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Research article

How do national university science parks influence corporate green innovation? Evidence from Chinese listed companies

Yue Zhang[1] **and Shijie Ding**[2]*

[1] School of Business, Central South University, Changsha 410083, China
[2] Department of Scientific Research, Central South University, Changsha 410083, China

* **Correspondence:** Email: dingshijie@csu.edu.cn; Tel: +8613787161985; Fax: 0731-88836032.

Abstract: As a cooperative platform connecting universities, enterprises, and the government, national university science parks (NUSPs) have a major impact on promoting technological innovation and industrial transfer and are a key component of higher education reform and innovation-driven development strategy in China. This study utilized panel data from Chinese listed firms from 2000 to 2020 and employed a difference-in-differences approach to evaluate the impact of NUSPs, initiated by the Chinese government in 2002, on corporate green innovation. The results show that NUSPs significantly enhance corporate green innovation performance. Specifically, channels such as research and development (R&D) investment, technical talent, and alleviation of financial constraints contribute to this stimulation. The moderating analysis reveals that the positive effect of NUSP projects on corporate green innovation is more pronounced in nonstate-owned and labor-intensive firms, as well as in non-heavy polluting industries, high-tech and technology-intensive enterprises. The heterogeneity analysis indicates that NUSPs have a comparatively notable positive influence on the green innovation level of enterprises that rely on double first-class universities, have government R&D subsidies, and are subject to relatively high regional environmental supervision intensity. Theoretically, it enriches the exploration of the correlation between NUSPs and corporate green innovation, reveals its internal influence mechanism, and broadens the research vista in the field of university-industry interactive innovation. Practically, it guides government policymaking to support parks and enterprise decisions to cooperate for enhanced green innovation and sustainable development, promoting industry-academia-research integration and a good innovation ecosystem.

Keywords: national university science parks; green innovation; R&D investment; technical talents; financial constraint

JEL Codes: L98, M21

1. Introduction

The trend toward high-quality development is changing economic patterns globally (Wang and Zhu, 2023) and climate change poses a huge threat to the development and stability of the global economy, which has drawn extensive notice from scholars (Gong and Liao, 2024). More and more scholars emphasize the need for firms to adhere to environmental regulations and assume social responsibility in pursuit of sustainable development goals. Meanwhile, climate change uncertainty poses enormous challenges for global businesses (Gong et al., 2022). The climate risk and environmental regulations are closely related to corporate green innovation. Achieving sustainable development requires green innovation, which provides a workable way to reconcile environmental concerns with economic progress (Chen, 2008; Chang and Chen, 2013; Zhang et al., 2020). Compared with general technological innovation, green innovation emphasizes environmental protection and sustainability more (Cui et al., 2024). Policies that promote green transformation are frequently implemented by governments in order to incentivize profit-driven corporations to take on environmental responsibility and participate in green innovation activities. This research attempts to add new perspectives to the expanding literature in this area by analyzing the way national innovation-driven parks impact green innovation.

As collaborative platforms connecting universities, enterprises, and governments, NUSPs are vital for promoting technological innovation and industrial transfer within higher education institutions. In NUSPs, knowledge spillovers are more likely to occur between universities and enterprises, which facilitates the exchange of technical knowledge, the commercialization of research results and the incubation of spin-off enterprises (Mian, 1997; Montoro-Sánchez et al., 2011; Lofsten and Klofsten, 2024). They are instrumental in higher education reform and innovation-driven development strategy in China. In 2002, the first batch of 22 NUSPs was jointly approved by China's Ministry of Education and the Department of Science and Technology. Since then, numerous high-tech enterprises have been established in these parks. There were 141 NUSPs at the end of 2021, with 10,127 enterprises incubated within these parks. The literature suggests that NUSPs contribute to regional economic development (Hobbs et al., 2020) and local innovation activities (Zou and Zhao, 2014; Unlu et al., 2023). However, while NUSPs are gaining increasing attention from both companies and academia (Qi et al., 2024), their environmental impact has largely been overlooked.

We posit that NUSPs can make a substantial contribution to corporate green innovation. On one hand, these parks provide platforms for technology transfer and collaboration, allowing enterprises to leverage universities' research and advanced technologies to quicken green technologies' development and application. On the other hand, the parks concentrate a wealth of highly qualified researchers and technical experts, providing companies with access to essential knowledge and skills. Additionally, research and development (R&D) support facilities and financial assistance programs within the parks help alleviate the financial pressures associated with green innovation. It is important to note that green technology innovation typically has a long payback period, information asymmetry, and high risk, which constitute the main financing constraints of green investment (Lin and Ma, 2022). Usually, traditional financial institutions are loath to offer loans to such high-risk, low-return green investments. However, NUSPs closely cooperate with government departments and actively promote the implementation of green finance policies within the parks, alleviating the financing pressure on enterprises. Meanwhile, by virtue of their platform advantages, the parks actively attract social capital to focus on the field of green innovation, build a communication bridge between enterprises and potential investors, and reduce information asymmetry. By collaborating closely with government departments, these parks also assist enterprises in securing green policy support and market promotion opportunities, further driving green innovation.

This study makes contributions to existing related research in several aspects. First, while some research explores government policy's impact on corporate green innovation performance (Lin et al., 2024; Liu et al., 2023), the relationship between NUSPs and green innovation remains underexplored. Although NUSPs are closely linked to green technologies, few studies have examined their environmental role. This research addresses this gap by investigating the influence of NUSPs on corporate green behavior at the firm level. Second, while previous studies have explored the relationship between NUSPs and corporate behavior, they have failed to identify the internal mechanisms driving this relationship (Lofsten and Lindelof, 2002; Lindelof and Lofsten, 2005). This study enriches the field by identifying several potential mechanisms through which NUSPs improve corporate green innovation performance, such as R&D investment and external financial constraints. Third, this study advances understanding of the university-industry interaction in the context of innovation via examining the firm-level impact of NUSPs on corporate innovation. Previous studies have mainly focused on formal and informal interactions between universities and companies (Schaeffer et al., 2020; Zhang et al., 2024). This study sheds new light on the part that universities play in advancing corporate green innovation and sustainable practices from a policy perspective.

The remaining sections of this research are arranged as follows: Section 2 reviews the backdrop of the policy and develops the hypotheses. Section 3 presents the research design. Section 4 displays the empirical outcomes. Section 5 concludes the study.

2. Policy background and theoretical analysis

2.1. Policy background

NUSPs play a key role in the national innovation system in many nations and have an essential impact on promoting scientific and technological innovation and incubating start-up enterprises (Link and Scott, 2006; Audretsch, 2009; Zou and Zhao, 2014). It is an organization that relies on universities with scientific research advantages, and combines talents, technology and other intellectual resources, with other social resource to provide academic research results transformation and technological innovation. NUSPs first originated in the United States. The famous Stanford Research Park is the world's first science park and was established in 1951. It aimed to promote the commercialization and industrialization of university scientific research results, which has now evolved into today's Silicon Valley (Vaidyanathan, 2008). Since the late 1970s, NUSPs, an innovative model that closely integrates research and economic development, have been rapidly promoted in countries and regions around the world. The findings of Link and Scott (2006) show that NUSPs work as a driving force in the transfer of academic research, knowledge spillovers, and the promotion of national and regional economic growth.

