# Impact of Intellectual Property Protection on R & D Output of Listed Enterprises in Six Central Provinces

## —— Based on the empirical study of mediating mediation effect

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**Abstract.** Based on the panel data of listed enterprises in six central provinces from 2011 to 2022, this paper takes the r & D expenditure of enterprises as the intermediary variable, enterprise scale and government capital investment as the adjustment variable, constructs the mediation effect model, and explores the influence mechanism of intellectual property protection on enterprise innovation performance. The empirical results show that: (1) the R & D expenditure plays a partial intermediary role in the process of intellectual property protection to promote enterprise innovation performance; (2) the enterprise scale plays a positive role in the R & D investment and innovation performance of listed enterprises, that is, the R & D investment is significantly better in the innovation performance of large enterprises; (3) the government investment in the R & D expenditure and innovation performance; (4) the intellectual property protection in the innovation performance of listed enterprises in the six central provinces and property rights.

**Keywords:** intellectual property protection; six provinces in central China; enterprise innovation performance; mediation effect.

## 1 Introduction

Innovation drives technological advancement and competitiveness for enterprises, particularly in the central region of China - Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan - bridging east-west and south-north divides with rich history and culture fostering creativity. However, a notable gap exists between this region's innovation ecosystem and the more advanced eastern coastal areas. While the coastal regions boast developed scales, levels of independent innovation, openness, and economic liberalization, the central region seeks to leverage innovation for strategic growth and regional elevation. Listed companies, as economic pillars, must innovate for sustainable, high-quality development, crucial for the central region's innovative progress and modern industrial advancement. Yet, challenges persist: low innovation output, inadequate environments, and benefit spillovers hinder market-driven compensation for external costs, dampening innovation incentives. Intellectual property protection, vital


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for innovation momentum and international competitiveness, is key to deepening the innovation-driven strategy. The 2022 IP Development Report shows varied growth across central provinces, with Hubei ranking 8th and Shanxi 26th, marking progress yet highlighting imbalances. While research on IP's influence on innovation abounds for national or coastal contexts, the central region remains understudied. Thus, examining IP rights and enterprise innovation performance in the central region offers empirical insights and policy guidance for effective IP protection.

This paper aims to contribute by:

First, clarifying IP protection's role on enterprise innovation output, considering R&D expenditure's intermediary effect and the influence of enterprise scale & gov't investment.

Secondly, exploring IP protection's impact on innovation production in six central provinces' A-share firms, offering insights for boosting innovation & competitiveness.

Thirdly, analyzing heterogeneity among state-owned, non-state-owned enterprises, & regions, broadening research scope.

The paper structure includes: literature review, theoretical analysis & hypotheses, empirical results, and conclusions.

## 2 Literature Review

With the economic development, the protection of intellectual property rights in a dilemma (efficiency and fairness), on the one hand, research that intellectual property is beneficial to encourage enterprise innovation, promote enterprise innovation output, to promote the whole society development, mainly reflected in the following three points: one is the direct influence of intellectual property protection on enterprise innovation output. Qing tao[1]By constructing an enterprise innovation model consisting of intellectual property protection and agglomeration spillover effect. Guo Feng and Yang Shangguang[2]With the help of the quasi-natural experiment of intellectual property demonstration city, the improvement of the judicial protection of intellectual property will help promote enterprises to improve the innovation level. Yu Yang et al[3]Based on the sample of A-share listed companies from 2004 to 2016, it was found that the number of inventions and innovations made by listed companies significantly increased with the improvement of intellectual property protection level. Yang Fei[4]Based on the data of listed enterprises from 2008 to 2016 and the use of double difference method, it is found that the construction of intellectual property court has significantly improved the innovation level of enterprises. Bao Zongke and Shi Yujie[5]It is believed that strict intellectual property protection can effectively correct the positive externalities of innovation output and better protect the innovation achievements of enterprises, which is an important institutional factor that affects the innovation activities of enterprises. Weng run[6]It is pointed out that intellectual property protection has a significant positive impact on the innovation efficiency of enterprises and the innovation output of Chinese manufacturing enterprises. Wu Chaopeng and Tang[7]It is found that the improvement of intellectual property protection enforcement will significantly improve the r & d investment and innovation patent output of enterprises.

