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How Do Intellectual Property Rights Affect Green Technological Innovation? Empirical Evidence from China

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Abstract: The aim of this research is to investigate the impact of intellectual property rights (IPR) on green technological innovation in China. The study utilizes a mixed-method approach, combining both qualitative and quantitative methods, to provide empirical evidence on the subject matter. According to the findings, IPR protection may have a favorable impact on the green technological innovation (GTI) of firms. According to mechanism testing, the channels by which IPR protection influences businesses' GTI are research and development (R&D) input and foreign investment entry, whereas the human capital and finance capability of firms can favorably moderate the link between IPR protection and GTI. According to heterogeneity tests, private firms, exporting firms, and firms in industries with a high degree of monopoly are more notable for their promotional effect of IPR protection on the GTI of firms.

Keywords: IPR protection; green technological innovation; mechanism; moderating effect; China

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1. Introduction

China has reached rapid economic growth relying on a heavy-industry-first development strategy, but the deepening of global production exchanges, coupled with rapid industrialization and urbanization, urban spatial expansion, excessive resource consumption, and ecological pollution have placed heavy pressure on human survival [1,2]. The industrial development of large cities follows the pattern of "high energy consumption" and "high emissions", and their economic growth usually comes at the cost of ecological and environmental natural resources such as land, forests, water, and energy [3–5]. To cope with the increasing pressure on the ecological environment, the Chinese government has taken active measures to promote green and low-carbon economic development. For example, "Double Carbon" goals were declared by the Chinese government in September 2020. The "promoting green development and harmonious coexistence between human beings and nature" strategy was written as a sole chapter in China's Outline of the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and Vision 2035 (14th FYP and SDV-2035).

Studies have shown that GTI is the key to energy conservation and emission reduction, and is an effective means to effectively address environmental pollution such as carbon emissions [6], which can promote low-carbon industrial development and low-carbon transformation of energy consumption [7,8], essentially materializing the transformation of the economic development mode. Enterprises are the main body in implementing the strategic goals of carbon peaking and carbon neutrality. Accelerating the development of GTI in enterprises could better promote the green and low-carbon transformation of enterprises and the green development of the economy. Furthermore, GTI provides important kinetic energy and technical support for the achievement of carbon peak and carbon-neutral targets. However, major developed countries have strengthened their exclusivity in the area of green technology in order to gain leadership in the global governance of climate

change. They have seen China as an important institutional competitor, trying to embed their domestic governance systems into the global governance and competing to seize the high ground in science and technology [9]. The promotion of the GTI of Chinese enterprises in this context is of great contemporary significance.

GTI features both 'green' and 'innovative' strategies, and can not only promote energy efficiency and reduce environmental pollution in the production process, but also enable enterprises to produce green and differentiated products and promote technological progress [10]. However, followers can achieve similar results by imitating pioneering companies. Although this can improve the overall social welfare, it undermines the interests of the pioneering enterprises and weakens their incentive to engage in GTI. In order to solve the problem of uncompensated appropriation by followers, the government can grant enterprises a certain degree of exclusivity in GTI through intellectual property (IPR) protection so that they can capture a certain market share and generate a certain amount of monopoly profits with their R&D achievements, thus increasing monopoly profits and promoting GTI. However, little research has focused on the above-mentioned channels and the role of IPR in enterprise GTI. This study aims to investigate the impact of IPR protection on enterprise GTI and to explore in detail its transmission pathways and possible moderating effects.

As far as the available research is concerned, IPR protection has not received the attention it deserves in enterprise GTI. In fact, the influence of IPR protection on technological innovation(TI) rather than GTI was studied by much of the literature. It makes intuitive sense that IPR is good for TI. Providing incentives for innovation is a path that most scholars agree on [11]. For example, Ang et al. argue that a stronger IPR protection positively affects firms' ability to acquire new external debt and allows firms to invest in more R&D, generate more innovation patents, and produce more sales from new products [12]. R&D efficiency and technological capabilities could be promoted through stronger IPR protection [13–15]. Furthermore, Parre's study shows that IPR protection can stimulate domestic innovation by creating the right environment to absorb potential gains from international migration [16].

However, some scholars argue that IPR protection could have a negative effect on TI. Research has shown that IPR protection may hinder the free flow of scientific knowledge from innovations in a standard endogenous growth model and stronger protection of IPR may discourage innovation [17]. IPRs are becoming increasingly poorly configured in the developed world, leading to a stifling of innovation, distortions in the direction of innovation, and a reduction in the benefits which accrue from any innovation that occurs [18]. Empirical findings also raise doubts with respect to the strengthening of IPR protection as a means to stimulate innovation [19–22].

Furthermore, the complex relationship between IPR protection and TI is also studied. One confusing truth is that the United States was not always a leading IPR advocate as it is today, but was a leading IPR violator during the 19th century [23]. Depending on certain factors, IPR protection may have different effects on TI. For example, the role of innovative production cost [16], innovation efficiency or innovation threshold [24], level of economic development [25], and so on.