China, as the fastest-growing emerging economy, has been vigorously developing science parks since the late 1980s to encourage the innovation and entrepreneurship ecosystem and technology transfer (Tan, 2006; Huang et al., 2012; Zou and Zhao, 2014). China initiated the Torch Program to construct NUSPs for R&D product commercialization in 1988. In addition, there exists a dramatic change of universities' role in China's national innovation system. Governments recognized universities and their affiliated science parks as essential pillars of economic development. Therefore, China started to explore the NUSPs program in the 1990s. After decades of development, NUSPs have functioned as the platform for academic research commercialization, the development of creative talent, as well as the incubation of new start-ups, which is a triple win for businesses, local governments, and academic institutions (Chen and Kenney, 2007). According to statistics, China has seen a rise in the quantity of NUSPs from 42 in 2004 to 141 in 2021. Regarding the distribution of the parks, most NUSPs are located in the eastern and western regions, with the eastern area making up 55%, the western area making up 19%, and the remaining regions making up less than 15% each. Meanwhile, with the national emphasis on innovation-driven development strategy, the Ministry of Science and Technology and the Ministry of Education have issued relevant policy documents which mainly include the "Guiding Opinions on Promoting the Innovative Development of national university science parks" and the "Circular on the Pilot Construction of national university science park" to support the establishment and development of NUSPs.

2.2. Theoretical analysis and research hypothesis

2.2.1. NUSPs and corporate green innovation

NUSPs can significantly influence green innovation in enterprises through policy support and financial inputs. In the development of NUSPs, innovative city building policies make a difference. First, NUSPs can activate the policy incentive effect. The policy supports NUSPs to strengthen technology research and development innovation as well as the transformation of scientific research results, which promotes green innovation of startups (Shao et al., 2024). The main promotion is green technological innovation, including economic, innovation and environmental benefits. Second, NUSPs can attract innovative resources and integrate them through innovative city building policies. Innovative city construction often encourages NUSPs to establish an integrated innovation mechanism that facilitates the rapid aggregation of capital, talent, and technology (Cui et al., 2024; Liu et al., 2024). In this case, firms make use of the scientific research capacity of universities, innovative talents and government resource inputs to upgrade their industrial structure and enhance their creativity for green technological innovation (Lai, 2023). Finally, NUSPs can promote financial investment, especially government subsidies and tax incentives for green innovation activities. This can alleviate the challenges and risks faced by firms, such as high R&D costs and long R&D cycles, which strongly penetrates green technology innovation in firms. The first hypothesis is proposed based on the above studies.

Hypothesis 1 (H1): NUSPs positively impact corporate green innovation.

2.2.2. NUSPs, R&D input, and corporate green innovation

The investment of enterprises in R&D, especially in the area of green innovation, dictates the innovation and application of green technologies. However, enterprise R&D activities have the characteristic of large investments, long lead times and high risks, and the social benefits are often greater than the private benefits, generating strong positive externalities. As a result, enterprises lack sufficient motivation to participate in R&D investment, and the actual level of R&D investment is much lower than the optimal level (Jones & Williams, 1998). To address this market failure, the government needs to provide subsidies or formulate preferential policies for enterprises engaged in R&D activities to incentivize them to invest in R&D (Cui et al., 2024). With the support of NUSPs, the government usually optimizes the allocation of resources, rationally adjusts financial expenditures to provide necessary infrastructure and equipment for scientific research. Meanwhile, based on the innovation-driven development strategy, the government will provide subsidies and tax incentives to enterprises that actively participate in the construction and innovation of NUSPs. It can increase the R&D investment and strengthen green technology innovation. Specifically, investing more in R&D will help firms become more innovative in the environment-protection field, which will benefit the transformation of scientific research and innovation results. Thus, we put forward the following hypothesis:

Hypothesis 2 (H2): NUSPs positively impact corporate green innovation through increasing R&D investment.

2.2.3. NUSPs, technical talents, and corporate green innovation

To encourage firms to innovate, a superior innovation service environment and effective innovation coordination need to be established. By synergizing individual resources, NUSPs forms a composite innovation resource, providing a platform for the integration of information, technology, and talents (Díez-Vial and Montoro-Sánchez, 2016). In collaboration with universities and research institutions, companies are capable of identifying outstanding graduates and doctoral researchers, thereby fostering a conducive atmosphere for the significant innovations (Thursby and Thursby, 2002). The primary channels for university science park-driven innovation includes partners' capacity to exchange technological expertise, exploitation of economies of scale in research activities, crucial knowledge-based inputs, and leveraging complementary assets (Powell et al., 1996; Teece, 1992). The NUSPs' coordination mechanism for ensuring innovation facilitates the efficient aggregation of elite talents and technological capital (Caloghirou et al., 2021). This mechanism acts as a pivotal support in encouraging enterprises to engage in green technological advancements. Moreover, NUSPs bolster the government's strategic guidance in safeguarding and utilization intellectual property. Consequently, enterprises will be able to access fundamental knowledge and shared technology R&D outcomes at reduced costs, thereby enhancing the overall quality of innovation. Thus, H3 is proposed according to the above analysis.

Hypothesis 3 (H3): NUSPs positively impact corporate green innovation through increasing technical talents.

2.2.4. NUSPs, financial constraint, and corporate green innovation

Finance performs a vital function in lessening greenhouse gas emissions and confronting climate change (Gong et al., 2023). Schumpeter's innovation theory points that the role of finance in supporting innovation. Given the unpredictability of returns, the existence of asymmetry of information in the innovation activities, and elevated regulatory expenses, creative undertakings face severe external financial constraints. These constraints subsequently hinder enterprises' innovative endeavors (Aghion et al., 2012).

Distinguished from traditional technology innovation, green technology innovation normally has a heightened demand for upfront capital investment, extended profit cycle, and unforeseen risks. Thus, additional financial support is indispensable to tackle issues related to market failures, including environmental externalities, path dependence, and inadequate capital markets. The implication is that green technology innovation requires additional funding to realize substantial technological leaps, which consequently increases the likelihood of enterprises encountering financial constraints during the development process. NUSPs often align with the green finance policies implemented in pilot zones, encompassing tax incentives, sector-specific subsidies, loans featuring favorable interest rates, and dedicated funds aimed at fostering innovative growth (Li et al., 2024).

To some degree, these financial policies have the capacity to decrease corporate investments in pollution projects while allocating increased funding towards green sectors and eco-friendly manufacturing methodologies. As a result, they mitigate financial limitations faced by enterprises and stimulate advancements in the realm of green technological innovation. We propose H4 as follows:

Hypothesis 4 (H4): NUSPs positively impact corporate green innovation through alleviating financial constraints.

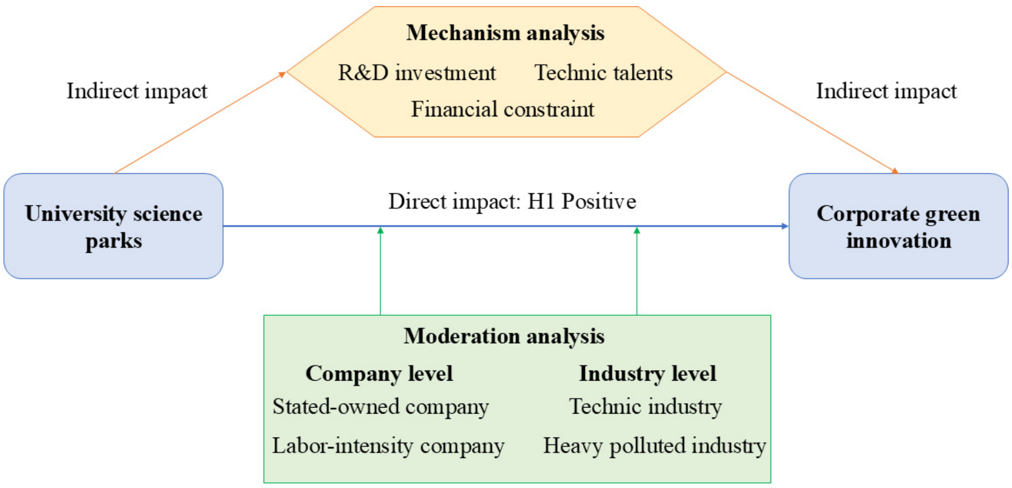

Figure 1. The research framework.

