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Research article

The impact of intellectual property rights protection on green innovation: A quasi-natural experiment based on the pilot policy of the Chinese intellectual property court

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Abstract: In the context of high-quality economic development in China, it is important to promote green innovation development by protecting intellectual property rights (IPR). Taking the pilot policy of the intellectual property courts in Beijing, Shanghai, and Guangzhou for example in a quasi-natural experiment, this article examines the effect of IPR protection on the development of corporate green innovation and its mechanisms by using a difference-in-differences model and a mediating effect model based on Chinese enterprise data from 2011 to 2019. The study found that first, IPR protection promotes enterprise green technological innovation; second, IPR protection affects green innovation through enterprise financing constraints and R&D investment; that is, increasing enterprise R&D investment and alleviating enterprise financing constraints are two important channels through which IPR protection promotes enterprise green technological innovation.

Keywords: intellectual property rights protection; green innovation; quasi-natural experiment; difference-in-differences model; ecological protection

1. Introduction

For decades, China has relied too much on high-polluting and high-energy-consuming industries to drive its economy. This development model, which over emphasized economic growth while

neglecting environmental protection, although boosting the country's economy in the short run, has seriously damaged China's ecological environment. As the environmental situation continues to deteriorate, China's previous fast rate of innovation, which primarily relied on the direct consumption of raw materials, needs to transform to high-quality innovation-characterized by green, intelligent, and sustainable development. In 2015, the Fifth Plenary Session of the 18th Central Committee proposed the Five Development Concepts, in which "green" and "innovation" were included as two important concepts, indicating that China's attention to green innovation had reached a new height. In 2021, the 14th Five-Year Plan proposed the implementation of a green technology innovation campaign, insisting on the green development concept. Enterprises play a significant role in boosting economic growth, but they also consume a considerable amount of natural resources. Promoting enterprise green transformation and accelerating the development of enterprise green technology innovation not only constitute an important measure to promote coordinated economic growth and environmental protection, they also constitute an effective path to achieve both economic efficiency and ecological protection. While R&D investment has continued to increase in China, regional green innovation performance has not increased proportionately [1].

Promoting enterprise green technology innovation cannot be achieved without the intellectual property rights (IPR) protection policies. Although scholars like Franklin Allen pointed out that the case of China contradicts the findings in the literature on law, institutions, finance, and growth, because, despite having underdeveloped legal and financial systems, it has managed to achieve one of the most rapid economic growth rates [2]; furthermore, sufficient evidence proved that a progressive legal system and technological advancements, supported by IPR policies have become a crucial factor in China's overall national strength competition [3–5]. Since the release of the National Innovation-Driven Development Strategy Outline, China's scientific and technological innovation has achieved rapid development with strong support and promotion from governments at all levels. In accordance with the 2019 Global Innovation Report, China's innovation ranking has risen to the 14th in the world.

However, China's IPR infringement issues are still not trending positive, and the IPR protection system urgently needs improvement. The results of the Business Confidence Survey showed that 78% of the surveyed companies had encountered IPR issues. The severe situation of IPR protection has made people's demand for improving the IPR protection system increasingly urgent. The Outline for Building Intellectual Property Power (2021–2035) emphasizes the importance of IPR protection. IPR protection provides strong institutional guarantees for scientists and enterprises to coordinate innovation in order to truly realize the transformation of applied basic research and new technologies and other achievements, thus promoting global sustainable and green technological innovation.

With the profound understanding of scholars on IPR protection and the deepening study on green innovation development, a large amount of related research has gradually emerged, mainly focusing on the factors affecting green innovation development. Firstly, there exists an extensive body of research that examines how environmental regulations affect the advancement of eco-friendly innovation in enterprises. Certain academics have concluded that environmental regulations that are market-based can offer stronger incentives for innovation [6,7]. According to certain studies, the implementation of low-carbon city pilot policies can drive innovation in green technologies related to energy conservation and alternative energy in enterprises [8,9]. Many Chinese scholars believe that direct environmental regulations have a more significant incentive effect on enterprises with strong innovation capabilities, and it is necessary for the Chinese government to guide enterprises through market mechanisms rather than using a one-size-fits-all approach [10,11].

Second, the effects of financial development on green innovation are studied in depth. Scholars generally believe that from the market's perspective, developing green finance can promote the innovation of green technology in enterprises. Some scholars have pointed out that the development of green finance by means of green credit can optimize the economic structure, thus creating incentives for enterprises to innovate green technologies and helping them to make the green transition [12,13]. Specifically, the stock market is found the most strongly associated with green technological innovation, and the better the development of the stock market, the stronger the promotional effect on green technological innovation [14,15]. Li et al. [16] found that green credit and related environmental protection subsidies can encourage enterprises to carry out clean production. Furthermore, certain academics have examined the correlation between green finance and eco-friendly innovation in countries with varying levels of development. Their findings suggest that green finance has a positive impact on green innovation in emerging countries, but it can have a negative impact in countries that have already achieved significant progress in green innovation [17,18].

