financial resources; and strategic cooperation with governmental departments can obtain special resources from the governmental departments and improve the social reputation of enterprises; strategic cooperation with other enterprises can improve the level of green innovation by utilizing the advantages of cooperative enterprises in market, knowledge and industry chain connection. Due to the differences in the resource endowment of cooperative partners, different types of strategic alliances may bring different impacts on enterprise green innovation.

Table 7. Heterogeneity of strategic alliances types.

	Industry-university-research alliances			Financial-enterprise alliances		
Variable	GI	Gipat	Gudpat	GI	Gipat	Gudpat
Alliance_School	0.216***	0.153**	0.140*			
	(2.790)	(1.962)	(1.845)			
Alliance_Fin				-0.013	-0.037	0.021
				(-0.251)	(-0.778)	(0.395)
Control	YES	YES	YES	YES	YES	YES
Constant	-3.441***	-3.369***	-3.936***	-3.486***	-3.408***	-3.957***
	(-4.407)	(-4.487)	(-5.430)	(-4.459)	(-4.535)	(-5.460)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	21324	21324	21324	21324	21324	21324
Adj. R^2	0.293	0.259	0.242	0.293	0.258	0.242
	Government-enterprise alliances			Enterprise alliances		
Variable	GI	Gipat	Gudpat	GI	Gipat	Gudpat
Alliance_Gov	0.072	0.008	0.100			
	(0.871)	(0.115)	(1.282)			
Alliance_Firm				0.029*	0.023	0.020
				(1.911)	(1.501)	(1.478)
Control	YES	YES	YES	YES	YES	YES
Constant	-3.466***	-3.397***	-3.940***	-3.415***	-3.345***	-3.915***
	(-4.430)	(-4.517)	(-5.430)	(-4.351)	(-4.434)	(-5.387)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
N	21324	21324	21324	21324	21324	21324
Adj. R^2	0.293	0.258	0.242	0.293	0.259	0.242

*Note: T statistics in parentheses. * p<0.10, ** p<0.05, *** p<0.01.*

Based on the different cooperation objects, this paper divides strategic alliances into industry-university-research alliances (Alliance_School) that cooperates with universities, hospitals, and research institutes, Financial-enterprise alliances (Alliance_Fin) that cooperates with financial institutions, government-enterprise alliances (Alliance_Gov) that cooperates with governmental departments, and enterprise alliances that cooperates with other enterprises (Alliance_Firm). The above four variables are treated in the same way as the core explanatory variables. The regression results are shown in Table 7, the industry-university-research alliance can significantly promote the enhancement of total, substantive and symbolic green innovation, enterprises alliance can only promote the total of green innovation. Probably due to the fact that the funds brought to enterprises by financial-enterprise alliance are not guaranteed to be used to drive enterprise green innovation, and that financial-enterprise alliance will bring enterprises investment opportunities that were difficult to grasp in the past, and invest the funds in financial assets with higher returns. The government-enterprise alliance embodies more of a helping nature, such as the introduction of industries, which may not be significant in enhancing green innovation of enterprises. Strategic alliances between enterprises may also fail to achieve the desired results due to the hiding of technology by firms.

6. Conclusion and Discussion

6.1. Conclusion

This article presents a study using double fixed-effects model and moderated-effects model to investigate the relationship between the strategic alliances and green innovation of Chinese A-listed enterprises from 2007 to 2022. Our findings are succinctly summarized as follows: Firstly, the research shows that the strategic alliances have a positive impact on the corporate green innovation, and the promoting effect on symbolic green innovation is stronger, indicting the existence of some concealment behaviors of enterprises. Secondly, public attention and productivity play an important role as moderating variables in this process. Thirdly, by categorizing the samples based on the intensity of industry competition, enterprises categories, and strategic alliances types, empirical results show that strategic alliances have stronger impacts on the green innovations of enterprises with higher industry competition; and have non-significant effect on symbolic innovation of heavy-polluting enterprises. In addition, only strategic alliances between enterprises and school, research institutions will have a significant positive effect on all types of green innovation, and enterprises alliances only promote total green patents.

