Journal of the Knowledge Economy
https://doi.org/10.1007/s13132-024-02133-2

Strategizing Intellectual Property Rights for Enhanced Innovation: the Moderating Effects of R&D and FDI in China's Regional Context

Xiaomeng Chi[1,4] · Mingxing Li[1,2] · Hongzheng Sun[1] · Saifullah[1] · Mengjuan Zhang[1,3] · Fredrick Oteng Agyeman[1]

Received: 21 December 2022 / Accepted: 5 June 2024

Abstract
This study investigates the strategic role of intellectual property rights (IPR) in driving technological innovation in China, focusing on the impact of research and development (R&D) and foreign direct investment (FDI) in different regional contexts. Given the critical importance of understanding how enhanced IPR protection can stimulate technological progress in emerging economies like China, this research addresses theoretical and practical gaps by proposing a region-specific approach to IPR strategy, considering the unique dynamics of R&D and FDI. Analyzing data from 21 Chinese provinces, cities, and autonomous regions from 2007 to 2019 using a fixed-effects model, the findings highlight that stronger IPR protection significantly boosts domestic technological innovation by motivating R&D efforts, which in turn increases the rate of invention patent applications. However, the study uncovers a complex interaction where increased IPR stringency might deter FDI flows, negatively impacting the IPR-innovation relationship. Furthermore, the interplay between FDI and R&D can hinder innovation outcomes, with the Western region of China being particularly affected by FDI's influence on innovation, in contrast to the Eastern and Central regions. These insights emphasize the necessity of aligning IPR protection with R&D and FDI policies to create an innovation ecosystem conducive to sustained technological development. This research contributes to the existing literature by offering empirical evidence on the optimal configuration of IPR, R&D, and FDI strategies for fostering innovation, providing valuable insights for policymakers and stakeholders in the knowledge economy.

Keywords IPR protection intensity · Technological innovation · Dual mediators · R&D investment · Foreign direct investment (FDI)

Extended author information available on the last page of the article

Published online: 15 June 2024

Introduction

The escalating Sino-US trade friction shows that the competition between countries is essentially a competition between science and technological innovation (Steinbock, 2019). The significance of intellectual property rights (IPR) for technological innovation has gained paramount importance in the global knowledge economy, transcending beyond the immediate implications of the US-China trade tensions. Therefore, this study shifts its focus from geopolitical friction to a broader examination of IPR's theoretical implications, especially its crucial role in shaping the innovation landscape of developing economies (Al-kalouti et al., 2020; Appelbaum et al., 2018). In addition, the global COVID-19 pandemic has accelerated an unprecedented reshuffling of the world technology landscape (De Massis et al., 2020; Feziwe et al., 2021). Technological innovation has been helpful in vaccine research and development, large-scale nucleic acid testing, big data tracking, traceability, and health code identification; all these processes need strong support from science and technology (Lin, 2022). Although China's performance is well below the European Union (EU) average for most innovation-related analytical indicators, the growth rate of the Chinese economy from 2008 to 2018 has been higher than that of the EU, indicating a convergence process (Xiao et al., 2021). China's development success hinges on bridging the technology gap through the introduction and enhancement of science and technology, as well as bolstering internal capabilities to exploit and improve these technologies (Kowalski, 2020).

A major practical issue worth studying is an approach that accurately grasps the vital components of science and technology innovation in the unpredictable global wave and domestic development needs. Faced with profound and complex domestic and international technological situations, China's 14th Five-Year Plan has put forward more urgent and strategic policies for accelerating technological innovation (Hepburn et al., 2021). Chinese leaders have clarified the critical position of intellectual property rights (IPR) protection in stimulating innovation (Li & Alon, 2019). Along with introducing and implementing the strategy of "developing the country through science and education," China is bound to strengthen the protection of intellectual property rights across the board (Brander et al., 2017).

Since the 18th Party Congress, a series of decisions such as the Action Plan for the In-depth Implementation of the National Intellectual Property Strategy (2014–2020) has been introduced to promote the continuous improvement of China's intellectual property protection system (Changyu, 2021). In 2019, China's social satisfaction with IPR protection improved by 15.29 points compared to 2012 (Tin, 2020). The 14th Five-Year Plan proposes that China should "implement the strategy of strengthening intellectual property rights" and integrate IPR protection into the country's overall economic and social development (Wang & Chen, 2017). According to the Global Innovation Index 2020 published by the World Intellectual Property Organization (WIPO), China's global ranking is unchanged from 2019 and has been the only middle-income economy to maintain

its 14th position or rank among the global innovation index (GII) top 30 (Androschuk, 2021). In the post-epidemic era, China's science and technology innovation has been revitalized, fully demonstrating the potential and resilience of the Chinese nation in dealing with unexpected "big tests."