Moreover, the effect of IPR protection on innovation has been a focus of academic study in the recent decade. Dinopoulos and Segerstrom [19] argued that IPR protection could promote regional innovation by increasing the rate of international technology transfer within multinational firms. Hudson and Minea [20] opined that the impact of IPR on innovation is intricate and can exhibit nonlinear trends, which are dependent on the initial levels of both IPR and per capita GDP. With a world sample, Sweet & Maggio [21] found that stronger IPR protection could promote innovation advances only in countries with above-average levels of development and complexity. Certain scholars from China have identified an inverted U-shaped connection between IPR protection and the innovation capability of industrial enterprises in China. However, most of the samples analyzed were located on the lower side of the turning point, suggesting that reinforcing IPR protection could still prove advantageous in enhancing China's industrial innovation [22,23]. Papageorgiadis and Sharma [24] focused on the relationship between innovation and the strength of IPR regulations and enforcement, and the researchers discovered that the level of IPR regulations and enforcement has a noteworthy impact on promoting innovation. Grimaldi et al. [25] found that not having any IPR protection strategy can be a barrier to outbound green innovation.

Prior theoretical and empirical work have provided a solid foundation and valuable reference for our study, but there is still room for further research, especially in emerging countries like China. In this study, we focus on the impact of IPR protection on green innovation development in China, with the marginal contribution mainly being as follows. First, the study takes the correlation between IPR protection and enterprise environmentally friendly innovation in China as its research object. Existing research mainly centers on the effect of IPR protection on innovation in general, with little research focusing on green innovation development. This paper regards the pilot policy of IPR protection as an external shock, exploring the effect of external regulations on the internal development of corporate green innovation. Second, the research delves into how IPR protection affects environmentally friendly innovation in Chinese enterprises, particularly exploring the mediating role of R&D investment and financing constraints in the impact of IPR pilot protection policy on the development of green technology innovation.

The rest of this paper is structured as follows. In Section 2, the research scheme is presented, which includes proposing research hypotheses based on theoretical analysis and constructing research models. Section 3 specifies the indicator selection and data sources. Section 4 discusses the empirical test on the impact of IPR on enterprise green innovation. Section 5 furthers the analysis on the impact

mechanism. Section 6 concludes the study and provides policy implications.

2. Research scheme

2.1. Theoretical analysis and research hypotheses

2.1.1. Effects of IPR protection on enterprise green innovation

Justification of the exclusiveness of an intellectual property right involves more than one theory, and typical theories involved include the theory of incentives for creation and the theory of compensation for public opening [26–30]. Therefore, strengthening judicial protection of intellectual property is a fundamental guarantee for the promotion of the vitality and driving force of enterprise innovation. Compared to traditional innovation, green innovation has a double externality issue, which results in a sub-optimal investment in green innovations; thus, policy regulations play a determinant role in motivating eco-friendly innovation [31–33] and thus reduce the incentives for its adoption. IPR protection can have a positive impact on enterprise green innovation by increasing the value of R&D results in environmental protection. In other words, when the protection of intellectual property is insufficient, the green innovation outcomes of enterprises will be imitated by competitors at will, resulting in lower-than-expected returns on green innovation and reduced profits, which will weaken the incentive for companies to pursue environmentally friendly innovation [34–36]. Therefore, the first hypothesis of this study is proposed.

Hypothesis 1: IPR protection promotes the development of enterprise green innovation.

2.1.2. Analysis of the mediating effect of R&D investment in the impact of IPR protection on enterprise green innovation

R&D investment is one of the decisive factors in determining the output of enterprise green innovation. Studies have shown a correlation between the R&D expenses of 28 E.U. nations and their ecological footprints [37]. It profoundly affects the entire process of enterprise innovation and is the economic foundation of the enterprise green technology innovation capabilities [38]. Some research has shown that increasing enterprise R&D investment can ensure their green technology improvement and innovation levels, guaranteeing their market competitiveness and good performance [39]. IPR protection can increase the enterprise R&D investment through the crowding-out effect. IPR protection can increase the imitation cost and infringement cost among competing enterprises. The increasing costs in introducing external technologies force enterprises to increase their R&D investment to obtain market competitiveness, which promotes green technology innovation [40, 41]. Therefore, we propose the second hypothesis.

Hypothesis 2: R&D investment is a channel through which IPR protection promotes enterprise green innovation.

2.1.3. Analysis of the mediating effect of enterprise financing constraints in the impact of IPR protection on enterprise green innovation

The ability of enterprises to obtain sufficient external financing is one of the main factors affecting

the success of R&D and innovation activities [42,43]. In addition, compared with traditional technological innovation, green innovation requires significant upfront investment and has a longer payback period. Therefore, it requires a certain amount of financial support to address a series of market mechanism problems that may arise during the innovation process [44–46]. This means that financing constraints are an important limiting factor in the process of enterprise green innovation. R&D and innovation activities of enterprises have information asymmetry characteristics. When external investors are not aware of the enterprise's green innovation achievements, they cannot evaluate the commercial value of this technology. However, when they are fully aware, they may directly imitate the enterprise's innovation achievements, making the enterprise unwilling to fully disclose information related to its R&D and innovation activities [47,48]. Therefore, effective solutions to the information asymmetry between external investors and enterprises constitute the reason why IPR protection can alleviate enterprise financing constraints. IPR protection can effectively restrict potential imitation and infringement behaviors, consequently prompting enterprises to provide necessary intellectual property and technology information to external investors, reducing information asymmetry between external investors and enterprises, helping enterprises to accelerate financing speed and reducing financing costs, thus providing a good foundation for enterprise green technology innovation activities [49]. Thus, the third hypothesis is proposed.