3. Data and methodology

3.1. Data and variable

The dataset utilized in this research comprises Chinese listed companies from 2000 to 2020. This study employs datasets originating from three distinct sources. First, data on specific cities, years, and the supporting universities of NUSPs in China are collected manually from the website of Ministry of Science and Technology of China. Second, following Chen et al. (2024), data regarding corporate green innovation is gathered from the Chinese Research Data Services Platform (CNRDS). Third, data on financial performance at the company level is obtained from the China Stock Market & Accounting Research Database (CSMAR). We eliminate ST companies, financial institutions, samples exhibiting abnormal data, firms listed for fewer than twelve months, and instances where data acquisition is unfeasible. Ultimately, our sample comprises 36,401 observations for each firm across different years. To reduce the impact of outliers, we apply winsorization to continuous variables, addressing extreme values at the 1st and 99th percentiles. Any values falling below the 1st percentile are replaced with the value corresponding to that percentile, while those exceeding the 99th percentile are adjusted to match its value.

3.1.1. Corporate green innovation

Based on Chang's work (Chang et al., 2024), this study considers the quantity of granted green patents to quantify corporate green innovation. Our research includes two types of granted green patents: green inventions and green utility. Green inventions represent product novelty, inventiveness, and practical applicability, whereas green utility patents signify technical solutions (Qiao et al., 2024). We designate the count of green inventions as *GII* to evaluate the quality of green innovation and green utility patents as *GIU* to denote the quantity of green innovation. The cumulative number of green patents (*GI*) functions is an indicator of the comprehensive level of corporate green innovation.

3.1.2. NUSPs

The independent variables in this article are comprised of the treatment group (*Treat*) and the implementation of the policy (*Post*). *Treat* is characterized as a binary variable and assigned a value of one if the firm is situated within a province that hosts a university science park and zero in all other instances. Characterized similarly, the value of *Post* is equal to 1 if the university science park has been operational since 2002. Based on the model's structure, the cross-multiplier term *Treat*×*Post (NUSP)* serves as the pivotal variable, and it is anticipated to be statistically significant if the NUSP effect is present (Wang and Li, 2022).

3.1.3. Mediating variables

Following Pan and Cao (2024), We measure R&D input by determining the natural logarithm of the total R&D spending by companies and then adding one to that figure. The measurement of technical talent is based on the ratio of R&D personnel (R&D Staff). Higher proportion of R&D staff suggest better and facilitative access for companies to technical talents.

And the financial constraints confronted by enterprises are gauged by the financing constraints (WW) index. Higher values denote an augmented degree of financial constraints encountered by the firm (Sun et al., 2024).

3.1.4. Control variables

Building on existing research (Song at al., 2024; Zhang et al., 2024), We account for a range of factors that could influence green innovation. Specifically, we consider the following control variables: the firm's size (*Size*), return on assets (*Roa*), age (*Age*), debt-to-equity ratio (*Lev*), ratio of cash flow derived from operating activities to total assets (*Cashflow*), proportion of nonexecutive directors (*Indep*), board size (*Board*), the duality of chief executive and chairman (*Dual*), and Tobin's Q value (*TobinQ*). Green innovation requires taking risks and changing existing practices, and new businesses are more aggressive, bolder, and have greater flexibility and agility than those with older ones (Tan and Tan, 2005). As a result, new companies are better able to take advantage of the new opportunities presented by environmental change (Qadeer et al., 2024). In addition, different decisions of the firm's management in green innovation may greatly influence its degree of green innovation. Therefore, the proportion of *Indep*, *Board*, *TobinQ*, and *Dual* are also relatively important.

3.2. Regression method

To test H1, the following regression model is built to exam the association between the NUSPs and corporate green innovation:

$$GI_{ij} = \beta_0 + \beta_1 NUSP_{ij} + \beta_2 Controls_{ij} + \beta_3 Industry_i + \beta_4 Year_j + \varepsilon_{ij} \quad (1)$$

where GI_{ij} denotes corporate green innovation, $NUSP_{ij}$ refers to the digital economy, and $Controls_{ij}$ are firm-level variables that have the potential to influence green innovation. We also account for fixed effects related to both industry and year. ε_{ij} is represents the random error, where *i* represents a specific company and *t* indicates the corresponding year.

To test H2–4, we adopt a methodology extensively employed in prior research to examine the mediating effect in the connection between NUSPs and corporate green innovation (Qiao et al., 2024):

$$Mediating_{ij} = \eta_0 + \eta_1 NUSP_{ij} + \eta_2 Controls_{ij} + \eta_3 Industry_i + \eta_4 Year_j + \chi_{ij} \quad (2)$$

$$GI_{ij} = \alpha_0 + \alpha_1 NUSP_{ij} + \alpha_2 Mediating_{ij} + \alpha_3 Controls_{ij} + \alpha_3 Industry_i + \alpha_4 Year_j + \delta_{ij} \quad (3)$$

Equation (1) turns out as Equation (3), where $Mediating_{ij}$ acts as the mediating variable, including R&D input (R&D), technical talents (R&D Staff), and financing constraints (WW), and the remaining variables align with those found in Equation (1). The steps for testing are as follows: Initially, assess the significance of β_1. If β_1 is found to be significant, we proceed with the subsequent test. Next, evaluate if $NUSP_{ij}$ significantly affects $Mediating_{ij}$, specifically checking the significance of η_1. If η_1 is significant, continue with the next test. Ultimately, $NUSP_{ij}$ and $Mediating_{ij}$ collectively undertake a regression examination on GI to verify the significance of the coefficients α_1 and α_2 in Equation (3). If α_1 and α_2 are significant and α_1 is smaller than β_1, then we assert that $Mediating_{ij}$ assumes an essential and partially mediating function in the domain of NUSPs and corporate green innovation.

4. Empirical results

4.1. Descriptive statistics

Table 1 shows the descriptive statistics of the variables. First, observing the corporate green innovation indicators (*GI*, *GII*, and *GIU*), their standard deviations are 0.63, 0.40, and 0.54 respectively, which suggests that there are substantial differences among the sample enterprises in terms of green innovation. Second, for the variable of NUSPs, the mean value is 0.60 and the median is 1.00. This indicates that approximately 60% of the sample enterprises are located in provinces with university science parks and most enterprises potentially affected by the policies of university science parks.

Table 1. Descriptive statistics.