Concerning the relationship between IPR protection and GTI, Vimalnath et al. point out that IPR strategies should shift from exclusive incentives for innovation to collaborative approaches that promote IP sharing for sustainable development [26]. Roh et al. note that IPR protection positively impacts GTI through open innovation using Korean manufacturing data from 2014 to 2016 [27]. Furthermore, The relationship between IPR protection and total factor productivity (TFP) is studied as well [28], indicating a positive relationship between them.

Another strand of the literature related to this study is about GTI. From the perspectives of researchers, some scholars conducted relevant studies from the enterprise view, such as how enterprise GTI should be defined and methods to measure/assess GTI [29], the management of GTI [30,31], the factors affecting GTI, and the influence of GTI on enterprise performance [32,33]. From the industry view, the low-carbon effects of GTI have been most

widely studied [34,35]. From the macro view, the formation and dynamic evolution of green innovation systems are examined from a holistic perspective [36]. Theories such as system engineering and environmental economics are used to make a reasonable assessment of green innovation systems [37].

Based on our analysis, the literature regarding the influence of IPR protection on GTI is limited, and further research is required to enhance and develop relevant studies. Therefore, our article may contribute to the existing literature in the following ways.

Firstly, our study is related to the literature on the factors that affect GTI in enterprises. Previous research has explored various factors, such as market conditions, technology, and internal and external environmental factors. However, limited research has examined the role of IPR protection. By focusing on this aspect, we aim to fill the gap in the literature and provide a more comprehensive understanding of the factors that affect GTI in enterprises.

Secondly, our research is related to the literature on how IPR protection influences enterprise GTI. Previous literature has investigated the relationship between IPR protection and total factor productivity (TFP) from the perspective of the government–business relationship and innovative expenditure [28]. In our study, we advance further by exploring the mechanism of foreign investment entry and R&D investment, as well as the moderating role of human capital and financing capacity. Our research enriches the existing literature on the institutional perspective of how IPR protection affects enterprise GTI in host countries.

Lastly, we employ microdata from Chinese listed firms to conduct an empirical analysis. As GTI is the mainstay of enterprises, the use of enterprise data can help to alleviate the problem of reverse causality to some extent. Additionally, we construct an instrumental variable based on distance and transportation to address the issue of reverse causality more accurately. By utilizing these methods, we aim to contribute to the literature by providing a more robust empirical analysis of the influence of IPR protection on enterprise GTI.

The article is partitioned into five sections, with the Section 1 serving as an introduction. Section 2 pertains to the theoretical framework and research hypotheses, while Section 3 outlines the methods implemented to accomplish the study's objectives. Section 4 provides an account of the results and subsequent discussion. Lastly, Section 5 is centered on the conclusion and policy implications.

2. Theoretical Framework and Research Hypotheses

2.1. Mechanism of R&D Input

IPR protection can significantly affect enterprise R&D input. R&D is characterized by public goods, externalities, and uncertainties [38], which can lead to the incomplete appropriation of R&D achievements by enterprises, and the scale of their R&D investment will be much lower than the socially optimal level under the uncertainty of future R&D returns [39]. However, IPR protection alleviates this situation to some extent. IPR confer patent owners the right to the knowledge and other information contained in their patents, granting them the exclusive right to their intellectual property and providing legal protection for the R&D achievements, thus reducing the risk of technology theft and imitation and granting more proprietary to the technology developed by enterprises, which will enable enterprises to capture a certain market share and generate a certain amount of revenue with their R&D achievements.

R&D is a fundamental path by which enterprises conduct GTI. It has been shown that R&D can positively contribute to green innovation efficiency and further promote the GTI of enterprises [40,41]. Through R&D inputs, firms can receive the accumulation of knowledge stock, and after the role of mediating factors, they can obtain the output of green patented or non-proprietary technologies. Consequently, this study proposes the given hypothesis:

Hypothesis 1. *IPR protection can promote GTI by boosting firms' R&D input.*

2.2. Mechanism of Foreign Investment Entry

IPR protection can attract more foreign investment inflows. It has been shown theoretically and empirically that a stronger IPR protection can not only attract a higher quantity of foreign investment [42], but also enhance the quality of foreign investment [43]. This is because MNCs have ownership advantages in technology, trademarks, and other aspects that can generate market power and cost-effectiveness [44]. However, due to the non-exclusivity of technology, if an IPR protection is weak, local firms can compete with MNCs' products through imitation and other means, which can make the expected returns of MNCs decrease and thus reduce foreign investment in the region. With strong IPR protection, imitation by local firms is effectively reduced and more resources are released to MNCs, thus allowing MNCs to maintain ownership advantages in the host country, increasing the expected returns of MNCs [42] and attracting more foreign investment [45].