Hypothesis 3: Alleviating enterprise financing constraints is the channel through which IPR protection promotes enterprise green innovation.

2.2. Model setting

2.2.1. Construction of the difference-in-differences model

The difference-in-differences (DID) model is commonly used in econometrics to quantitatively evaluate the implementation effects of public regulations or projects. The DID model uses data obtained from quasi-natural experiments based on non-randomly assigned regulation experimental and control groups. By controlling for preexisting differences between the research subjects, the model effectively separates the actual effects of policy impacts. In 2014, Beijing, Shanghai, and Guangzhou were chosen as pilot cities to establish intellectual property courts, while no such court had previously been established in China. This meets the prerequisite conditions required by the DID model. To eliminate unobserved impacts on the results, we constructed a DID model with fixed years and enterprises to evaluate the impact of IPR protection on the development of enterprise green innovation. The model setting was as follows:

$$\text{lngreen patent}_{i,t} = \beta_0 + \beta_1 \text{policy}_{i,t} + \beta_j \text{controls}_{i,t} + \text{year} + \text{firm} + \varepsilon_{i,t} \quad (1)$$

where i stands for the enterprise, t represents the year, and $\varepsilon_{i,t}$ is the random error term; $lngreen\ patent$ represents the explained variable, i.e., green innovation, and $policy = treat * post$ is the core explanatory variable, i.e., the pilot policy of the intellectual property court; $treat$represents the treatment effect, where enterprises located in Beijing, Shanghai, and Guangzhou are defined as the experimental group and assigned a value of 1, while others are defined as the control group and assigned a value of 0; $post$ stands for the time effect, where years after 2015 (the year the pilot policy put into effect) are assigned a value of 1, while other years are assigned a value of 0; the

company asset size (*size*), company age (*age*), company leverage ratio (*LEV*), company total asset turnover ratio (*ROA*), number of board members (*board*), percentage of independent directors (*Indep*), nature of company's ownership (*SOE*), and company annual revenue growth rate (*growth*) are control variables.

2.2.2. Building a mediating effect model

To analyze whether the R&D investment and the financing constraints play a mediating role in promoting green innovation development through IPR protection, we have introduced a mediating variable to construct a mediating model. Following the practices of Sun and Song [50] as well as Huang et al. [51], we adopted the per capita R&D investment of enterprises as a measure of the level of enterprise R&D investment. In reference to the practices of Hadlock and Pierce [52] and Song et al. [53], this study adopts the FC (financial constraints) indicator in the SA (size-age) index as a measure of financial constraints. Both the per capita R&D investment and the FC indicator were taken as mediating variables to establish a stepwise regression model for testing the mediating effect [54,55]. The results were further validated by using the Sobel test. The specific models are as follows:

(i) With the per capita R&D investment as the mediating variable:

$$\text{green patent}_{i,t} = \beta_0 + \beta_1 \text{policy}_{i,t} + \beta_j \text{controls}_{i,t} + \text{year} + \text{firm} + \varepsilon_{i,t} \quad (2)$$

$$\text{R\&D}_{i,t} = \beta_0 + \beta_1 \text{policy}_{i,t} + \beta_j \text{controls}_{i,t} + \text{year} + \text{firm} + \varepsilon_{i,t} \quad (3)$$

$$\text{green patent}_{i,t} = \beta_0 + \beta_1 \text{policy}_{i,t} + \beta_2 \text{R\&D}_{i,t} + \beta_j \text{controls}_{i,t} + \text{year} + \text{firm} + \varepsilon_{i,t} \quad (4)$$

(ii) With the FC indicator as the mediating variable:

$$\text{green patent}_{i,t} = \beta_0 + \beta_1 \text{policy}_{i,t} + \beta_j \text{controls}_{i,t} + \text{year} + \text{firm} + \varepsilon_{i,t} \quad (5)$$

$$\text{FC}_{i,t} = \beta_0 + \beta_1 \text{policy}_{i,t} + \beta_j \text{controls}_{i,t} + \text{year} + \text{firm} + \varepsilon_{i,t} \quad (6)$$

$$\text{green patent}_{i,t} = \beta_0 + \beta_1 \text{policy}_{i,t} + \beta_2 \text{FC}_{i,t} + \beta_j \text{controls}_{i,t} + \text{year} + \text{firm} + \varepsilon_{i,t} \quad (7)$$

where R&D represents the mediating variable for enterprise R&D investment, FC represents the mediating variable for financial constraints, and the variables have the same meanings as the ones in Eq (1).