Variable	Mean	Sd	Min	P50	Max	N
GI	0.24	0.63	0.00	0.00	6.68	36401
GII	0.10	0.40	0.00	0.00	5.52	36401
GIU	0.18	0.54	0.00	0.00	6.37	36401
NUSP	0.60	0.49	0.00	1.00	1.00	36401
Roa	0.04	0.06	−0.18	0.04	0.2	36401
Lev	0.45	0.20	0.06	0.45	0.87	36401
Size	22.01	1.26	19.74	21.82	25.83	36401
Cashflow	0.05	0.07	−0.15	0.050	0.23	36401
Indep	35.90	7.65	0.00	33.33	57.14	36401
Board	2.16	0.21	1.61	2.20	2.71	36401
Age	2.73	0.42	1.39	2.77	3.43	36401
TobinQ	1.91	1.15	0.89	1.52	7.31	36401
Dual	0.22	0.41	0.00	0.00	1.00	36401

4.2. Baseline results

Employing Equation (1), the influence of NUSPs on GI is assessed. Table 2 presents the specific estimated outcomes. In Columns (4)–(6), control variables are introduced. All industry and time fixed effects are considered. The empirical findings suggest that the coefficient of NUSPs was significantly positive when control variables were not added. Column (1) shows that NUSPs have a significant positive effect (0.081, $p < 0.01$) on total green innovation. Although the coefficient undergoes some changes after the introduction of control variables, its value remains significantly positive, which indicates that the NUSPs effectively raises the enterprise green innovation level. These results support H1.

Table 2. Baseline regression results.

Variables	(1) GI	(2) GII	(3) GIU	(4) GI	(5) GII	(6) GIU
NUSP	0.081***	0.051***	0.060***	0.069***	0.042***	0.051***
	(4.29)	(4.40)	(3.85)	(3.92)	(4.01)	(3.49)
Roa				0.095	−0.109	0.159*
				(0.91)	(−1.56)	(1.87)
Lev				0.109**	−0.001	0.122***
				(2.53)	(−0.05)	(3.44)
Size				0.106***	0.077***	0.076***
				(7.39)	(7.40)	(6.41)
Cashflow				−0.036	−0.009	−0.031
				(−0.54)	(−0.21)	(−0.57)
Indep				0.001	0.001	0.000
				(0.57)	(1.38)	(0.44)
Board				0.043	0.036	0.028
				(0.99)	(1.26)	(0.78)
Age				−0.103***	−0.035**	−0.083***
				(−4.15)	(−2.53)	(−3.95)
TobinQ				0.002	0.010***	−0.003
				(0.27)	(2.92)	(−0.66)
Dual				0.029	0.017	0.025
				(1.51)	(1.38)	(1.55)
Constant	−0.115***	−0.055***	−0.086***	−2.263***	−1.680***	−1.619***
	(−4.13)	(−5.48)	(−3.72)	(−7.16)	(−7.29)	(−6.24)
Observations	36,401	36,401	36,401	36,401	36,401	36,401
R−squared	0.079	0.039	0.066	0.122	0.084	0.101
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: (Standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.)

4.3. Robustness tests

4.3.1. Propensity score matching method

In accordance with Chang and Fang (2024), we employ the kernel matching method. By the matching procedure, we reduce the disparity between control group and treatment group. Subsequently, regression is carried out with the matched samples. From the data in Column (1) of Table 3, it can be seen that the NUSP's coefficient is markedly positive. These results verify the robustness of our findings.

4.3.2. Alternate variables

In the previous regression, we use the logarithm of patents plus 1 to measure the enterprise green innovation. However, the estimators generated by this treatment may lack meaningful interpretation when there contain many zero values (Cohn et al., 2022). To tackle this issue, this paper employs the inverse hyperbolic sine (IHS) transformation for robustness examination. IHS transformation is similar to logarithmic transformation in that it can make variables closer to normal distribution, reduce heteroscedasticity, and mitigate the impact of outliers. Moreover, it has a prominent advantage of allowing the retention of 0 observations (Bellemare and Wichman, 2020). In Column (2) of Table 3, we denote the number of patents after IHS transformation as *GI1*. As we can see, the regression coefficient of NUSPs is remarkably positive and extremely close to the benchmark regression result.

Furthermore, this paper also attempts to estimate using the linear probability model (LPM). We create a new variable, *GIA*, setting samples that have applied for patents as 1 and others as 0. For this 0-1 dummy variable, no additional treatment of zero values is required and the coefficient of the core variable measures whether NUSPs increase the probability of listed companies applying for green patents. The data in Column (3) of Table 3 prove that NUSPs can significantly increase the probability of green innovation among listed companies.

4.3.3. Alternate sample

To prevent the results from being driven by a few samples, this paper also conducts robustness tests by altering sample. First, we exclude firm observations in Guangdong and Zhejiang which is shown in Column (4) of Table 3, since Guangdong and Zhejiang take the largest number of enterprise samples. Second, we exclude firm observations in Guangdong and Shanghai which is shown in Column (5), as the provinces and cities have the densest distribution of NUSPs.

Finally, considering the interference of the COVID-19 pandemic on the dependent variable, we exclude the data during the pandemic in 2020. The data in Column (6) are the regression results. Obviously, the results remain robust, indicating that NUSPs can indeed promote the green innovation of corporate.

Table 3. Alternate sample.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	GI	GI1	GIA	GI	GI	GI
NUSP	0.075***	0.045***	0.029***	0.062***	0.076***	0.069***
	(4.12)	(3.86)	(3.14)	(3.18)	(4.04)	(4.04)
Constant	−2.218***	−1.353***	−0.801***	−2.189***	−2.153***	−2.235***
	(−6.62)	(−7.35)	(−6.83)	(−6.55)	(−6.52)	(−7.01)
Observations	17,219	36,401	36,401	27,439	28,018	33,018
R−squared	0.121	0.127	0.116	0.124	0.121	0.119
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: (Standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.)

4.4. Endogenous tests

4.4.1. Parallel trend test

Passing the parallel trend test is the premise of the difference-in-difference model. This assumption means that the green innovation levels of the treatment group and the control group follow the similar development trend prior to the establishment of NUSPs. Referring to previous studies. In this paper, multiple dummy variables (*Before*, *Current*, and *After*) are set in the regression model to verify the year-by-year impact of NUSPs on corporate green innovation. We construct Equation (4) to test the dynamic effect.

$$GI_{it} = \lambda_0 + \lambda_1 Before3_{it} + \lambda_2 Before2_{it} + \lambda_3 Current_{it} + \lambda_4 After1_{it} + \lambda_5 After2_{it} + \lambda_6 After3_{it} + \mu_{it} \quad (4)$$

if the company is in the p year before the establishment of the NUSP, then *"Beforepi,t"* has a value of 1. Similarly, if the company is in the p year after the establishment of the NUSP, then *"Afterpi,t"* is 1. Otherwise, these dummy variables are equal to 0. We estimate for three years before NUSPs and three years after NUSPs. The fixed effect was the same as the benchmark regression model. From the Figure 2, we can see that the coefficients for *Before* are not significant, while *After2* and *After3* are statistically significant, satisfying the parallel trend assumption.