The second is to analyze the influence process of intellectual property protection on enterprise innovation through the intermediary effect. Fang Zhongxiu[8]The quantitative study of Chinese a-share listed companies by multi-layer linear model shows that intellectual property protection can affect the innovation performance of enterprises by affecting the R & D input and technology spillover of enterprises. Xiao Zhenhong and Li Yan[9]It is found that improving the level of intellectual property protection can positively affect the efficiency and efficiency of regional green innovation by affecting R & D input. Lu Xinxiang and Da Qiongyao[10]From the perspective of knowledge spillover, it is found that intellectual property protection can positively affect the innovation output of enterprises by affecting knowledge spillover. He Limin et al[11]Using the provincial data research from 2012 to 2018, it is found that the influence of new technologies has a significant intermediary effect in the influence of intellectual property protection on the innovation investment of high-tech enterprises. Xing Fei and Zhou Taiyun[12]Using the data of China's A-share listed companies in 2008-2017 to discuss the policy effect of the intellectual property protection policy on the innovation market failure, and find that the intellectual property protection policy can promote the technological innovation of enterprises by reducing the innovation dynamic market failure. Zhang Nan and Xu Liangguo, et al[13]It is found that intellectual property rights protection can enhance the promotion effect of product market competition on enterprise innovation investment.

Third, to explore the characteristics of intellectual property protection to promote enterprise innovation. Hu Yiting and Luo Qing[14]The panel negative binomial fixed effect model and hierarchical regression analysis found that intellectual property protection, as one of the three elements of intellectual capital, can play a positive regulating role between mental capital and innovation performance. Liu Jing and Zhan Shaowen[15]Based on the method of beyond log-random frontier analysis, it is found that the improvement of intellectual property protection ability will promote the improvement of enterprise innovation efficiency and strengthen the positive impact of intellectual property ability on innovation.peep[16]The empirical research based on the panel data of Chinese provinces and cities found that intellectual property protection is not an isolated impact on the R & D intensity of enterprises, but is combined with the technology gap.

On the other hand, some scholars believe that intellectual property protection increases the cost of technology diffusion, and excessive protection will hinder the further development of enterprises' innovation ability, and even cause regression. Lemer[17], Bessen, and Maskin[18]And the Mccalman[19]Empirical research believes that strengthening intellectual property protection is not conducive to innovation. Sun Fangcheng and Wu Guilin[20]By analyzing digital inclusive finance, intellectual property protection and enterprise innovation under the same framework, we find that excessive intellectual property protection may undermine the confidence of enterprises in innovation. Jing Jing Bo and Xu Lijun, etc[21]It is found that the improvement of intellectual property protection level will increase the cost of imitation and innovation of local enterprises, and have a certain degree of negative adjustment effect on the innovation generated by foreign-invested local enterprises. Wang Yu[22]By examining the influence of IPR protection level on the innovation performance of new enterpris-

es by studying the GEM listed companies in 2011-2016, it is found that intellectual property protection has a negative external effect on the innovation performance of enterprises. As the research continues to deepen, the Schneider[23], Futagami[24], Hudson[25]It is found that intellectual property protection and innovation are in a complex nonlinear relationship.

Academic consensus on IP protection & enterprise innovation performance remains elusive. Existing studies overlook factors like enterprise scale & gov't investment. This 2011-2020 study on A-share firms in China's central 6 provinces examines IP protection's impact on innovation output, moderating effects of scale & gov't investment, and further explores property rights & regional heterogeneity.