Entry of foreign investment can bring significant technology spillover effects and promote GTI in enterprises [46]. With the global consensus on sustainable development, green governance has become an essential consideration for MNCs, and environmental competence enables MNCs to overcome environmental entry barriers in host countries [47]. This implies that MNCs are more advanced in GTI and their experience in dealing with environmental issues. Foreign investment brings both explicit and implicit technologies to local enterprises. Explicit technologies, such as advanced green technologies from the home country, can be learned independently by local firms. Meanwhile, implicit technologies, such as management techniques from the foreign firm, are also brought over. When employees with these implicit technologies move from one company to another, the knowledge is more likely to spread between firms [47]. Consequently, this study proposes the given hypothesis:

Hypothesis 2. *IPR protection can promote GTI by attracting foreign investment entry.*

2.3. The Moderating Effect of Financing Capacity

According to the analysis above, R&D input and foreign investment entry are mechanisms through which IPR protection affects the GTI of enterprises. Both of the abovementioned mechanisms require a large amount of capital as a guarantee, especially for firms' R&D. Its cycle is long, and firms need to pay a high salary to maintain a large R&D team for an extended period [48]. Meanwhile, the results of R&D are uncertain. With no stable source of funding to which the enterprise is subject, it is less likely that the enterprise will conduct R&D [49]. When IPR protection is strengthened, firms with a higher financing capacity are able to finance themselves faster and obtain financial support, which in turn positively affects their GTI through the abovementioned mechanisms. Consequently, this study proposes the given hypothesis:

Hypothesis 3. *The relationship between IPR protection and firms' GTI could be positively moderated by firms' financing capacity.*

2.4. The Moderating Effect of Human Capital

When absorbing foreign investment spillovers and carrying out the firms' R&D process, human capital is a critical factor [50,51]. First, although foreign investment has the potential for technology spillover, this may be affected by the absorption capacity to some extent [52]. Human capital is one vital part of absorption capacity. The lack of professional skills in the labor force always becomes a major obstacle to the absorption of advanced technology by developing country enterprises [53], while high-quality human capital can accelerate the absorption of advanced technology. As for enterprise R&D, enterprises with more human capital have stronger cognitive and understanding abilities, are more flexible in facing complex internal and external environments, and are more accurate in grasping enterprise R&D strategies with greater risks [54]. Thus, the probability of succeeding in

R&D is high. When the level of IPR protection increases, firms with a higher human capital can promote GTI by virtue of their absorption and transformation of advanced technologies and their precise grasp of R&D activities. Consequently, this study proposes the given hypothesis:

Hypothesis 4. *The relationship between IPR protection and firms' GTI could be positively moderated by firms' human capital.*

3. Material and Methods

3.1. Benchmark Regression Model

The benchmark specification is given below:

$$GTI_{ijt} = \alpha_0 + \alpha_1 ipr_{jt} + \beta X_{it} + \gamma X_{jt} + \varphi_i + \varphi_j + \varphi_t + \varepsilon_{ijt} \quad (1)$$

where i is firm, j is province, and t is time. ipr_{jt} is IPR protection in province j in year t. GTI_{ijt} is the level of GTI of enterprise i in province j in year t. X_{it} are control variables at the firm-level. X_{jt} are control variables at the province level. φ_i, φ_j, φ_t are fixed effects at firm, province, and time level, respectively. The given error term is assumed to be normally distributed at zero mean value [55,56] and constant variance [57–59].

3.2. Measurement

3.2.1. Intellectual Property Rights

According to Wei and Wu's research [60], the formula for calculating the efficiency of law enforcement in each province of China is the product of the GP index and the enforcement efficiency of laws. The efficiency of law enforcement is determined by various factors, including the degree of legalization of society, the rate of settlement of patent infringement cases, and the proportion of patents not being infringed upon. The degree of legalization of a society is a reflection of the cultural norms and thinking habits of people in different social cultures. In a society that upholds the rule of law, people's behavior is governed entirely by legal provisions [61]. To measure the degree of legalization of society in each province, the number of lawyers per 10,000 people is divided by 5 [62].

The rate of the settlement of patent infringement cases reflects the efficiency of the enforcement agency in managing cases related to intellectual property rights (IPR). The conclusion rate of patent infringement cases, i.e., the number of cases concluded divided by the number of cases received in each region, is used to measure this indicator, and it is positively correlated with the level of IPR protection enforcement.

The proportion of patents not being infringed upon is another measure of the strictness of IPR protection enforcement in a region. The higher the level of enforcement, the greater the deterrent effect on patent infringement and other illegal acts. The local patent non-infringement rate, calculated as 1 minus the patent infringement rate, is used to measure this effect. The patent infringement rate is calculated by dividing the number of local infringement disputes by the cumulative local patent grants.