This study is important because it provides an in-depth analysis of the role of intellectual property rights protection intensity on technological innovation by employing a sample from 21 provinces, cities, and autonomous regions from 2007 to 2019 for analysis. Further, this study contributes to the existing body of knowledge by introducing two mediating variables: research and development (R&D) and foreign direct investment (FDI), employing the fixed-effects model for the empirical analysis. Thus, by exploring these dimensions, the study aims to contribute significantly to the existing body of knowledge, providing empirical insights that could inform policy formulations aimed at enhancing the innovation ecosystem in China and other developing countries. Moreover, by examining the intricate relationship between IPR protection, R&D, FDI, and technological innovation, this study endeavors to provide comprehensive insights that enrich the global discourse on strategizing IPR for enhanced innovation.

Theoretical Background

The Impact of IPR Protection on Technological Innovation and Enterprise Value

The IPR system is an essential property rights system for reasonably optimizing the allocation of knowledge resources and promoting technological progress (Santoro et al., 2020). The development of countries, regions, industries, individuals, and enterprises cannot be achieved without being driven by innovation; thus, the importance of technological innovation cannot be understated (Mothe & Nguyen-Thi, 2021; Mtar & Belazreg, 2020), while the IPR protection has not fully supported the transformation of innovation into a competitive advantage, various mechanisms can be implemented to achieve its full benefits. First, local innovation is positively correlated with the level and dynamics of foreign and domestic IPR rights (Gmeiner & Gmeiner, 2021). Countries with foreign and domestic IPR rights that are equally respected tend to have higher levels of innovation. Secondly, suppose the intensity of IPR protection is weak, and the research and development (R&D) results cannot be effectively protected. In that case, there is a great risk of intellectual R&D outcomes being stolen, which will seriously dampen the innovation enthusiasm of R&D personnel. Thus, in the long run, few companies will take the initiative to carry out independent R&D. Fundamental R&D is the prerequisite for independent innovation.

The reduction of R&D activities and the sudden drop in R&D willingness will eventually lead to a decline in the innovation capability of the entire region. Extant investigations have pointed out that social and economic development can only be achieved when appropriately protected innovative activities are implemented (Arora et al., 2008). Timely and effective IPR protection will significantly reduce the possibility of illegal imitation and theft of patented technology. Commonly, victims of

intellectual property (IP) theft suffer harm, which poses a risk to the long-term innovation competitiveness of the perpetrators (Hurmelinna-Laukkanen et al., 2008). When the threat of infringement and litigation is under control, firms are more willing to further improve their innovation capabilities by conducting R&D activities, thus obtaining monopoly profits through the monopoly of innovation results (Levin et al., 1985). This path is beneficial to increase the enthusiasm of enterprises for independent innovation and bring about a significant increase in the overall innovation standard of countries (Enkel & Sagmeister, 2020).

On the other hand, strengthening the intensity of IPR protection can effectively alleviate the external financing constraints of enterprises. When intellectual property rights are effectively protected, investors will have optimistic expectations about the investment returns brought by innovations, and their willingness to invest will also increase. China's small and medium enterprises (SMEs) and start-ups still rely mainly on external financing for their R&D activities due to their inherent disadvantages, such as small scale and unstable operation (Landoni et al., 2020). If the financing condition is improved and the pressure of enterprise financing is reduced, the willingness and enthusiasm for innovation and entrepreneurship will be effectively stimulated. In addition, the increase in the threshold level of IPR protection intensity has, to a certain extent, contributed to the improvement of the technological performance of China's high-tech industries (Bruno et al., 2021).

For SMEs in advanced manufacturing industries, there is an "inverted U-shaped" relationship between the impact of IPR protection on enterprise value and a "U-shaped" relationship between IPR protection and technological innovation (Tou et al., 2020). Countries with lenient IPR protection policies enhance their enterprises' corporate profits as IPR protection increases (Azembila et al., 2020). As the differences between domestic and international country IP regimes increase, technological innovation performance worsens. However, some scholars also pointed out that IPR protection has the effect of first promoting and then inhibiting enterprise technological innovation (Hasan & Kobeissi, 2012). Based on the studies analyzed earlier, the following hypothesis is proposed:

H1: Strengthening IPR protection intensity can promote scientific and technological innovation.