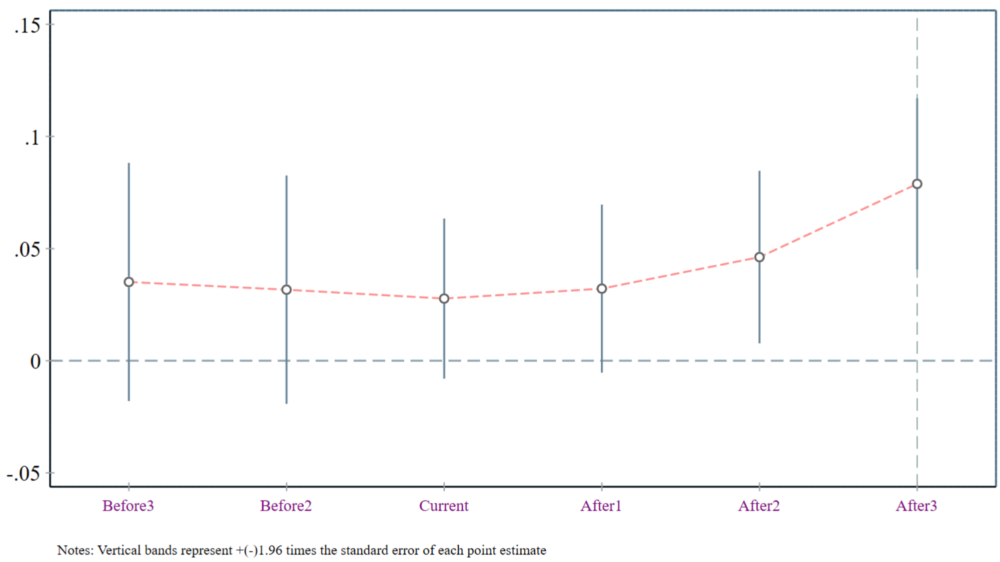

Figure 2. The parallel test.

4.4.2. Placebo test

To ensure the accuracy of the test, we used the method of randomly selecting the treatment group and the experimental time to perform the placebo test. The specific method is to obtain the number of enterprises that have been affected by the NUSPs. Subsequently, a new treatment group is formed by randomly choosing an equal number of enterprises from all enterprise samples, and a random year is chosen to generate a policy time dummy variable. Finally, we generated a pseudo-policy virtual variable for the placebo test. According to the method of Zhao et al. (2021), we conduct simulations

500 times, and the result is shown in Figure 3. We can observe that the k-density trend of the p-value adheres to the normal distribution and doesn't deviate markedly from zero. Thus, this once again validates Hypothesis 1.

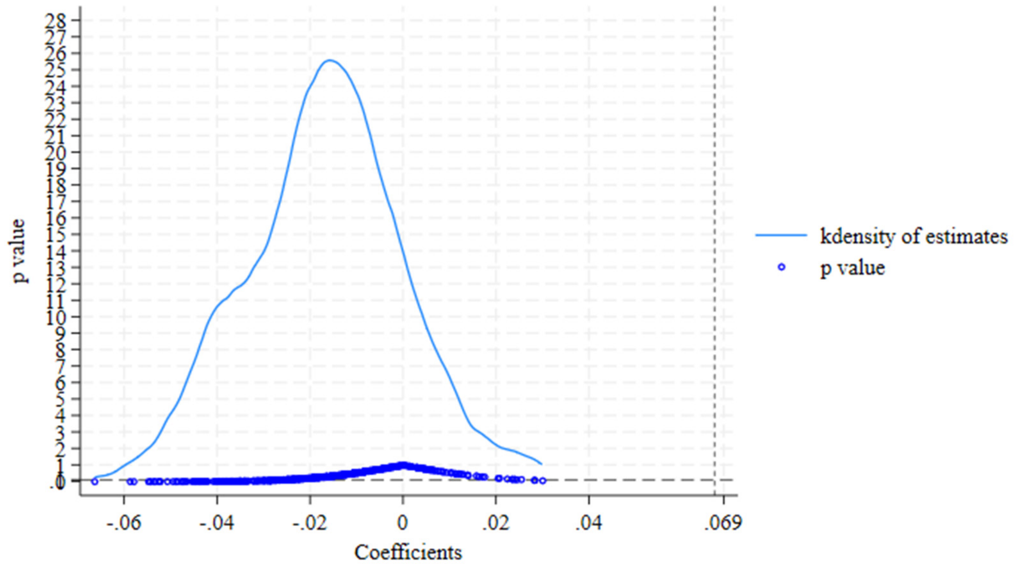

Figure 3. The placebo test.

4.4.3. Excluding innovative cities policy effect

During the sample period, the pilot program for innovative cities was rapidly expanded. When a city is appointed as an innovative pilot city, it will enhance its strategic leading role, facilitate the concentration of factors, and place greater emphasis on improving the innovation environment. In this way, the city has a higher likelihood of establishing a national university science park, which may lead to omitted variable issues. To address this issue, we add a dummy variable to denote whether it is an innovative city among control variables. As can be seen from the data in Table 4, NUSPs still significantly drive corporate green innovation.

Table 4. Excluding innovative cities policy effect.

	(1)
Variables	GI
NUSP	0.053***
	(2.87)
Constant	−2.263***
	(−7.16)
Observations	36,401
R−squared	0.123
Controls	Yes
Year FE	Yes
Industry FE	Yes

Note: (Standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.)

4.5. Mechanism analysis

Table 5 shows the regression results of the mechanism test in this paper. NUSP's coefficient is significantly positive in Column (1), meaning that NUSPs can significantly increase corporate R&D investment. Both the regression of NUSPs and R&D in Column (2) are significantly positive, indicating a partial mediating effect and suggesting that the more R&D investment a company has, the higher its level of green innovation. Therefore, H2 is supported. In fact, the NUSPs have promoted the intellectual property rights protection and enhanced public awareness of environmental protection. Both external pressures and internal awareness have jointly increased enterprises' attention to green innovation technologies, prompting them to increase the R&D investment, thereby promoting the green innovation level.

The Columns (3) and (4) show the results regarding the mediating role of technical talents. In Column (3), the regression coefficient of NUSPs is positive and statistically significant, suggesting that NUSPs can notably increase the proportion of research and development personnel in enterprises. In Column (4), the regression coefficient of R&D Staff is positive and statistically significant. This suggests that NUSPs promote green technology innovation in enterprises by enhancing their technical talent advantage, supporting H3. The NUSPs have reduced the cost of technical information gathering between enterprises and universities, making it more convenient for enterprises to access technical support from universities. Simultaneously, these NUSPs draw in high-level talents to be committed to green technology research and development in enterprises, thereby driving the enterprises green innovation.

The results of the mediating role of financial constraint are presented in Columns (5) and (6). In Column (5), the coefficient of NUSPs is negative significantly, indicating that NUSPs can significantly reduce the financial constrain of enterprises. In Column (6), the coefficient of WW is positive and statistically significant, lending support for H4. The NUSPs establishment is conducive to enterprises obtaining external financing support and thereby promote enterprise innovation.

Table 5. Mechanism analysis.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	R&D	GI	R&D Staff	GI	WW	GI
NUSP	0.248***	0.059***	3.694***	0.036	−0.002**	0.068***
	(6.33)	(2.62)	(9.94)	(1.39)	(−2.43)	(3.72)
R&D		0.110***				
		(11.42)				
R&D Staff				0.010***		
				(9.26)		
WW						−0.181**
						(−2.44)
Constant	−2.695***	−2.661***	22.388***	−3.435***	0.072***	−2.414***
	(−4.56)	(−6.44)	(3.32)	(−7.16)	(5.28)	(−7.09)
Observations	22,266	22,266	14,791	14,791	32,372	32,372
R−squared	0.492	0.132	0.329	0.129	0.671	0.129
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: (Standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.)