## 3 Theoretical Analysis and Hypothesis

### 3.1 The Direct Effect of Intellectual Property Protection on the Innovation Output of Listed Enterprises

IPR protection boosts enterprise innovation output by securing exclusivity, deterring imitation, and promoting innovation accumulation. However, excessive IPR protection can hinder competition, inflate innovation costs for SMEs/startups, and delay technology dissemination, limiting societal benefits. Hence, crafting IPR policies requires a delicate balance between fostering innovation and avoiding negative consequences for optimal societal welfare.

Hypothesis 1a: Intellectual property protection positively affects the innovation output of listed enterprises in central China.

Hypothesis 1b: Intellectual property protection negatively affects the innovation output of listed enterprises in central China.

### 3.2 Intermediation Effect of Intellectual Property Protection on the Innovation Output of Listed Enterprises

In addition, for enterprises with stronger willingness and demand for innovation, on the premise of full protection of intellectual property, the research and development of enterprises will give rise to intellectual property, which will help enterprises to establish advantages in technological competition[26], Especially for the high-tech industry, intellectual property protection has a positive effect on r & d investment[27], The enhancement of intellectual property protection can promote enterprise R & D investment by reducing the spillover effect of enterprise R & D activities[28]. And for those who interest in learning new knowledge and innovation is low and used to imitate innovation enterprises, if they have intellectual property or intellectual property from intellectual property peers or competitors more expensive, even often because of intellectual property with the will to get intellectual property, this will force the r & d investment is not willing to allocate funds for r & d investment, in order to obtain independent intellectual property rights[29]. To sum up, intellectual property protection can better protect the innovation achievements of enterprises with strong research and development willingness, thus promote enterprises to increase R & D investment, and

also force enterprises that are unwilling to innovate to innovate. Based on the above analysis, this paper makes the following assumptions:

Hypothesis 2a: Intellectual property protection positively affects the r & d investment of listed enterprises.

Hypothesis 2b: The r & d investment of listed enterprises positively affects the innovation output of listed enterprises.

### 3.3 Adjustment Effect of Enterprise scale

Enterprise size positively influences R&D input & innovation output. Large firms, with abundant resources & capital, can withstand R&D costs & uncertainties, fostering innovation. Their brand influence & scale reduce costs, enhancing R&D efficiency. Small firms, constrained by capital & resources, struggle with large-scale R&D & high-risk innovation, whereas large enterprises' capital & social resources enable stronger innovation capabilities. At the same time, in the process of their development, large enterprises will often form their own brands, which can use their advantages to achieve their own scale effect, which can reduce the cost of innovation[30]Thus, it will also have more efficient research and development efficiency, and it will be easier to achieve good innovation results. Secondly, the enterprise scale has a linear positive contribution to the R & D investment intensity[31]. Large companies are more able to attract partners to integrate resources to maximize resources and more efficiently to successfully translate R & D spending into innovation output.

To sum up, the enterprise scale has a positive adjustment effect on R & D input and innovation output, and large-scale enterprises are more likely to carry out innovation activities and achieve good innovation results. This paper makes the following assumptions:

Hypothesis 3: Enterprise size plays a positive role in regulating R & D investment and innovation performance of listed companies.

### 3.4 The Adjustment Effect of Government Subsidies

Government financial support boosts enterprise social recognition, attracting external innovation investment, enhancing innovation investment & performance. SMEs, in particular, rely on government funding for R&D & scientific personnel. Government intervention sends a positive signal, fostering innovation. Gov't funds often target key, high-potential innovations, encouraging enterprises to invest more in R&D, scale up innovation, & hone core technologies. Additionally, gov't investment signals enterprise stability & quality, attracting more private investors, mitigating risk aversion & boosting investment intentions. Hence, the following assumptions are proposed: Gov't support fosters innovation investment, performance, & attracts external capital:

Hypothesis 4: Government subsidies play a positive role in regulating the r & d expenditure of listed enterprises and the innovation performance of listed enterprises.

# 4 Model Design and Descriptive Statistics

## 4.1 Sample Selection and Data Source

In this paper, A-share listed firms on Shenzhen & Shanghai Stock Exchanges (2011-2020) were selected, excluding ST firms, financial firms, and incomplete data samples. Innovation data sourced from CNRDS; IP protection levels (logarithm of infringement cases/lawyers per province) and other financial data from CSMAR.