3. Indicator selection and data sources

3.1. Indicator selection

The explained variable in this study is the level of green innovation of listed companies. According to the division of green patents in the International Patent Classification (IPC) Green

Inventory developed by the IPC Committee of Experts, green patents are divided into two categories: green invention and green utility model patents. Following the approach of Deng et al. [56], this research measures the level of green innovation by using the application number of green invention patents as the indicator. This choice is based on two reasons: one is that the application threshold for green invention patents is higher than that for green utility model patents, and that there is a greater requirement for the company's green innovation level [57]; the other is that due to the complex and long patent authorization process, relative to the number of patent authorizations, the number of patent applications is believed to have the features of timeliness, reliability, and stability [58]. Since the application number of green invention patents has a right-skewed distribution feature, this study adopts the number of green innovation patent applications plus one taking the natural logarithm to measure the explained variable.

The core explanatory variable is the IPR protection pilot policy, which is measured by the interaction between the location and the time of the intellectual property court pilot policy implementation. The reason for using the interaction term as the core explanatory variable is that, since the research objective was to evaluate the impact of IPR protection policies on the level of green innovation of enterprises, it is necessary to examine the policy change-related factors, which involve time and place, that is, the time and space factors. Spatial factors and the economic status of Chinese cities have a close correlation; the high economic status of the city is often the pilot area of the policy, and mainland China's policy pilots tend to start from the oversized first-tier cities. In terms of the policy implementation location variable, enterprises with offices located in the three pilot cities were defined as the treatment group and assigned a value of 1, while the rest were defined as the control group and taken a value of 0. Regarding the policy implementation time variable, the years after 2015 had a value of 1, and other years had a value of 0.

To control the impact of other economic indicators on green innovation in enterprises, we have introduced the following control variables based on existing literature: 1) Enterprise size, which is calculated by the year-end total assets. Generally, the size of a company has a significant effect on its innovation. Larger companies tend to raise their R&D investment to ensure their technology development level and competitiveness. 2) Enterprise age, which represents the maturity level of an enterprise. Studies have shown that the more mature an enterprise, the stronger its innovation consciousness [59,60]. This study measures the enterprise age by the length of time it has been listed. 3) Enterprise debt. Reasonable debt management can provide enterprises with more capital for technology and research activities. This study uses the asset-liability ratio of the enterprise as an indicator of enterprise debt. 4) Enterprise profitability, which is calculated by the return on assets (ROA) in this study. The higher the ROA, the stronger the company's profitability. It is generally believed that companies with higher profitability have stronger innovation capabilities. 5) Enterprise management level, which is evaluated by the number of board members and the percentage of independent directors, because the structure of the director board and the percentage of independent directors reflect the decision-making level and governance structure of the company's management. 6) Enterprise ownership. Different enterprise ownership leads to different levels of technological innovation. If an enterprise is a state-owned enterprise (SOE), the value is 1, and if it is a non-SOE, the value is 0. 7) Enterprise development capability, which is assessed by the annual revenue growth rate, reflecting the company's development status. Generally, the greater the company's development potential, the more it will increase its investment in technological innovation.

The variables selected and specific measurement indicators for the empirical study in this paper

are presented in Table 1.

Table 1. Variables and measurement.

Variable type	Symbol	Indicator	Measurement
Explained variable	green patent	Green innovation	Number of green invention patent applications
Explanatory variable	policy	IPR protection policy	Pilot location × Pilot time
Control variables	size	Enterprise size	Year-end total assets of the enterprise
	age	Enterprise age	The length of time a company has been listed
	LEV	Enterprise debt	Asset-liability ratio of the enterprise
	ROA	Enterprise profitability	ROA of the enterprise
	board	Enterprise management level	Number of directors in the corporate board
	Indep		Proportion of independent directors in the enterprise board
	SOE	Enterprise ownership	SOE/non-SOE (1/0)
	growth	Enterprise development capability	Annual revenue growth rate

3.2. Data source

Since the intellectual property pilot courts (put into effect in 2015) are relatively new, to ensure the symmetry of data before and after the establishment of the intellectual property pilot courts and the comparability of results, we selected green invention patent application data and the corresponding economic data of A-share listed companies in China from 2011 to 2019[1]. The green patent data of listed companies were obtained from the Chinese National Intellectual Property Administration, and the selection of green patent applications is based on the International Patent Classification (IPC) Green Inventory. The relevant economic data of companies are acquired from the China Stock Market & Accounting Research (CSMAR) Database.

To ensure data validity, we processed the original samples of listed companies as follows: 1) considering that the data of financial enterprises are not suitable for measuring the level of enterprise green innovation, companies belonging to the financial industry are excluded; 2) companies without continuous five-year observations or are under special treatment (ST) were excluded; 3) to avoid the influence of extreme values, all continuous variables selected were winsorized at the upper and lower 1%. Finally, a valid annual sample of 19,285 companies was obtained.

The descriptive statistics of all variables involved in the empirical analysis are shown in Table 2. The specific statistical characteristics of the variables are as follows:

[1] To prevent shocks to the results from the financial crisis (2008 global financial crisis) and the major public health crisis (COVID-19 epidemic), the data sample in this paper does not include the time periods of 2008–2010 and 2020 to the present.