4.6. Moderation effect analysis

For the purpose of investigating how the relevant differences at the enterprise level moderate the relationship between NUSPs and enterprise green technology innovation, a moderating effect analysis is conducted from four perspectives: enterprise ownership (state-owned/nonstate-owned), industry affiliation (heavy polluting industry/non-heavy polluting industry), technological nature of the enterprise (high-tech enterprise/nonhigh-tech enterprise), and labor intensity (labor-intensive/technology-intensive).

State-owned enterprises are inclined to place greater emphasis on macro-policy guidance and the fulfillment of social responsibilities. Their decision-making processes are relatively intricate and are subject to multiple constraints. In contrast, nonstate-owned enterprises typically possess a more flexible market-oriented decision-making mechanism and can respond more expeditiously to market fluctuations. Regarding pollution attributes, enterprises within heavy pollution industries encounter more stringent environmental regulations, which impel them to bear stronger external pressures in the realm of green innovation. By comparison, enterprises in non-heavy polluting industries are exposed to relatively lower environmental regulatory pressures, and their impetus for green innovation predominantly stems from market competition and the demands of sustainable development strategies. In terms of technological characteristics and labor intensity, high-tech enterprises and technology-intensive enterprises, relying on their advantages in technology research, talent reserve, and innovation capabilities, are more capable of conducting in-depth cooperation with NUSPs to achieve knowledge sharing and collaborative technological innovation. In contrast, labor-intensive enterprises are relatively weak in technical foundation and innovation ability, and may face more difficulties when docking with NUSPs and utilizing relevant resources, thus affecting the effectiveness of enterprise green innovation.

Columns (1) and (2) in Table 6 add the interaction terms between NUSPs and state-owned enterprises, as well as between NUSPs and heavy pollution industries, respectively, on top of the baseline regression. Results show that the coefficients of these interaction terms are negative and statistically significant, indicating that the interaction between NUSPs and state-owned enterprises, as well as with heavy pollution industries, exerts an inhibitory influence on enterprise green innovation level. In other words, state-owned enterprises and heavy pollution industries diminish the effectiveness of NUSPs. The decision-making process of state-owned enterprises is relatively complex and restricted by multiple factors, such as government policy orientation and the objective constraints of maintaining and increasing the value of state-owned assets. This makes them unable to respond quickly and adjust innovation strategies like nonstate-owned enterprises when facing innovation opportunities brought by NUSPs. Heavy pollution industries have formed relatively fixed production technologies and processes over a long period of time, with a serious dependence on technological paths. Therefore, the green innovation in heavy pollution industries requires large investments and has a long return cycle, and green technology innovation faces high costs and risks. As a result, heavy pollution industries mainly focus their efforts on meeting environmental compliance requirements, and their green innovation is mostly a passive response, neglecting long-term green technology research and development, thus limiting the role of science parks.

Columns (3) to (5) in Table 6 consider the moderating effects of the technological nature and labor intensity of enterprises by adding the interaction terms between NUSPs and high-tech industries, between NUSPs and technology-intensive enterprises, and between NUSPs and labor-intensive enterprises respectively. The data demonstrate that the interaction terms coefficients between NUSPs and high-tech industries as well as between NUSPs and technology-intensive enterprises are significantly positive. In contrast, the coefficient with labor-intensive enterprises is negative. This implies that NUSPs can markedly raise the enterprise green innovation level in high-tech and technology-intensive enterprises. High-tech/technology-intensive have a stronger sensitivity and absorption ability to cutting-edge technologies and possess stronger scientific research transformation capabilities, enabling them to conduct effective knowledge sharing and collaborative innovation with the park. In contrast, labor-intensive enterprises lack corresponding R&D and innovation capabilities, which restricts their ability to effectively utilize the resources of the park, resulting in a negative coefficient of the interaction term. Meanwhile, labor-intensive enterprises focus on traditional production and have limited investment in green innovation, which also leads to less satisfactory results in promoting green innovation.

Table 6. Moderation effect analysis.

	(1)	(2)	(3)	(4)	（5）
Variables	GI	GI	GI	GI	GI
NUSP*Soe	−0.111***				
	(−3.36)				
NUSP*Pollute		−0.072**			
		(−2.20)			
NUSP*HighTech			0.116***		
			(3.84)		
NUSP*TechInten				0.120***	
				(3.39)	
NUSP*LaborInten					−0.128***
					(−4.69)
Constant	−2.414***	−2.467***	−2.204***	−2.325***	−2.172***
	(−7.08)	(−7.90)	(−7.12)	(−7.42)	(−7.07)
Observations	34,145	36,401	36,401	36,401	36,401
R−squared	0.119	0.150	0.138	0.141	0.133
Controls	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes

Note: (Standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.)

4.7. Heterogeneity analysis

Next, we perform a heterogeneity analysis of the impact of NUSPs on enterprise green innovation from two aspects: the types of universities on which NUSPs rely and relevant policies at the government level: relying on university types (double first-class/non-double first-class), government R&D subsidies (with R&D grants/without R&D grants), and regional degree of environmental regulatory pressure (high environmental regulation pressure/low environmental regulation pressure).

In Columns (1) and (2) of Table 7, analysis is conducted on enterprises relying on universities classified as double first-class and enterprises relying on non-double first-class universities, respectively, regarding NUSPs and enterprise green innovation. Based on the data in the table, NUSPs exert a relatively remarkable positive influence on the green innovation of enterprises affiliated with double first-class universities. However, the coefficient of enterprises relying on non-double first-class universities is not significant. This indicates that double first-class" universities help NUSPs promote enterprise green innovation. "Double-first class" universities often possess more abundant scientific research resources, top-notch scientific research talents, and cutting-edge scientific research achievements. These scientific research strengths and resource advantages enable them to better align with the R&D needs of enterprises. Through knowledge sharing and technology transfer, NUSPs can promote enterprise green innovation, which is in line with the mechanism of gathering technical talents mentioned earlier.

In Columns (3) and (4) of Table 7, regressions are performed for firms that received R&D grants and firms that did not, respectively. The coefficient of enterprises having received R&D grants is significantly positive at the 1% level, and its coefficient magnitude is notably higher than that of enterprises not having received subsidies. This implies that enterprises that have received subsidies can better exert the role of NUSPs in raising the green innovation level of enterprise. Enterprises that receive government R&D subsidies are usually given attention and support by the government in terms of innovation and possess a certain innovation foundation and potential. When combined with the national university science park, enterprises can utilize the subsidy funds to further increase their investment in green innovation, forming a complementarity with the R&D resources provided by the science park and accelerating the transformation of innovation achievements. Additionally, the government subsidy sends a positive signal to the market, attracting more resources to converge on the enterprise. This echoes the mechanism by which the national university science park alleviates the financial constraints of enterprises and promotes the increase of R&D investment, jointly promoting enterprise green innovation.

In Columns (5) and (6) of Table 7, regression analyses are carried out on enterprises facing high environmental regulation pressure and those facing low environmental regulation pressure respectively. The results show that the promoting effect of NUSPs on enterprises facing higher regional environmental regulation intensity is more significant. At present, China has established one of the most stringent environmental supervision systems in the world, urging companies to update their products and production models to make them greener (Kong, 2024). In regions with higher environmental regulatory intensity, enterprises face greater environmental protection pressure and have a more urgent need for green innovation. Driven by the dual motives of meeting environmental regulatory requirements and enhancing competitiveness, enterprises are more actively cooperating with science parks and utilizing their resources to improve their own green innovation capabilities. This indicates that environmental regulatory pressure acts as an external driving factor with the internal promotion mechanism of the NUSPs and jointly affects the level of enterprise green innovation.