## 4.2 Variable Definitions (see Table 1)

(1) Invention patents justify as index: signify unique tech innovations, reflect R&D strength, demand high investment, foster innovation, indicate perseverance & spirit, effectively measuring enterprise innovation. Annual applications +1 serve as innovation output index, with variables delayed due to R&D cycle and lag effect.

(2) Interpretive vars.: Regional IP protection level measured by multiple factors, including national legislative protection and local judicial level.

(3) Mediation vars.: Annual R&D investment (logarithmic) taken as intermediary for IP protection level's influence on enterprise innovation output.

(4) Adj. vars.: Enterprise size (measured by total assets) and gov't subsidies selected. Size shown by final total assets; subsidy by natural log of R&D subsidy under non-operating income in annual report.\.

**Table 1.** Variable definition and measurement method

| variable | symbol | definition |
|---|---|---|
| explained variable | Patent | Innovation output, the number of invention patents declared by the enterprise in the year, Ln (1 + the number of invention patents declared by the enterprise in the year) |
| Core explanatory variables | IPR | Ln [(number of intellectual property infringement cases / total population + number of regional lawyers / total population) / 2] |
| metavariable | Ini | R & D investment, ln (1 + R & D expenditure) |
| regulated variable | GOV | Ln (Government R & D input) |
| | SIZE | Enterprise size, ln (total assets) |
| controlled variable | LEV | Asset-liability ratio, total liabilities / total assets |
| | ROA | Return on total assets, net profit / total assets |
| | Age | Enterprise age, ln (number of years from year) |
| | Growth | Enterprise growth sex, operating income growth rate |
| | Anst | Market attention, ln (1 + analyst attention) |
| | Cash | Capital stock, ln (trading financial assets + monetary funds) |
| | Industry | Industry virtual variable, according to the industry virtual variable produced by the industry |
| | Time | Time dummy variables, generated by year |

### 4.3 Model Design

#### 4.3.1 Mediator Effect.

In this paper, Bootstrap test method is selected, which has high statistical power compared with other test methods. Bootstrap method is accepted to replace the product of coefficients[32]. Bootstrap Test $H_0$: A b = 0, for the extracted sample, an estimate of the product of its coefficients can be obtained, thus forming a 95% confidence interval for ab. If the confidence interval does not include 0, the null hypothesis is rejected and the product of coefficients is significant[33].

The model of panel data (1) - (3) is constructed as follows:

$$Paten\text{-}t_{i,j,t}=\alpha_0+\alpha_1 IPR_{j\text{-}1,t}+\alpha_2 GOV_{i,j\text{-}1,t}+\alpha_3 SIZE_{i,j\text{-}1,t}+\alpha_4 LEV_{i,j\text{-}1,t}+\alpha_5 ROA_{i,j\text{-}1,t}+\alpha_6 Age_{i,j\text{-}1,t}+\alpha_7 Growth_{i,j\text{-}1,t}+\alpha_8 Anst_{i,j\text{-}1,t}+\alpha_9 Cash_{i,j\text{-}1,t}+Z'_i\phi+\varepsilon_{i,j,t} \quad (1)$$

$$In\text{-}i_{i,j,t}=\beta_0+\beta_1 IPR_{j\text{-}1,t}+\beta_2 GOV_{i,j\text{-}1,t}+\beta_3 SIZE_{i,j\text{-}1,t}+\beta_4 LEV_{i,j\text{-}1,t}+\beta_5 ROA_{i,j\text{-}1,t}+\beta_6 Age_{i,j\text{-}1,t}+\beta_7 Growth_{i,j\text{-}1,t}+\beta_8 Anst_{i,j\text{-}1,t}+\beta_9 Cash_{i,j\text{-}1,t}+Z'_i\phi+\varepsilon_{i,j,t} \quad (2)$$