Table 2. Variables and descriptive statistical results.

Variable symbol	Sample number	Mean	Standard deviation	Minimum	Maximum
green patent	19,285	3.953	23.309	0	915
policy	19,285	0.113	0.316	0	1
size	19,285	22.219	1.247	19.885	25.93
age	19,285	2.829	0.347	1.792	3.466
LEV	19,285	0.424	0.204	0.057	0.896
ROA	19,285	0.039	0.058	-0.193	0.206
board	19,285	2.138	0.195	1.609	2.639
Indep	19,285	0.375	0.054	0.333	0.571
SOE	19,285	0.378	0.485	0	1
growth	19,285	0.164	0.376	-0.543	2.213

It can be seen in Table 2 that the standard deviations of both the explanatory variable and the explained variable are relatively large, indicating significant heterogeneity in both the green technology innovation and local intellectual property protection policies of enterprises. By comparing the coefficients of variation between the explanatory variable and the explained variable, we found that the coefficient of variation of green technology innovation is larger, i.e., close to 600%, and that of the intellectual property policy change is close to 300%. As for the control variables, only the enterprise size has a relatively large coefficient of variation, but it is only 5.6%.

4. Econometric tests of the impact of IPR protection on enterprise green innovation

4.1. Benchmark regression

This research adopted a DID model to assess the impact of IPR protection on enterprise green innovation, and the DID benchmark regression results are presented in Table 3, where Columns (1) and (2) control for fixed effects at the enterprise level, while Columns (3) and (4) control for fixed effects at both enterprise and time levels; additionally, control variables are added to Columns (2) and (4). All regression analyses were performed by using the enterprise-level clustering adjusted standard errors.

As shown in Table 3, it is obvious that IPR protection promotes enterprise green innovation. The establishment of intellectual property pilot courts effectively promotes the technological innovation of enterprise green technology, thus verifying Hypothesis 1. The regression coefficient relative to green invention patents in Column (1) is 0.410, which is significant at the level of 1%. When controlling for the year and company fixed effects, the regression coefficient of relative to green invention patents in Column (3) is 0.0846, significant at 5% and smaller than that in Column (1). This suggests that there are time and firm factors that affect green technology innovation in enterprises. Therefore, controlling for firm and time fixed effects effectively eliminates the interference of some random factors and enables a more accurate analysis of the net impact of the pilot policy implementation.

Considering that various company characteristics, such as debt, management structure, and development capabilities, can also have an impact on green technology innovation, selected control variables were further added to the model. After adding control variables, the regression coefficients

relative to green invention patents in Columns (2) and (4) were 0.0731 and 0.0732, respectively, significant at 5% and still supporting the expected result of this study.

Table 3. Benchmark regression results.

	(1)	(2)	(3)	(4)
	lngreen patent	**lngreen patent**	**lngreen patent**	**lngreen patent**
policy	0.410***	0.0731**	0.0846**	0.0732**
	(0.0298)	(0.0306)	(0.0329)	(0.0320)
size		0.283***		0.266***
		(0.0226)		(0.0232)
age		0.598***		0.171
		(0.0532)		(0.137)
Lev		-0.127**		-0.0782
		(0.0642)		(0.0649)
ROA		-0.0299		0.0276
		(0.124)		(0.124)
board		0.0270		0.0177
		(0.0707)		(0.0702)
Indep		-0.0305		-0.0693
		(0.215)		(0.214)
SOE		0.166***		0.169***
		(0.0557)		(0.0556)
growth		-0.0198		-0.0203
		(0.0123)		(0.0125)
constant		-7.448***		-5.955***
		(0.476)		(0.648)
controls	NO	YES	NO	YES
year	NO	NO	YES	YES
firm	YES	YES	YES	YES
R-squared	0.024	0.150	0.124	0.154
N	19,285	19,285	19,285	19,285

Note: *, **, and *** represent the significance levels of 10%, 5%, and 1%, respectively. Standard errors of the regression coefficients are shown in parentheses.

The results shown in Table 3 indicate that augmenting IPR protection is conducive to enhancing the development capability of green innovation in enterprises. However, most evaluation criteria prioritize quantity over quality, resulting in a large amount of low-quality innovation that pursues short-term benefits in the innovation process, which not only wastes resources, going against the concept of green development, but also fails to solve the bottleneck of high-end technology faced by China. Therefore, the Chinese government should vigorously promote the establishment and improvement of the IPR protection system, as represented by the intellectual property court, and strengthen the protection of green innovation rights and interests, creating an environment that truly conforms to the concept of green innovation.

4.2. Parallel trend test

The prerequisite for adopting the DID method is that the trends of change between the treatment group and the control group must be consistent before being processed. Based on this, we decided to demonstrate the stability of the model through a parallel trend test. Figure 1 displays the parallel trends of enterprise green innovation output from 2011 to 2019. The solid line represents the average number of green patent applications in the treatment group, while the dashed line represents the average number of green patent applications in the control group. The vertical dashed line represents the start of the IPR pilot policy taking effect.