To standardize these three indicators, the researchers use a specific formula:

$$F_j^l = \frac{f_j^l - f_{min}^l}{f_{max}^l - f_{min}^l} \quad (2)$$

where l represents one of the three indicators and j is province. F_j^l represents the standardized result of the lth indicator in province j. f_j^l represents the original value of the lth indicator in province j, f_{min}^l denotes the minimum value of the lth indicator among all provinces in that year, and f_{max}^l denotes the maximum value of indicator l in all provinces in that year. After that, the arithmetic average of these three indicators is summed up in this study to obtain the legal enforcement efficiency indicator related to IPR protection

in a province, and then this indicator is multiplied by the GP index. Thus, we obtain the indicator of IPR protection.

3.2.2. Enterprise GTI

The GTI of enterprises (*gpatent*) is expressed by the sum of all the applications of green invention patents and green utility model patents.

3.2.3. Mediating Variables and Other Control Variables

R&D input (*lnrd*) is expressed as the log of "firm's R&D expenditure + 1", while the foreign investment entry (*fi*) is expressed as the ratio of the firm's foreign ownership. The firm-level control variables include: firm size (*lnta*), measured by the log of the firm's total assets; capital intensity (*lnkl),* measured by the log of "firm's net fixed assets ratio to the number of employees"; firm's age (*lnage),* measured by the log of "the current year minus the year of establishment + 1"; government subsidies (*lngov*), taking into account the lag effect of government subsidies, it is measured by the log of the government subsidies in the last period; current asset turnover (*laz*); return on assets(*roa*); and gearing ratio (*lev*). The provincial control variables include urban population ratio (*up*), measured by the ratio of urban population to total population and gross domestic product (GDP) growth rate (*gdpmg*), measured by the GDP of the current year minus the GDP of the last year and divided by the GDP of the last year. The above data involving units are expressed in tens of thousands of yuan.

3.3. Data Source

We access three databases for listed firms in China. WIND database, CSMAR database for basic information, and CNRDS database for patent data. The enforcement of IPR protection in each province is obtained from the Chinese State Intellectual Property Office (CSIPC) and the China Statistical Yearbook (CSY), and the provincial control variables are obtained from CSY (provincial). Since the statistics of enterprises' R&D expenditures in the WIND database started in 2006, and to avoid the possibility of differences in enterprises' behaviors before and after the financial crisis, we take 2008 as the starting year; based on the availability of data, the Chinese State Intellectual Property Office stopped updating enforcement-related data on IPR protection in 2019, so this study takes 2018 as the ending year. Provinces with severe missing data (Tibet) were excluded; ST and *ST listed companies were excluded; financial and real estate listed companies were excluded; listed companies issued both in A shares and B shares were excluded; listed companies with missing main data were excluded; and 0.5% and 99.5% tailoring was also applied to all data. Finally, we obtain 10,803 sample observations. Summary statistics are shown in Table 1.

Table 1. Summary statistics of the variables.

Variables	Obs	Mean	SD	Min	Max
gpatent	10,803	13.779	37.645	1.000	363.000
ipr	10,803	2.892	0.662	0.761	4.500
lnta	10,803	13.204	1.329	10.423	16.345
lnkl	10,803	3.388	1.013	1.135	5.814
lnage	10,803	2.735	0.397	0.000	3.761
lngov	10,803	6.843	2.364	0.000	9.818
laz	10,803	1.313	0.869	0.166	4.219
roa	10,803	0.041	0.051	−0.189	0.160
lev	10,803	0.448	0.201	0.084	0.923
up	10,803	0.483	0.598	0.331	0.897
gdpmg	10,803	0.089	0.072	−0.989	0.299

4. Results and Discussion

4.1. Benchmark Regression

Benchmark specification (1) is regressed. To test if the control variables' selection affects the regression result, in Table 2, control variables are added to each column in turn. The results indicate that the GTI of enterprises can be positively influenced by IPR protection, and this finding is largely unaffected by the selection of control variables and has some degree of robustness.

Table 2. Benchmark regression results.

Variables	(1)	(2)	(3)	(4)
	gpatent	gpatent	gpatent	gpatent
ipr	1.506 *	1.219 **	1.596 **	1.790 **
	(1.809)	(2.267)	(2.009)	(2.272)
lnta				4.920 ***
				(2.731)
lnkl				1.224
				(1.207)
lnage				24.280 **
				(2.175)
lngov				−0.365
				(−1.347)
laz			−3.433 ***	−3.561 ***
			(−2.730)	(−2.689)
roa			24.050 ***	20.480 ***
			(3.505)	(2.842)
lev			6.511 *	−4.178
			(1.736)	(−0.989)
up		3.969	−10.412 **	−10.027 **
		(1.214)	(−2.213)	(−2.297)
gdpmg		3.711 **	7.361 **	6.635 **
		(1.991)	(2.470)	(2.278)
Constant	10.000 ***	−15.820	77.130 **	−53.840
	(4.156)	(−0.743)	(2.441)	(−1.230)
Observations	10,221	10,803	10,221	10,221
R-squared	0.726	0.051	0.729	0.734

t-statistics are given in parentheses. ***, **, and * indicate significance level of parameters at the 1%, 5%, and 10%, respectively.