Table 7. Heterogeneity analysis.

Variables	(1) GI Double first-class universities	(2) GI Non-double first-class universities	(3) GI R&D grants	(4) GI NonR&D grants	（5） GI High ER	(6) GI Low ER
NUSP	0.052*	0.035	0.091***	0.036*	0.068***	0.067**
	(1.73)	(0.92)	(4.04)	(1.73)	(3.32)	(2.50)
Constant	−2.163***	−2.472***	−2.813***	−1.968***	−2.278***	−2.681***
	(−3.73)	(−4.44)	(−6.64)	(−4.76)	(−5.96)	(−5.55)
Observations	12,477	12,300	19,186	17,215	15,785	15,927
R-squared	0.123	0.136	0.099	0.144	0.121	0.116
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: (Standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.)

5. Conclusion and discussions

This study uses 36,401 firm-year observations of Chinese listed companies from 2002 to 2020 and the relevant data of NUSPs are collected manually. An empirical analysis is carried out on the connection between NUSPs and enterprise green innovation and the potential mediating mechanism. The research findings suggest that NUSPs significantly boost enterprise green innovation, and these results remain sturdy in various tests. Additionally, the positive influence of NUSPs on enterprise green innovation is mediated through increasing R&D investment, attracting technical talents, and reducing financial constraints. The analysis of moderating effects shows that this positive impact is relatively weaker in state-owned enterprises and heavy pollution industries, while it is more prominent in high-tech industries and technology-intensive enterprises. Moreover, the heterogeneity analysis indicates that NUSPs have a more positive effect on companies relying on double-first-class universities, receiving government R&D subsidies, and being subject to higher environmental regulation.

The study offers several important implications for policymakers and businesses. First, governments should enhance policy support and financial investment in NUSPs, providing preferential policies, tax reductions, exemptions, and other measures to create a conducive environment for innovation and entrepreneurship. Additionally, the government can use the university science and technology park as a platform to promote cooperation between the government, enterprises, universities, and other research institutions to promote the integration of industry, academia, and research and improve the efficiency of green innovation. Furthermore, integrating the concept of green development into the evaluation criteria for NUSPs could help cultivate higher-quality productivity within these facilities.

For businesses, it is crucial to consider the influence of NUSPs when making investment decisions. Green innovation depends on knowledge within the firm and on the ability to access external information, such as universities and markets. In such cases, formal agreements and informal interactions between firms and universities can be invaluable in capturing academic research, introducing new products to the market, and understanding developments outside the region.

Furthermore, enterprises should attach importance to the positive impacts of green finance pilot reforms on their external governance environments. They should look to increase both the quantity and quality of green invention patents. Moreover, they should actively undertake the transition from high-carbon to low-carbon operations.

Author contributions

Yue Zhang: methodology, data collection, and writing original draft preparation. Shijie Ding: reviewing, editing, and supervision.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

References

Aghion P, Askenazy P, Berman N, et al. (2012) Credit constraints and the cyclicality of R&D investment: Evidence from France. *J Eur Econ Assoc* 10: 1001–1024. https://doi.org/10.1111/j.1542-4774.2012.01093.x

Audretsch DB (2009) The entrepreneurial society. *J Technol Transfer* 34: 245–254. https://doi.org/10.1007/978-1-4419-0058-6_5

Bellemar MF, Wichman CJ (2020) Elasticities and the inverse hyperbolic sine transformation. *Oxford B Econ Stat* 82: 50–61. https://doi.org/10.1111/obes.12325

Caloghirou Y, Giotopoulos I, Kontolaimou A, et al. (2021) Industry-university knowledge flows and product innovation: how do knowledge stocks and crisis matter? *Res Policy* 50: 104195. https://doi.org/10.1016/j.respol.2020.104195

Chang CH, Chen YS (2013) Green organizational identity and green innovation. *Manage Decis* 51: 1056–1070. https://doi.org/10.1108/md-09-2011-0314

Chang K, Luo D, Dong Y, et al. (2024) The impact of green finance policy on green innovation performance: Evidence from Chinese heavily polluting enterprises. *J Environ Manage* 352: 119961. https://doi.org/10.1016/j.jenvman.2023.119961

Chang LL, Fang SH (2024) Climate actions and corporate carbon emissions along the supply chain. *Econ Lett* 235: 111503. https://doi.org/10.1016/j.econlet.2023.111503

Chen F, Zeng X, Guo X (2024) Green finance, climate change, and green innovation: Evidence from China. *Financ Res Lett* 63: 105283. https://doi.org/10.1016/j.frl.2023.105283

Chen K, Kenney M (2007) Universities/research institutes and regional innovation systems: the cases of Beijing and Shenzhen. *World Dev* 35: 1056–1074. https://doi.org/10.1016/j.worlddev.2006.05.013

Chen YS (2008) The driver of green innovation and green image–green core competence. *J Bus Ethics* 81: 531–543. https://doi.org/10.1007/s10551-007-9522-1

Cohn JB, Liu Z, Wardlaw MI (2022) Count (and count-like) data in finance. *J Financ Econ* 146: 529–551. https://doi.org/10.1016/j.jfineco.2022.08.004

Cui LS, Zhao J, Zhao LJ, et al. (2024) Top Executives' Overseas Background on Corporate Green Innovation Output: The Mediating Role of Risk Preference. *Economics* 18: 20220105. https://doi.org/10.1515/econ-2022-0105

Cui Z, Ning Y, Song J, et al. (2024) Impact of National Innovative City Policy on Enterprise Green Technology Innovation—Mediation Role of Innovation Environment and R&D Investment. *Sustainability* 16: 1437. https://doi.org/10.3390/su16041437

Díez-Vial I, Montoro-Sánchez Á (2016) How knowledge links with universities may foster innovation: The case of a science park. *Technovation* 50: 41–52. https://doi.org/10.1016/j.technovation.2015.09.001

Gong X, Fu CB, Huang QP, et al. (2022) International political uncertainty and climate risk in the stock market. *J Int Financ Mark I* 81: 101683. https://doi.org/10.1016/j.intfin.2022.101683

Gong X, Liao Q (2024) Physical climate risk attention and dynamic volatility connectedness among new energy stocks. *Energ Econ* 136: 107711. https://doi.org/10.1016/j.eneco.2024.107711

Gong X, Song YJ, Fu CB, et al. (2023) Climate risk and stock performance of fossil fuel companies: An international analysis. *J Int Financ Mark I* 89: 101884. https://doi.org/10.1016/j.intfin.2023.101884

Hobbs KG, Link AN, Shelton TL (2020) The regional economic impacts of university research and science parks. *J Knowl Econ* 11: 42–56. https://doi.org/10.1007/s13132-019-00577-8

Huang Y, Audretsch DB, Hewitt M (2012) Chinese technology transfer policy: The case of the national independent innovation demonstration zone of East Lake. *J Technol Transfer* 38: 828–835. https://doi.org/10.1007/s10961-012-9292-5

Jones CI, Williams JC (1998) Measuring the social return to R&D. *Q J Econ* 113: 1119–1135. https://doi.org/10.1162/003355398555856

Kong FJ (2024) The Influences of Multi-Level Environmental Regulations on Firm Performance in China. *Economics* 18: 20220089. https://doi.org/10.1515/econ-2022-0089