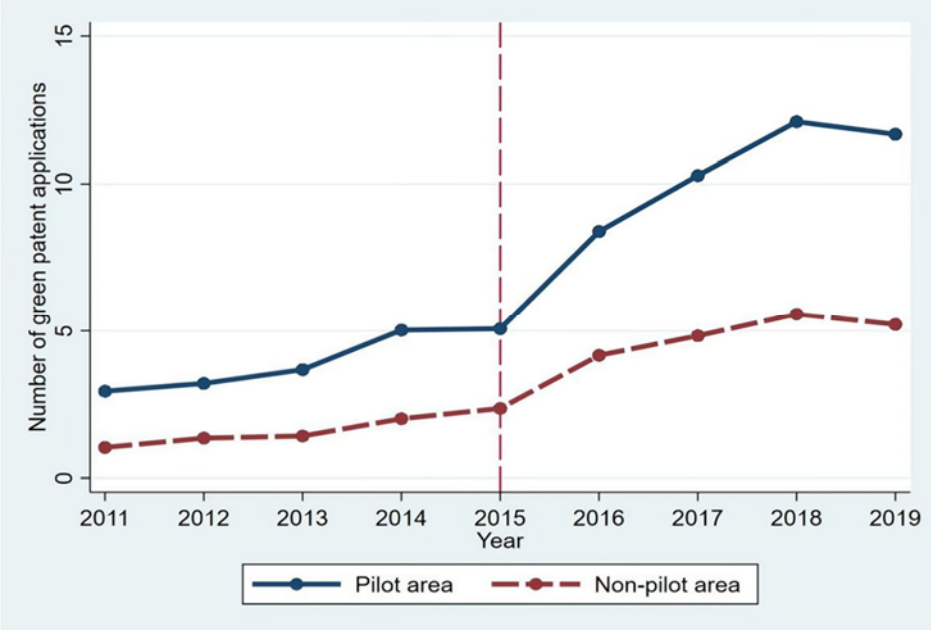

Figure 1. Parallel trends.

The DID model of this research passed the robustness test. As indicated in Figure 1, before the establishment of intellectual property pilot courts, the trend of the number of green invention patent applications in the experimental group (Beijing, Shanghai, Guangzhou) was similar to that in the control group, maintaining a parallel trend. However, after implementing the pilot policy, the gap between the two groups of green invention patents significantly widened. The number of green invention patents in the three pilot cities grew much faster than in other cities, and this trend was maintained until the end of the sample period. These results indicate that the DID model passed the parallel trend test. The specific results are presented in Table 4.

Table 4 reveals that before the establishment of the intellectual property pilot courts, there was no significant difference between the experimental and control groups. However, in the "current" year (i.e., the first year after the policy was implemented), the difference between the two groups began to be significant, indicating that the pilot policy of intellectual property courts directly impacted the green technology innovation of enterprises in the experimental group. No lag effect was observed, which again confirms that the experimental and control groups passed the parallel trend test.

Table 4. Parallel trend test results.

	(1)	(2)
Variables	**lngreen patent**	**lngreen patent**
d_3	0.0183	0.0183
	(0.0395)	(0.0395)
d_2	0.0178	0.0178
	(0.0409)	(0.0409)
d_1	0.0512	0.0512
	(0.0447)	(0.0447)
current	0.0542	0.0542
	(0.0462)	(0.0462)
d1	0.135***	0.135***
	(0.0503)	(0.0503)
d2	0.122**	0.122**
	(0.0525)	(0.0525)
d3	0.0393	0.0393
	(0.0554)	(0.0554)
d4	0.133**	0.133**
	(0.0579)	(0.0579)

Note: *, **, and *** represent the significance levels of 10%, 5%, and 1%, respectively; the standard errors of the regression coefficients are shown in parentheses.

5. The impact mechanism of the IPR protection on enterprise green innovation

5.1. The mediating effect of the R&D investment

We employed the stepwise method and the Sobel test to confirm the mediating effect of the R&D investment in the influence of the IPR protection on enterprise green innovation, and Table 5 shows the test results.

The results in Table 5 show that R&D partially mediates the impact of IPR protection on promoting enterprise green innovation. In Column (1), the regression coefficient for policy is 0.0815, which is significant at the 5% level, indicating that IPR protection has a positive promotional effect on enterprise green technology innovation. Therefore, further testing was performed. Column (2) presents the regression estimation for IPR and R&D, with a regression coefficient for policy of 0.376, which is also significant at 5%, indicating that the protection of intellectual property exerts a positive driving impact on increasing R&D investment in enterprises. Column (3) outlines whether the level of enterprise innovation in green technology will be greatly impacted by the presence of IPR protection and R&D investment. The results show that IPR protection still significantly affects green innovation in enterprises at the 5% level and that the regression coefficient for R&D investment is significant at the 1% level. This indicates that there is a partial mediating effect between IPR protection and enterprise green innovation. Strengthening IPR protection can increase enterprise R&D investment

and thereby have a positive effect on green technology innovation. R&D investment is the transmission path through which IPR protection affects green technology innovation in enterprises, thus Hypothesis 2 is verified.