$$Paten\text{-}t_{i,j,t}=\gamma_0+\gamma_1 IPR_{j,t}+\gamma_2 Ini_{i,j\text{-}1,t}+\gamma_3 GOV_{i,j\text{-}1,t}+\gamma_4 SIZE_{i,j\text{-}1,t}+\gamma_5 LEV_{i,j\text{-}1,t}+\gamma_6 ROA_{i,j\text{-}1,t}+\gamma_7 Age_{i,j\text{-}1,t}+\gamma_8 Growth_{i,j\text{-}1,t}+\gamma_9 Anst_{i,j\text{-}1,t}+\gamma_{10} Cash_{i,j\text{-}1,t}+Z'_i\phi+\varepsilon_{i,j,t} \quad (3)$$

Where, i = 1,2,... (indicating each listed company), t = 2011,2012,..., 2020 (indicating each year), $\varepsilon_{it}$For the random perturbation term, $Z'_i\phi$ C for the fixed-effect model$_i$, For $\phi + \mu$ in the random-effects model$_i$, $\alpha$, $\beta$, and $\gamma$ indicate the regression coefficient.

#### 4.3.2 Regulation of the Mediation Effect.

In this paper, we take the mediation effect as the core and base the mediation effect on the mediation effect, that is, to prove the existence of the mediation path of IPR-> Ini-> Patent, indicating the mediation effect, and then analyze whether the mediation effect exists.

The panel data model (4) - (6) is constructed as follows:

$$Paten\text{-}t_{i,j,t}=a_0+a_1 IPR_{j\text{-}1,t}+a_2 Ini_{i,j\text{-}1,t}+a_3 GOV_{i,j\text{-}1,t}+a_4 SIZE_{i,j\text{-}1,t}+a_5 Ini_{i,j\text{-}1,t}*GOV_{j\text{-}1,t}+a_6 LEV_{i,j\text{-}1,t}+a_7 ROA_{i,j\text{-}1,t}+a_8 Age_{i,j\text{-}1,t}+a_9 Growth_{i,j\text{-}1,t}+a_{10} Anst_{i,j\text{-}1,t}+a_{11} Cash_{i,j\text{-}1,t}+Z'_i\phi+\varepsilon_{i,j\text{-}1,t} \quad (4)$$

$$Paten\text{-}t_{i,j,t}=b_0+b_1 IPR_{j\text{-}1,t}+b_2 Ini_{i,j\text{-}1,t}+b_3 GOV_{i,j\text{-}1,t}+b_4 SIZE_{i,j\text{-}1,t}+b_5 Ini_{i,j\text{-}1,t}*SIZE_{i,j\text{-}1,t}+b_6 LEV_{i,j\text{-}1,t}+b_7 ROA_{i,j\text{-}1,t}+b_8 Age_{i,j\text{-}1,t}+b_9 Growth_{i,j\text{-}1,t}+b_{10} Anst_{i,j\text{-}1,t}+b_{11} Cash_{i,j\text{-}1,t}+Z'_i\phi+\varepsilon_{i,j\text{-}1,t} \quad (5)$$

$$Paten\text{-}t_{i,j\text{-}1,t}=c_0+c_1 IPR_{i,j\text{-}1,t}+c_2 Ini_{i,j\text{-}1,t}+c_3 GOV_{i,j\text{-}1,t}+c_4 SIZE_{i,j\text{-}1,t}+c_5 Ini_{i,j\text{-}1,t}*GOV_{j\text{-}1,t}+c_6 Ini_{i,j\text{-}1,t}*SIZE_{i,j\text{-}1,t}+c_7 LEV_{i,j,t}+c_8 ROA_{i,j\text{-}1,t}+c_9 Growth_{i,j\text{-}1,t}+c_{10} Age_{i,j\text{-}1,t}+c_{11} Anst_{i,j\text{-}1,t}+c_{12} Cash_{i,j\text{-},t}+Z'_t\phi+\varepsilon_i \quad (6)$$

Model (4) and (5) test whether the main coefficients a5 and b5 are significant, that is, determine whether the regulation effect of the enterprise capital input on the enterprise R & D expenditure; the model (6) add the coefficients c5 and c6 are significant, and further judge the regulation effect of the government R & D expenditure and the enterprise R & D expenditure on the output.