Lai J (2023) Influence of population concentration in urban agglomeration on corporate green innovation. *Asian J Econ Bus Account* 23: 65–79. https://doi.org/10.9734/ajeba/2023/v23i161027

Li F, Li J, Wang D (2024) Policy instruments and green innovation: evidence and implications for corporate performance. *J Clean Prod* 471: 143443. https://doi.org/10.1016/j.jclepro.2024.143443

Lin B, Ma R (2022) How does digital finance influence green technology innovation in China? Evidence from the financing constraints perspective. *J Environ Manage* 320: 115833. https://doi.org/10.1016/j.jenvman.2022.115833

Lin X, Zhang J, Yu L, et al. (2024) Does macroprudential policy matter for corporate green innovation? The role of financing constraints and public environmental concerns. *Econ Anal Policy* 82: 877–892. https://doi.org/10.1016/j.eap.2024.04.018

Lindelof P, Lofsten H (2005) Academic versus corporate new technology-based firms in Swedish science parks: an analysis of performance, business networks and financing. *Int J Technol Manage* 31: 334–357. https://doi.org/10.1504/IJTM.2005.006638

Link AN, Scott JT (2006) US university research parks. *J Prod Anal* 25: 43–55. https://doi.org/10.4337/9781786432797.00009

Liu B, Gan L, Huang K, et al. (2023) The impact of low-carbon city pilot policy on corporate green innovation: Evidence from China. *Financ Res Lett* 58: 104055. https://doi.org/10.1016/j.frl.2023.104055

Liu B, Li Z, Yang X, et al. (2024) National innovative city and green technology progress: empirical evidence from China. *Environ Sci Pollut Res* 31: 36311–36328. https://doi.org/10.1007/s11356-023-27912-3

Lofsten H, Klofsten M (2024) Exploring dyadic relationships between Science Parks and universities: bridging theory and practice. *J Technol Transf* 49: 1914–1934. https://doi.org/10.1007/s10961-024-10064-y

Lofsten H, Lindelof P (2002) Science Parks and the growth of new technology-based firms—academic-industry links, innovation and markets. *Res Policy* 31: 859–876. https://doi.org/10.1016/S0048-7333(01)00153-6

Mian SA (1997) Assessing and managing the university technology business incubator: An integrative framework. *J Bus Venturing* 12: 251–285. https://doi.org/10.1016/S0883-9026(96)00063-8

Montoro-Sánchez A, Ortiz-de-Urbina-Criado M, Mora-Valentín EM (2011) Effects of knowledge spillovers on innovation and collaboration in science and technology parks. *J Knowl Manag* 15: 948–970. https://doi.org/10.1108/13673271111179307

Pan A, Cao X (2024) Pilot free trade zones and low-carbon innovation: Evidence from listed companies in China. *Energ Econ* 136: 107752. https://doi.org/10.1016/j.energyecon.2023.107752

Powell WW, Koput KW, Smith-Doerr L (1996) Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Admin Sci Quart* 41: 116–145. https://doi.org/10.2307/2393988

Qadeer A, Jiang X, Rehman RU et al. (2024). Does state participation promote or damage green innovation? *Creat Innov Manag* 33: 61–76. https://doi.org/10.1111/caim.12581

Qi XZ, Li EPH, Wei ZY et al. (2024) Bridging the valley of death: examining university science parks' influence on revenue generation. *Int J Entrep Behav R* 30: 1093–1121. https://doi.org/10.1108/IJEBR-05-2023-0475

Qiao P, Liu S, Fung HG, et al. (2024) Corporate green innovation in a digital economy. *Int Rev Econ Financ* 92: 870–883. https://doi.org/10.1016/j.iref.2024.02.073

Schaeffer V, Öcalan-Özel S, Pénin J (2020) The complementarities between formal and informal channels of university–industry knowledge transfer: a longitudinal approach. *J Technol Transfer* 45: 31–55. https://doi.org/10.1007/s10961-018-9674-4

Shao S, Xu L, Yang L, et al. (2024) How do energy-saving policies improve environmental quality: Evidence from China's Top 10,000 energy-consuming enterprises program. *World Dev* 175: 106466. https://doi.org/10.1016/j.worlddev.2023.106466

Song Y, Pang X, Zhang Z, et al. (2024) Can the new energy demonstration city policy promote corporate green innovation capability? *Energ Econ* 136: 107714. https://doi.org/10.1016/j.energyecon.2023.107714

Sun G, Fang J, Li J, et al. (2024) Research on the impact of the integration of digital economy and real economy on enterprise green innovation. *Technol Forecast Soc* 200: 123097. https://doi.org/10.1016/j.techfore.2023.123097

Tan J (2006) Growth of industry clusters and innovation: Lessons from Beijing Zhongguancun Science Park. *J Bus Venturing* 21: 827–850. https://doi.org/10.1016/j.jbusvent.2005.09.001

Tan J, Tan D (2005) Environment-strategy co-evolution and co-alignment: A staged model of Chinese SOEs under transition. *Strategic Manage J* 26: 141–157. https://doi.org/10.1002/smj.437

Teece DJ (1992) Competition, cooperation, and innovation: Organizational arrangements for regimes of rapid technological progress. *J Econ Behav Organ* 18: 1–25. https://doi.org/10.1142/9789812796929_0016

Thursby JG, Thursby MC (2002) Who is selling the ivory tower? Sources of growth in university licensing. *Manage Sci* 48: 90–104. https://doi.org/10.1287/mnsc.48.1.90.14271

Unlu, H, Temel, S, Miller, K (2023) Understanding the drivers of patent performance of University Science Parks in Turkey. *J Technol Transf* 48: 842–872. https://doi.org/10.1007/s10961-022-09929-x

Vaidyanathan G (2008) Technology parks in a developing country: The case of India. *J Technol Transfer* 33: 285–299. https://doi.org/10.1007/s10961-007-9041-3

Wang X, Zhu L (2023) How does export VAT rebates policy affect corporate investment efficiency? Evidence from corporate tax stickiness. *Pac-Basin Financ J* 82: 102130. https://doi.org/10.1016/j.pacfin.2023.102130

Wang Y, Li M (2022) Credit policy and its heterogeneous effects on green innovations. *J Financ Stabil* 58: 100961. https://doi.org/10.1016/j.jfs.2021.100961

Zhang J, Liang G, Feng T, et al. (2020) Green innovation to respond to environmental regulation: how external knowledge adoption and green absorptive capacity matter? *Bus Strateg Environ* 29: 39–53. https://doi.org/10.1002/BSE.2349

Zhang JA, O'Kane C, Bai T (2024) How do university-firm interactions affect firm innovation speed? The case of Chinese science-intensive SMEs. *Res Policy* 53: 105027. https://doi.org/10.1016/j.respol.2023.105027

Zhang Z, Luo C, Zhang G, et al. (2024) New energy policy and green technology innovation of new energy enterprises: Evidence from China. *Energ Econ* 136: 107743. https://doi.org/10.1016/j.eneco.2024.107743

Zhao Y, Peng B, Elahi E, et al. (2021) Does the extended producer responsibility system promote the green technological innovation of enterprises? An empirical study based on the difference-in-differences model. *J Clean Prod* 319: 128631. https://doi.org/10.1016/j.jclepro.2021.128631

Zou Y, Zhao W (2014) Anatomy of Tsinghua University Science Parks in China: institutional evolution and assessment. *J Technol Transfer* 39: 663–674. https://doi.org/10.1007/s10961-013-9314-y