Table 5. The mediating effect of the R&D investment.

Plan A: The mediating effect test results			
	(1)	**(2)**	**(3)**
Explanatory variables	**Total effect**	**R&D investment**	**Mediating effect of R&D investment**
Policy	0.0815**	0.376**	0.0748**
	(0.0369)	(0.191)	(0.0367)
lnrd			0.0177***
			(0.00354)
Size	0.325***	0.691***	0.313***
	(0.0274)	(0.116)	(0.0276)
Age	-0.0205	-0.604	-0.00985
	(0.151)	(0.631)	(0.150)
Lev	-0.135*	-1.184***	-0.114
	(0.0775)	(0.391)	(0.0774)
ROA	-0.0625	0.922	-0.0788
	(0.141)	(0.721)	(0.140)
Board	0.0378	-0.324	0.0435
	(0.0770)	(0.353)	(0.0771)
Indep	-0.0448	-0.640	-0.0335
	(0.236)	(0.943)	(0.234)
SOE	0.147**	0.119	0.145**
	(0.0643)	(0.310)	(0.0634)
Growth	-0.0204	-0.138**	-0.0180
	(0.0154)	(0.0661)	(0.0155)
Constant	-6.708***	-9.795***	-6.535***
	(0.738)	(2.855)	(0.740)
Controls	YES	YES	YES
Year	YES	YES	YES
Firm	YES	YES	YES
Observations	16,278	16,278	16,278
Number of stkcd	2,147	2,147	2,147
R-squared	0.167	0.188	0.170

Plan B：Mediating effect test							
Mediating variable	**c**	**a**	σ_a	**b**	σ_b	**Z**	**Mediating effect weight**
R&D investment	0.2223	2.2792	0.0931	0.0566	0.0018	19.1***	58.06%

Note that *, **, and *** indicate significant levels of 10%, 5%, and 1%, respectively; the standard errors of the regression coefficients are shown in parentheses.

In order to confirm that R&D investment has a crucial role in the impact of IPR protection on the innovation of green technology in enterprises, we further adopted the Sobel test to check if the mediating effect is significant. As shown in Table 5, the Z value of the mediating effect of R&D investment passes the test at the 1% significance level, and the mediating effect of R&D investment accounts for 58.06%, once again indicating that IPR protection affects enterprise green innovation through the R&D investment channel.

The empirical findings imply that the role of intellectual property protection for enterprise green innovation should be intensified from two aspects. One is to reinforce the rapid and coordinated protection of intellectual property. Local IPR management departments need to strengthen information communication, share relevant information of enterprises under their jurisdiction, collect information on IPR protection needs and case clues, and increase the efforts of administrative adjudication of patent infringement disputes among enterprises to provide rapid and coordinated protection of IPR. Another aspect is to strengthen the assistance of enterprises in IPR defence. Local IPR management departments should actively innovate the working mode, promote the extension of the work system of IPR protection and assistance at the grassroots level, and explore the development of special actions for IPR protection and assistance.

5.2. The mediating effect of financing constraints

Having investigated the mechanism by which IPR protection affects enterprise green innovation, with R&D investment as the mediating variable, we further introduced financing constraints as a mediating variable to explore whether financing constraints also have a mediating effect in the process of IPR protection promoting the advancement of green innovation. The test results are presented in Table 6.

Based on the findings in Table 6, financing constraints have a negative impact in the process of IPR protection promoting enterprise green innovation. In other words, the smaller the financing constraints, the bigger the enterprise's green innovation capability; conversely, the greater the financing constraints, the more the green innovation capability will be inhibited. The regression findings in Column (2) show that the implementation of the intellectual property court pilot policy has a restraining impact on financing constraints. That is, financing constraints impede the development of green innovation, but the strengthening of IPR protection helps to mitigate the hindering impact of financing constraints on green innovation, thereby achieving the effect of promoting enterprise green innovation. One possible explanation is that strengthening IPR protection can increase the value of innovation achievements, thus allowing enterprises to obtain more financing [9]. The regression results presented in Column (3) demonstrate that even after adding financing constraints as a mediating variable with a negative effect, the DID coefficient of the policy remains significantly positive at 0.0549, indicating that the mitigating effect of IPR protection on financing constraints exists, and confirming Hypothesis 3.

Similarly, to further verify whether financing constraints act as a mediating variable in the influence of IPR protection on green innovation in enterprises, the Sobel test was employed to check whether the mediating effect is significant. As shown in Table 6, the Z-value of the mediating effect of financing constraints has been found to be significant at the 5% level, and the weight of the mediating effect of financing constraints is -0.8769%, indicating once again that IPR protection promotes enterprise green innovation by mitigating the impact of financing constraints.

Table 6. The mediating effect of financing constraints.