6.2. Policy Recommendations

Based on the above conclusions, this paper forms the following policy recommendations:

First, enterprises should take the initiative to seek cooperation opportunities, and when choosing a strategic alliance partner, they should select a more suitable alliance partner based on their own business needs and industry characteristics. Enterprises need to strengthen their analysis and understanding of the upstream and downstream development dynamics of the industry, and select alliance partners according to local conditions and time, so as to maximize the role of strategic alliances in promoting green innovation. In addition, before developing a strategic alliance, enterprises also need to consider the cultural differences between alliance partners and the mode of cooperation. Enterprises should focus on communication and coordination to ensure smooth and effective cooperation among alliance members.

Second, the mechanism analysis in this paper also shows that public attention has a very important reinforcing effect on the green innovation of enterprises. This suggests that after developing strategic alliances, enterprises can fully grasp the opportunity of external publicity to strengthen the publicity and introduction of the strategic cooperation object, the content of cooperation, the mode of cooperation and the results of cooperation. By

expanding the enterprises' external publicity and shaping a good image of the enterprises' positive enterprising, win-win cooperation and mutual benefit, it can bring a greater boost to the strategic alliance to promote green innovation.

Third, the Government can encourage enterprises to make full use of alliance resources through alliances and cooperation to improve productivity. In addition, the Government can strengthen cooperation with other countries and regions, promote the interconnection of the international industrial chain and supply chain, and optimize the pattern of the global industrial division, thereby promoting the formation of international strategic alliances. Finally, while encouraging cooperation among enterprises, the government needs to further formulate and improve policies conducive to cooperation, especially in terms of intellectual property rights protection and other aspects to provide strong legal support for enterprises, so as to provide strong support and guarantee for the green innovation activities of regional enterprises.

6.3. Discussion

Our results provide realistic guidelines for enterprises to achieve long-term healthy development and enhance their green innovation ability in the increasingly fierce globalization competition and the context of carbon peaking and carbon neutrality. With the acceleration of the globalization process and constraints of carbon peaking and carbon neutrality, enterprises are facing more and more intense international competition pressure, how to achieve long-term sustainable development and enhance green innovation ability in such competition has become an important topic. Our findings show that strategic alliance, as a special kind of enterprises social network, can be one of the important measures to enhance the green innovation ability of enterprises. Establishing strategic alliances is one of the important ways for enterprises to realize long-term sustainable development. By establishing a close relationship with partner enterprises, enterprises can jointly utilize the market position of alliance members to improve their business credit and market power, thus gaining more advantages in market competition. At the same time, in an alliance, enterprises can acquire strategic resources, including technology, brands, talents and so on, through sharing, learning and other interactive mechanisms, so as to improve their core competitiveness and market share. Alliances can also promote innovation and collaboration among enterprises, and promote long-term business development, thereby creating a sustainable international competitive advantage for the enterprise.

Of course, there are some shortcomings in the research of this paper: First, this paper constructs strategic alliance indicators based on the information disclosed in the annual reports and announcements of listed companies, and cannot avoid the opportunistic disclosure of information by the management, such as the management will exaggerate the disclosure of strategic alliance information in order to cater to the market or conceptual hype, and choose to hide part of the business information in order to cope with market competition. The above questions will inevitably have some impact on the results of this paper. Second, the information on strategic alliances disclosed by listed companies is relatively brief, and there is a lack of detailed disclosure of the form and purpose of the alliance, which limits the more in-depth research on strategic alliances in this paper. Last, our research on green innovation focuses only on the level of patent applications, which still needs to be deepened, and can be followed up with research on patent strategies, patent diversity and patent cooperation (Luo & Zor, 2024; Zor, 2023).

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Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

Author contributions

Conceptualization: Yanming Chen, Kangjie Zhao; Investigation: Yanming Chen, Kaiwen Peng; Methodology: Yanming Chen, Kaiwen Peng; Formal analysis: Yanming Chen, Kaiwen Peng; Writing – original draft: Kaiwen Peng; Writing – review & editing: Yanming Chen, Kangjie Zhao.

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