4.2. Robustness Test

In this subsection, measurements of the explained and core explanatory variables are substituted with alternative indicators to test if the results above are robust.

4.2.1. Explained Variable

In this subsection, we use the number of invention patents applied by firms instead of the sum applied number to measure GTI to examine the possible errors brought about by the selection of the explained variable. As mentioned in the previous section, in Table 3, control variables are still added to the regressions in turn. The results indicate that the error due to the selection of the explained variables is not severe.

Table 3. Robustness test 1.

Variables	(1) ginvent	(2) ginvent	(3) ginvent	(4) ginvent
ipr	1.002 *	0.714 **	1.028 *	1.135 **
	(1.817)	(2.101)	(1.876)	(2.125)
lnta				3.053 ***
				(2.767)
lnkl				0.615
				(0.938)
lnage				14.310 *
				(1.877)
lngov				−0.293 *
				(−1.663)
laz			−1.648 **	−1.720 **
			(−2.345)	(−2.315)
roa			13.840 ***	11.390 **
			(3.071)	(2.438)
lev			2.381	−4.023
			(0.963)	(−1.408)
up		1.853	−6.299 **	−6.034 **
		(0.998)	(−2.026)	(−2.076)
gdpmg		2.232 *	4.831 **	4.375 *
		(1.694)	(1.974)	(1.837)
Constant	4.815 ***	−6.885	45.640 **	−32.860
	(3.024)	(−0.570)	(2.179)	(−1.086)
Observations	10,221	10,803	10,221	10,221
R-squared	0.690	0.044	0.694	0.698

t-statistics are given in parentheses. ***, **, and * indicate significance level of parameters at the 1%, 5%, and 10%, respectively.

4.2.2. Explanatory Variable

Referring to Hu et al. [63], in order to address the measurement error introduced by the construction of IPR protection indicators, in Table 4, the ratio of technology market turnover to local GDP (*ipr1*) in each province is used to substitute for the original indicator. Control variables are added into columns in turn as well. The results indicate that the endogeneity problem caused by the measurement error of the explanatory variable is not prominent. The large coefficient of ipr1 is noted, which may be due to the small value of ipr1 (ratio, less than 1) and the large value of gpatent (greater than or equal to 1). However, this rarely affects our judgments.

Table 4. Robustness test 2.

Variables	(1)	(2)	(3)	(4)
	gpatent	gpatent	gpatent	gpatent
ipr1	269.413 **	−48.149	492.807 ***	437.402 ***
	(2.330)	(−0.344)	(3.101)	(2.963)
lnta				5.137 ***
				(2.927)
lnkl				1.199
				(1.169)
lnage				19.180 *
				(1.870)
lngov				−0.360
				(−1.331)
laz			−3.497 ***	−3.490 ***
			(−2.784)	(−2.648)
roa			25.010 ***	20.570 ***
			(3.739)	(2.919)

Table 4. *Cont.*

Variables	(1)	(2)	(3)	(4)
	gpatent	gpatent	gpatent	gpatent
lev			7.422 **	−2.899
			(1.982)	(−0.682)
up		3.370	−4.392	−4.857
		(1.471)	(−1.061)	(−1.201)
gdpmg		3.853 **	6.260 **	5.763 **
		(2.162)	(2.151)	(2.010)
Constant	7.903 ***	−7.271	30.700	−82.113 **
	(2.855)	(−0.517)	(1.103)	(−1.998)
Observations	10,221	10,803	10,221	10,221
R-squared	0.728	0.051	0.733	0.736

t-statistics are given in parentheses. ***, **, and * indicate significance level of parameters at the 1%, 5%, and 10%, respectively.

4.3. Endogeneity Test

By utilizing firm-level data, this study can partially mitigate the issue of reverse causality between firms' GTI and IPR protection. However, in theory, the higher a province's firms' GTI, the more inclined they will be to seek a greater degree of IPR protection, thereby engendering reverse causality. Based on this, we refer to Tang et al. [64] and construct a distance index with the help of the shortest spatial distance from each province to Beijing, Guangdong, Fujian, Hainan, Tianjin, Shanghai, Liaoning, Zhejiang, Hebei, Shandong, Jiangsu, and Guangxi (provinces belonging to Beijing; five special economic zones (SEZ) and fourteen coastal open cities (COC). The reason is that Beijing, the five SEZs and the fourteen COCs have more cutting-edge knowledge of the IPR protection system, and thus, the distance index is strongly correlated with IPR protection. However, due to the differences in resource endowment and geographical conditions among Chinese provinces, and the years of rough development in China, the same GTI does not necessarily have the same adaptability in different regions, so even if a region is close to the abovementioned regions, it is difficult to make the GTI develop better. Thus, the "distance index" also meets the requirement of exogeneity.