Descriptive statistical results of each variable are shown in Table 2:

**Table 2.** Descriptive statistical results

| variable | sample capacity | average value | standard error | least value | median | crest value |
|---|---|---|---|---|---|---|
| Patent | 1351 | 0.622 | 1.026 | 0 | 0 | 6.227 |
| IPR | 1351 | -0.115 | 0.334 | -1.004 | -0.11 | 0.432 |
| Ini | 1351 | 18.03 | 1.328 | 11.58 | 17.96 | 22.29 |
| SIZE | 1351 | 22 | 1.175 | 19.35 | 21.82 | 26.28 |
| GOV | 1351 | 16.668 | 1.642 | 0 | 16.655 | 21.421 |
| LEV | 1351 | 0.394 | 0.204 | 0.0274 | 0.38 | 1.685 |
| ROA | 1351 | 0.0356 | 0.0738 | -1.164 | 0.0346 | 0.48 |
| Age | 1351 | 2.884 | 0.32 | 1.442 | 2.925 | 3.676 |
| Growth | 1351 | 0.652 | 5.83 | -0.997 | 0.124 | 134 |
| Anst | 1351 | 1.98 | 0.881 | 0.693 | 1.946 | 4.111 |
| Cash | 1351 | 20.11 | 1.203 | 16.59 | 20.04 | 24.27 |

Table 1 reveals low median innovation output (0, SD=1.026) among central China's 6 provinces, with vast disparities among enterprises. IP protection levels are average (min=-1.004, SD=0.334), indicating uniformity among provinces. Gov't R&D support varies (avg=16.668, SD=1.642), with enterprises relying more on self-funded R&D than government grants. Enterprise sizes also significantly differ (avg=22, SD=1.175).

# 5 Empirical Results and Analysis

## 5.1 Results of Model Selection and Regression Analysis

### 5.1.1 Model Selection.

The panel data is judged to fit the fixed or random effects model by Hausman test, null hypothesis H0: $\mu_i$Was not correlated with all of the explanatory variables. The test results are shown in Table 3, and all models (1) - - (6) reject the null hypothesis H0, that is, all fixed-effect models are used.

### 5.1.2 Analysis of the Regression Results.

**Table 3.** Results of the bootstrap test

| | Observed Coefficient | std.err | P>\|z\| | ［95% conf.intervel］ |
|---|---|---|---|---|
| _bs_1 | 0.0207 | 0.0111 | 0.000 | 00.0159 .04435 |
| _bs_2 | 0.3216 | 0.0560 | 0.047 | 00.1352 .2664 |

**Table 4.** Results of the model regression

| variable | (1) Patent | (2) Ini | (3) Patent | (4) Patent | (5) Patent | (6) Patent |
|---|---|---|---|---|---|---|
| IPR | 0.2678** | 0.7552** | 0.8489** | 0.2426*** | 0.2216 | 0.2411*** |
| Ini | | | 0.1620*** | 0.1304*** | 0.1640*** | 0.1311*** |
| SIZE | 0.4391*** | 0.7682*** | 0.3009*** | 0.2975*** | 0.29357*** | 0.2968*** |
| GOV | 0.0198** | 0.0563*** | 0.0062 | 0.0090 | 0.0074 | 0.0088 |
| Ini*SIZE | | | | 0.0599*** | | 0.0583*** |
| Ini*GOV | | | | | 0.0289*** | 0.0018 |
| LEV | -0.5650*** | -0.1665 | -0.4638** | -0.4339** | -0.4656** | 0.0803** |
| ROA | -1.1695* | -0.0973 | -1.1093* | -1.0612* | -1.0720* | -1.0588* |
| Age | 0.0791 | -0.0307 | -0.0014 | 0.0808 | 0.0765 | 0.0803* |
| Growth | -0.0014 | 0.0007*** | 0.0769 | -0.0024 | -0.0017 | -0.0024 |
| Anst | 0.0507* | 0.1345*** | 0.0296 | 0.0331 | 0.0282 | 0.0330 |
| Cash | -0.0156 | 0.0046 | -0.0125 | -0.0276 | -0.0186 | -0.0275 |
| Industry | control | control | control | control | control | control |
| Year | control | control | control | control | control | control |
| c | -8.9710*** | -0.4958 | -9.0144*** | -8.1082*** | -8.5391*** | -8.1019*** |
| N | 1351 | 1351 | 1351 | 1351 | 1351 | 1351 |
| R-squared | 0.2974 | 0.7461 | 0.2949 | 0.3029 | 0.2978 | 0.3029 |
| Haus-man-Test | Prob>chi$^2$ =0.0000 | Prob>chi$^2$ =0.0000 | Prob>chi$^2$ =0.0000 | Prob>chi$^2$ =0.0000 | Prob>chi$^2$ =0.0000 | Prob>chi$^2$ =0.0000 |