Plan A：Results of the mediating effect test							
	(1)			**(2)**		**(3)**	
Explanatory variables	**Total effect**			**Financing constraints**		**The mediating effect of financing constraints**	
Policy	0.0732**			-0.00330***		0.0549*	
	(0.0320)			(0.00117)		(0.0309)	
FC						-5.553***	
						(0.677)	
Size	0.266***			0.00608***		0.300***	
	(0.0232)			(0.00109)		(0.0243)	
Age	0.171			0.0290***		0.332**	
	(0.137)			(0.00475)		(0.136)	
Lev	-0.0782			0.00779***		-0.0344	
	(0.0649)			(0.00289)		(0.0624)	
ROA	0.0276			-0.00135		0.0211	
	(0.124)			(0.00389)		(0.123)	
Board	0.0177			0.00426**		0.0422	
	(0.0702)			(0.00215)		(0.0708)	
Indep	-0.0693			0.00893		-0.0196	
	(0.214)			(0.00622)		(0.214)	
SOE	0.169***			0.000897		0.174***	
	(0.0556)			(0.00152)		(0.0548)	
Growth	-0.0203			0.00192***		-0.00970	
	(0.0125)			(0.000438)		(0.0125)	
Constant	-5.955***			1.077***		0.0244	
	(0.648)			(0.0243)		(0.810)	
Controls	YES			YES		YES	
Year	YES			YES		YES	
Firm	YES			YES		YES	
Observations	19,285			19,283		19,283	
Number of stkcd	2,321			2,321		2,321	
R-squared	0.154			0.846		0.167	
Plan B：Mediating effect test							
Mediating variable	**c**	**a**	σ_a	**b**	σ_b	**Z**	**Mediating effect weight**
Financing constraints	0.2152	0.0023	0.0011	-0.8134	0.1352	-2.003**	-0.8769%

Note that *, **, and *** indicate significant levels of 10%, 5%, and 1%, respectively; the standard errors of the regression coefficients are shown in parentheses.

According to the empirical conclusions, in order to alleviate financing constraints and enhance the effect of intellectual property protection on enterprise green technological innovation, policy guidance can be carried out in terms of three aspects: first is the acceleration of policy innovation that balances demand and supply. Policy innovation in the new era should adhere to systematic thinking.

Second, in terms of the top-level design of the national innovation policy system, compared with supply-side support policies, it is more important to give play to the role of demand-side support policies. Third, it is important to enhance the pertinence of governmental policies for various types of enterprises and optimize the implementation methods and mechanisms of policies. Full consideration should be given to the differences in enterprise attributes, and targeted support should be implemented with precision.

6. Conclusions and policy implications

This study conducted a natural experiment based on the pilot policy of the intellectual property courts in Beijing, Shanghai, and Guangzhou. By matching data from the CSMAR database of A-share listed companies and the National Intellectual Property Office from 2011 to 2019, the study selected the number of green invention patent applications filed by companies as a measure of their green innovation level. Utilizing a DID model and a mediating effect model, the study examined the effect of IPR protection on the development of enterprise green innovation and explored the impact mechanism.

6.1. Main conclusions

First, strengthening IPR protection plays a significant role in promoting enterprise green innovation. After a series of robustness tests, such as the propensity score matching (PSM) and placebo tests, the conclusion still holds. IPR protection has a constructive impact on promoting industry transformation and achieving green development.

Second, R&D investment plays a partial mediating role in promoting green innovation development through IPR protection. The establishment of the intellectual property pilot courts not only ensures enterprise IPR and better safeguards enterprise technical patent achievements, it also has a certain role in promoting the enterprise technology R&D, promoting the enterprise green innovation capabilities.

Third, financing constraints have a negative mediating effect on the development of enterprise green innovation. Faced with investment uncertainty, investors usually use a company's patent technology achievements as a measure of the company's development potential. Higher quality patents often easily garner investment, and strengthening IPR protection can alleviate the financing constraints faced by enterprises and enhance their green innovation capabilities.

Although this paper explores that local intellectual property protection has a positive effect on green technology innovation in enterprises and obtains channels of influence and some valuable conclusions, the heterogeneity of this impact can be further investigated.

6.2. Policy implications

In order to better utilize the intellectual property protection system, create a favorable business environment, and promote green innovation and technological progress for enterprises, we propose the following policy implications.

China should persist in strengthening and improving the pilot policies of the intellectual property court to promote the advancement of enterprise green innovation.

The scope of the pilot program should be expanded, the judicial trial system for IPR protection

should be reformed, and law enforcement capabilities should be improved. Besides, various policy measures should be adopted to stimulate the vitality of non-state-owned enterprises in green innovation.

The government should give full play to its institutional and supportive role in intellectual property rights protection, assisting non-state-owned enterprises in creating a favorable intellectual property environment for green innovation.

What's more, a long-term incentive mechanism should be established for green innovation. For the purpose of accelerating the implementation of the national innovation-driven development strategy, central and local governments have successively launched a series of innovation incentive policies and measures to promote enterprise innovation. All innovation incentive policies should focus on optimizing the green innovation environment and fully implement the concept of "lucid waters and lush mountains are invaluable assets" into policies.

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

The authors declare there is no conflict of interest.

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