For the measurement of the distance index, first, for the provinces belonging to Beijing, the five special economic zones, and the fourteen coastal open cities, their internal distances D_{ll} are calculated according to the method of Redding and Venables [65], and assuming that the ensemble of these provinces is C, the distance index of the lth province can be expressed as:

$$DI_l = \begin{cases} 100D_{ll}^{-1}, l \in C \\ 100(minD_{lk} + D_{kk})^{-1}, l \notin, k \in C \end{cases} \quad (3)$$

This distance index varies only with the cross-section and not with time. To solve this, we select a time-varying exogenous variable that reflects the meaning of the "distance index" and multiply it with the "railroad density" in year t − 1. In this case, "railroad density" refers to the density of railroads in all the provinces passed on the way from a province to the nearest 20 regions; thus, $IV_{lt} = D_l \times railway_{l,t-1}$. Railway mileage data are obtained from the China Transport Statistical Yearbook.

To address the potential issue of reverse causality, the study employs the 2sls method and presents the regression results in Table 5. The first and third columns show the first stage regression results without and with control variables, respectively. The analysis suggests a strong correlation between the instrumental variable (IV) and intellectual property rights (IPR). The validity of the IV is confirmed by the *p*-value of the LM statistic being less than 0.1, indicating that the IV passes the under-identification test. Furthermore, the weak instrumental variable test is also passed as the C-D statistic and the K-P statistic are greater than the corresponding 10% threshold. These findings support the use of the constructed instrumental variables. The results in columns two and four reveal that there

is no significant reverse causality between IPR protection and enterprise GTI. Based on the analysis, we conclude that the endogeneity problem of the benchmark regression is not severe.

Table 5. Results of 2sls.

Variables	(1)	(2)	(3)	(4)
	ipr	gpatent	ipr	gpatent
IV/ipr	0.007 ***	19.626 ***	0.007 ***	18.204 ***
	(8.348)	(2.676)	(7.930)	(62.344)
Control variables	No	No	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
Under-identification test	75.10		70.76	
LM statistic/*p*-value	(0.000)		(0.000)	
Weak instrumental variable test				
Cragg–Donald Wald F statistic	18.69		17.84	
Kleibergen–Paap rk Wald F statistic	69.49		62.81	
Weak instrumental variables 10%/15% threshold	16.38/8.96		16.38/8.96	
Transition recognition test				
Hansen J test	0	0	0	0
	Adequate identification	Adequate identification	Adequate identification	Adequate identification
Observations	10,569	10,569	10,569	10,569

t-statistics are given in parentheses. *** indicates significance level of parameters at 1%.

4.4. Heterogeneity Test

4.4.1. Ownership Heterogeneity

In China, there is a difference in the status of SOEs, private enterprises, and foreign enterprises. The government shows a "supporting hand" to local enterprises, and local SOEs are the priority for the "supporting hand" [66]. As Cao et al. [67] showed, local SOEs have access to more long-term loans and lower sales costs compared to private firms, enhancing their competitive position. The study hypothesizes that IPR protection has a stronger impact on the GTI of private firms, given that SOEs already possess a certain "dominant position". In contrast, foreign enterprises already have established technological advantages, so IPR protection may not have a significant effect on their GTI. To test this hypothesis, the sample is divided into SOEs, private enterprises, and foreign enterprises in columns (1), (2), and (3) of Table 6, respectively. The results confirm our expectations, showing that the impact of IPR protection on GTI is more significant for private firms while having little effect on foreign enterprises.

Table 6. Heterogeneity test 1.

Variables	(1)	(2)	(3)	(4)	(5)
	gpatent	gpatent	gpatent	gpatent	gpatent
Ipr	0.343	1.405 *	−3.189	2.552 **	−1.760 **
	(0.300)	(1.705)	(−1.623)	(2.305)	(−2.000)
Constant	−30.903	−102.501 ***	−83.307	−54.825	12.641
	(−1.302)	(−2.837)	(−1.165)	(−0.982)	(0.179)
Control variables	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	4299	5193	232	6951	3093
R-squared	0.792	0.698	0.766	0.724	0.827

t-statistics are given in parentheses. ***, **, and * indicate significance level of parameters at the 1%, 5%, and 10%, respectively.

4.4.2. Export Heterogeneity

Considering that exporting firms face both domestic and foreign markets, and according to Melitz's heterogeneity theory, exporting firms generally have higher productivity and thus their (green) technological innovation level should be generally higher than that of domestic non-exporters. It is foreseeable that when the level of domestic IPR protection improves, exporting firms can directly transfer their existing green technologies in overseas markets back to domestic use, while the impact on non-exporters will be slower. Therefore, the study anticipates that IPR protection will have a more pronounced positive impact on the GTI of exporting firms. To test this hypothesis, Table 6 presents subsample regressions for exporting and domestic firms based on whether they have overseas business revenues, in columns (4) and (5), respectively. The results are consistent with our expectations, indicating a stronger positive effect of IPR protection on the GTI of exporting firms. However, we were surprised to find a negative impact of IPR protection on the GTI of non-exporting firms. This suggests that for non-exporting firms, pursuing internationalization strategies may be an effective approach to mitigate the negative effects of escalating IPR protection.