Note:,are statistically significant at the levels of 1%, 5% and 10% respectively, the same below. Table 3 validates positive direct & indirect effects of IPR protection on innovation. Table 4's fixed effects regression results show IPR boosts innovation output (M1) & R&D investment (M2), enhancing output via R&D (M3). R&D spending positively impacts innovation, with size amplifying this (M4). Gov't R&D support enhances efficiency (M5), but no significant interaction with enterprise R&D (M6), implying enterprise capacity & strategies dominate. Hence, H3 holds, but H4 is not supported.

## 5.2 Robustness Test and Endogeneity Test

### 5.2.1 Robustness Test.

In this paper, the robustness test uses the variable replacement method with "ln(number of employees + 1)" as the replacement for enterprise scale (data from guotai'an database). Regression results (Table 5) show consistent symbol and significance of the estimated coefficient of the interaction term between enterprise size and R&D investment with previous findings, confirming robustness of the enterprise size regulation effect.

**Table 5.** Results of the robustness test

| variable | (1) Patent | (2) Ini | (3) Patent | (4) Patent | (5) Patent | (6) Patent |
|---|---|---|---|---|---|---|
| IPR | 0.3663** | 1.0262*** | 0.3037* | 0.2989* | 0.2735* | 0.2946 |
| Ini | | | 0.2051*** | 0.1592*** | 0.1945*** | 0.1608*** |
| SIZE | 0.2208*** | 0.4343*** | 0.1308** | 0.1326*** | 0.1277*** | 0.1319*** |
| GOV | 0.0343* | 0.0782** | 0.0187 | 0.0166 | 0.0148 | 0.0162* |
| Ini*SIZE | | | | 0.0632*** | | 0.0588*** |
| Ini*GOV | | | | | 0.0322*** | 0.0049 |
| Control | control | control | control | control | control | control |
| Industry | control | control | control | control | control | control |
| Year | control | control | control | control | control | control |
| C | -4.4925*** | 7.1850*** | -6.2045*** | -5.3003*** | -5.7887*** | -5.2995*** |
| N | 1351 | 1351 | 1351 | 1351 | 1351 | 1351 |
| R-squared | 0.2705 | 0.7282 | 0.2871 | 0.2972 | 0.2921 | 0.2973 |

### 5.2.2 Endogenity Problems.

This paper may face endogeneity issues due to missing variables. Thus, the instrumental variable method was applied, using patent infringement cases accepted by the Intellectual Property Office as the IV for the intellectual property protection index.

The patent uninfringement rate (cases not infringed/authorized) reflects IP protection, with higher rates indicating better protection (data: 2011-2020 China Intellectual Property Yearbook). First-stage regression shows infringement case acceptance strongly predicts IPR (F-test passed, no weakness/overidentification). Second-stage confirms IPR index and R&D spending*enterprise size significantly impact, affirming model robustness.