4.4.3. Industry Monopoly Degree Heterogeneity

The relationship between innovation and industry monopoly has been a long-standing debate in academia, and this study is also interested in the different effects of IPR protection on GTI in industries with different levels of monopoly. By constructing the Herfindahl index (*hhi*), which measures the degree of market competition, the industries above the average monopoly level are regarded as high monopoly industries, while the rest are labeled as low monopoly industries. The *hhi* in columns (1) and (2) of Table 7 is the ratio of the top four main business revenues in the industry to the total main business revenues in the industry; the *hhi* in columns (3) and (4) of Table 7 is the sum of the squares of the total assets of the enterprises in the industry over the total assets of the industry. The results indicate that, regardless of which indicator is used, IPR protection significantly promotes firms' GTI in high monopoly industries (columns (1) and (3) of Table 7). The possible explanation for this result is that firms in high monopoly industries can obtain monopoly profits through high market concentration and thus obtain positive R&D profits, while firms in monopoly industries face higher competition and have difficulty in obtaining positive profits from their R&D achievements (GTI). As a result, IPR protection promotes firms' GTI only for firms in high monopoly industries.

Table 7. Industry monopoly degree heterogeneity.

Variables	(1)	(2)	(3)	(4)
	gpatent	gpatent	gpatent	gpatent
ipr	2.521 *	1.177	2.311 **	1.386
	(1.851)	(1.167)	(1.976)	(1.477)
Constant	−38.490	−42.921	30.814	−45.553
	(−0.567)	(−0.678)	(0.352)	(−0.806)
Control variables	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes
Observations	4644	5301	3520	6496
R-squared	0.804	0.643	0.850	0.640

t-statistics are given in parentheses. ** and * indicate significance level of parameters at the 5% and 10%, respectively.

4.5. Mechanism and Moderating Effects Test

The test of mechanisms adopts the three-step method proposed by Baron and Kenny to test two mechanisms of R&D input and foreign investment entry, respectively.

4.5.1. Test of R&D Mechanism

To test the R&D mechanism, in Table 8, the following three models are separately regressed:

$$GTI_{ijt} = \alpha_0 + c \times ipr_{jt} + \beta X_{it} + \gamma X_{jt} + \varphi_i + \varphi_j + \varphi_t + \varepsilon_{ijt} \quad (4)$$

$$rd_{ijt} = \alpha_1 + a \times ipr_{jt} + \beta X_{it} + \gamma X_{jt} + \varphi_i + \varphi_j + \varphi_t + \varepsilon_{ijt} \quad (5)$$

$$GTI_{ijt} = \alpha_2 + c' \times ipr_{jt} + b \times rd_{ijt} + \beta X_{it} + \gamma X_{jt} + \varphi_i + \varphi_j + \varphi_t + \varepsilon_{ijt} \quad (6)$$

Table 8. Mechanism of R&D.

Variables	(1)	(2)	(3)
	gpatent	lnrd	gpatent
ipr	1.790 **	0.198 **	1.590 **
	(2.272)	(2.183)	(2.043)
lnrd			1.010 ***
			(3.767)
Control variables	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes
Observations	10,221	10,221	10,221
R-squared	0.734	0.665	0.736

t-statistics are given in parentheses. *** and ** indicate significance level of parameters at the 1%, and 5%, respectively.

If coefficient c is positively significant and both coefficients a and b are positively significant, the mechanism holds.

The results indicate that IPR protection can enhance the GTI of enterprises by promoting the R&D input. Hypothesis 1 is thus confirmed.

4.5.2. Test of Foreign Investment Entry Mechanism

As described above, in Table 9, the following three models are separately regressed:

$$fi_{ijt} = \alpha_1 + a \times ipr_{jt} + \beta X_{it} + \gamma X_{jt} + \varphi_i + \varphi_j + \varphi_t + \varepsilon_{ijt} \quad (7)$$

$$GTI_{ijt} = \alpha_2 + c' \times ipr_{jt} + b \times fc_{ijt} + \beta X_{it} + \gamma X_{jt} + \varphi_i + \varphi_j + \varphi_t + \varepsilon_{ijt} \quad (8)$$

Table 9. Mechanism of foreign investment entry.

Variables	(1)	(2)	(3)
	gpatent	fi	gpatent
ipr	2.635 ***	0.209 *	2.619 **
	(2.589)	(1.729)	(2.572)
fi			0.0760 *
			(1.710)
Control variables	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes
Observations	10,221	10,221	10,221
R-squared	0.725	0.580	0.725

t-statistics are given in parentheses. ***, **, and * indicate significance level of parameters at the 1%, 5%, and 10%, respectively.