**Table 6.** The regression results of the endogeneity test

| f irst-stage regression of stage | | | |
|---|---|---|---|
| explained variable | Intellectual Property Protection Level (IPR) | | |
| IV:IPR | 1.1901*** | | |
| Controls | control | | |
| R-squared | 0.8068 | | |
| F price-IV | 44.6222 (p =0.000) | | |
| second -stage regression of stage | | | |
| variable | (1) Patent | (2) Ini | (3) Patent |
| IPR(IV) | 0.6742*** | 0.8021*** | |
| IPR | | | 0.6709*** |
| Ini*SIZE | | | 0.0715*** |
| Controls | control | control | control |
| Industry | control | control | control |
| Year | control | control | control |
| R-squared | 0.2816 | 0.7213 | 0.2957 |

### 5.3 Heterogeneity Analysis

According to the proportion of state-owned capital to total capital after 2011, listed companies are divided into state-owned enterprises (more than or equal to 50%) and non-state-owned enterprises (less than 50%). The results are shown in Table 7.

**Table 7.** Group tests based on property rights

| | Non-state-owned enterprises | | | | state-owned enterprises | | | |
|---|---|---|---|---|---|---|---|---|
| variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | Patent | Ini | Patent | Patent | Patent | Ini | Patent | Patent |
| IPR | 0.0174 | 0.3644*** | -0.0377 | -0.0319 | 0.5681* | 0.7441*** | 0.1972*** | 0.6870** |
| Ini | | | 0.1514*** | 0.1382*** | | | 0.6920** | 0.1148 |
| SIZE | 0.2725*** | 0.7713*** | 0.1558** | 0.1516** | 0.72858*** | 0.6996*** | 0.5905*** | 0.5493*** |
| Ini*SIZE | | | | 0.0365** | | | | 0.0637** |
| Control | control | control | control | control | control | control | control | control |
| Industry | control | control | control | control | control | control | control | control |
| Year | control | control | control | control | control | control | control | control |
| N | 891 | 891 | 891 | 891 | 460 | 460 | 460 | 460 |
| R-squared | 0.2028 | 0.7549 | 0.2141 | 0.2184 | 0.4884 | 0.7441 | 0.4982 | 0.5039 |

Table 6 contrasts regressions: for non-state enterprises, IP protection lacks direct/indirect effect on innovation output. Conversely, for state enterprises, enhanced IP protection boosts invention patent apps, likely due to their stronger innovation base, R&D capabilities, and conditions for independent innovation. The interaction of R&D spending and enterprise size, significant at 5% for both types, indicates scale positively modulates R&D investment's impact on innovation output, aligning with prior findings.

## 6 Conclusion

This paper to enterprise innovation as the explanatory variable, using the central six provinces in 2011~2020, a total of 10 years of listed company data, r & d investment as an intermediary variable, the enterprise scale and the government for the enterprise investment as a regulatory variable, and the heterogeneity analysis, empirical test the influence of intellectual property protection on enterprise innovation output and function mechanism, improve and supplement the intellectual property protection of related research, and based on the results of the following conclusions and policy Suggestions:

（1）IP protection boosts enterprise invention & innovation output, enhancing R&D investment & innovation performance. Central China's gov'ts should strengthen IP protection, enforcing laws to spur enterprise innovation enthusiasm.

（2） Enterprise scale positively impacts R&D spending & innovation output. Larger firms invest more in R&D, enhancing innovation performance. Gov'ts should tailor IP protection policies, addressing SME needs, unleashing their innovation potential.

（3）Heterogeneity test shows IP protection boosts innovation more in SOEs than non-SOEs. Central China's provinces should focus on IP protection for non-SOEs, exploring their needs, to unleash their innovation potential amidst innovation-driven strategies.

（4）IP protection boosts innovation in developed & high-IP-protected provinces, less in less-developed ones. Hubei, as a leading province, can learn from developed nations to aid enterprise globalization. Lower-tier provinces should address IP system barriers, set realistic goals aligned with current development, avoiding haste, to meet China's new-era targets.

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