The results indicate that IPR protection can enhance the GTI of enterprises by attracting the foreign investment. Hypothesis 2 is confirmed.

4.5.3. Moderating Effect of Financing Capacity

To test the moderating effect, this study first conducts the benchmark regression, and then adds the interaction term of IPR protection and corporate financing capacity (take the inverse of the KZ index and root square it three times to get finc. It is positively related to financing capacity) to the benchmark specification. In Table 10, column (1) is the benchmark specification and column (2) is the regression with interaction term. The results indicate that financing capacity positively moderate the relationship between IPR protection and enterprise GTI. Hypothesis 3 is thus confirmed.

Table 10. Tests for moderating effects.

Variables	(1)	(2)	(3)
	gpatent	gpatent	gpatent
ipr	1.790 **	1.484 **	2.264 **
	(2.272)	(2.000)	(2.541)
ipr×finc/ipr×hc		0.796 *	24.044 **
		(1.855)	(2.251)
Constant	−30.031	−30.736	−183.208 *
	(−0.362)	(−0.361)	(−1.866)
Control variables	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes
Observations	10,221	10,054	6675
R-squared	0.725	0.724	0.738

t-statistics are given in parentheses. ** and * indicate significance level of parameters at the 5% and 10%, respectively.

4.5.4. Moderating Effect of Human Capital

As mentioned above, we replace the interaction term to IPR protection × human capital level (the human capital level of enterprises is measured by the proportion of employees with a master's degree or higher to the total employees) to the benchmark regression. The results are shown in column (1) and column (3) of Table 10. The results indicate that human capital positively moderate the relationship between IPR protection and enterprise GTI. Hypothesis 4 is thus confirmed.

5. Conclusions and Policy Implications

In the background of China's "double carbon" goal, this study focuses on the GTI of enterprises and examines the impact of IPR protection on the GTI of enterprises. Two affecting mechanisms and two moderating effects of IPR protection on firms' GTI are summarized and tested: R&D investment and foreign investment entry; financing capacity and human capital. The findings are as follows.

First, IPR protection could promote firms' GTI, and this conclusion holds after various robustness and endogeneity tests. Second, the heterogeneity test reveals that higher levels of IPR protection promote GTI more significantly for private firms, exporting firms and firms in more monopolistic industries. Third, in terms of the mechanism, IPR protection can enhance the GTI of enterprises by promoting R&D input and foreign investment entry. Meanwhile, the financing capacity and human capital of enterprises can positively moderate the relationship between IPR protection and enterprises' GTI.

The findings of this study have important policy implications. "Double Carbon" goals were claimed by the Chinese government in September 2020. The "promoting green development and harmonious coexistence between human beings and nature" was written as a sole chapter in China's 14th FYP and SDV-2035. This highlights the importance of green development for China to establish a modern country, and GTI is the foundation and guarantee of green development. At the same time, China has also strengthened the implementation of IPR protection strategies and introduced a series of policy measures.

The affect of IPR protection on enterprise GTI is verified by the findings of the paper, and references can be provided for China to formulate relevant policies.

First, gradually improve the construction of IPR protection system and strengthen the enforcement of IPR protection. This study finds that an improved level of IPR protection can not only directly promote GTI, but also promote GTI by attracting foreign investment entry and increasing R&D input. Therefore, attention should be paid to IPR protection in the process of GTI by enterprises. Meanwhile, the difference in the level of IPR protection among provinces does not lie in the IPR protection system itself, but in the level of the enforcement of laws related to IPR protection. Therefore, in addition to improving the construction of the IPR protection system itself, it is important to further enhance the enforcement of IPR protection in each province in China so as to fully utilize IPR protection in promoting the GTI of enterprises.

Second, different levels of IPR protection could be implemented for different industries. Encourage firms to internationalize (export) and reduce their financing burden. The research in this study finds that IPR protection is more effective in promoting the GTI of exporting enterprises and enterprises in high monopoly industries. Meanwhile, the financing capacity of enterprises can positively moderate the relationship between IPR protection and enterprises' GTI. Therefore, according to the characteristics of different industry types, different levels of IPR protection with different monopoly intensities should be implemented, alleviating enterprises' financing pressure and encouraging exports, so that different heterogeneous enterprises can enjoy the bonus brought by the increased level of IPR protection.

Third, make full use of R&D and foreign investment in promoting enterprises' GTI and pay attention to enterprises' human capital accumulation. This study finds that R&D investment and foreign investment entry are the mechanisms through which IPR protection affects enterprises' GTI. Meanwhile, R&D investment and foreign investment entry themselves can also promote enterprises' GTI. Therefore, the government and enterprises should fully utilize the important role of R&D input and foreign investment entry on the GTI of Chinese enterprises. Meanwhile, this study finds that the human capital of enterprises can positively moderate the relationship between IPR protection and the GTI of enterprises. Therefore, attention should be paid to the accumulation of the human capital of enterprises while actively using R&D and foreign investment.

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