R&D Investment Mediating the Relationship Between IPR Protection Intensity and Technological Innovation

Current research has shown that increasing R&D investment can significantly accelerate a firm's growth (Gupta, 2001; Tsai & Wang, 2004). World-famous enterprises like Amazon became a world R&D leader in 2017 by increasing their R&D investment more than ten times compared to 2011, attracting a skyrocketing expansion of its corporate market capitalization and coming close to becoming the world's largest company in electronic commerce and other ventures (Holtzman & McManus, 2008). The rise in firm size and market capitalization facilitates the maintenance of stable

R&D investment, which in turn enhances firm innovation performance (Huang et al., 2021) and improves a firm's innovation quality (Jordaan, 2017).

Liu et al. (2021) found that R&D intensity is an essential factor in determining the quality of innovation in firms. Innovation investment can promote innovation output by increasing R&D funding and introducing R&D personnel. With sufficient and multi-source R&D investments, the scale and quality of regional R&D outputs show significant changes, and the scale effect brought by the concentration of R&D factors and its knowledge resource allocation efficiency has a positive impact on the innovation level. Enterprises are the main body to absorb R&D investment and carry out R&D activities, but under the current market competition mechanism, market risks and failures cause enterprises to invest in R&D at a scale lower than the optimal level (Piper et al., 2006), which in turn affects the return on R&D investment. When firms are less willing to invest in R&D activities, the level of innovation will stagnate. Therefore, the government needs to develop relevant policies to intervene moderately in the market operation to protect and incentivize R&D investment. Nevertheless, financial subsidies alone are insufficient (Hossain, 2021), and IPR protection has been widely recognized by academia and policymakers as a policy tool to address market failures (Wan et al., 2021).

Monopoly profits generated by IPR protection maintain the leading position of R&D enterprises in the industry, and the high revenue compensates for the expenditure of R&D costs and guarantees the stability of the R&D capital chain, thus enhancing the innovation motivation of various enterprises. Thus, IPR protection brings "security" to R&D investors (Lin & Long, 2021). With the increasing intensity of IP protection, R&D achievements are protected, the return on investment rises rapidly, and the enterprises' willingness to invest in R&D is enhanced. With the support of stable R&D funds, R&D activities can be carried out smoothly. The enterprises' enthusiasm for innovation is significantly enhanced; a virtuous and orderly cycle is formed, technological innovation is advanced, and high-quality patents keep emerging. Feng and Li (2021) found that enhanced IPR protection could significantly promote technological innovation. Liu et al. (2021) pointed out that the government can strengthen the quality of innovation of enterprises by increasing IPR protection. This study introduces the following hypothesis based on the analyzed studies above:

H2a: Increasing IPR protection intensity can promote R&D investment.
H2b: Increasing R&D investment is beneficial to science and technology innovation.
H2c: R&D investment plays a mediating role in the relationship between IPR protection intensity and science and technology innovation.

FDI Mediating Relationship Between IPR Protection Intensity and Technological Innovation

Scholars have carried out numerous empirical studies on whether FDI can promote scientific and technological innovation in the host country (Majeed & Ahmad,

2007). These investigations can be categorized into two broad academic schools of thought: promotion theory and suppression theory. The promotion theory argues that FDI promotes the standard of technological innovation in the host country by demonstrating imitation, competition, and increasing investment in R&D (Ding & Xue, 2023). Conversely, the suppression theory argues that FDI inflows crowd out the domestic market. The over-reliance on FDI saps the sense of domestic innovation, leading to a negative technology spillover effect (Barrios & Strobl, 2002). The source, investment scale, penetration intensity, and technology content of FDI can have multiple impacts on science and technology innovation to varying degrees (Chen et al., 2022). Wang and Wu (2016) emphasized that the government's motive of attracting investment without focusing on the process but on the results and the perception of "more is better" is the most fundamental reason for the low quality of FDI in China's high-tech industry. The impact of low-quality FDI on the efficiency of technological progress is "significantly negative." Nevertheless, studies have indicated that IPR protection is related to FDI. Thus, there is a positive relationship between IPR protection and FDI in the long run (Noon et al., 2018; SÁIz & Castro, 2017).

FDI inflows to developing countries are also positively correlated with IPR protection in neighboring developing countries (Klein, 2018). More robust IPR protection attracts more FDI inflows in countries with smaller informal economies but not in countries with larger informal economies. In countries with strong institutions, IPR protection promotes FDI inflows by reducing illegal imitation and freeing up more resources for multinationals. Notwithstanding, China's current enhanced IPR protection is not entirely conducive to the technology spillover effect of FDI (Lee et al., 2018). Multinational companies have significantly increased their investments in developing countries and regions since the 1990s. The investment of multinational companies in China has made China attractive for foreign capital with two significant advantages (huge market share and abundant and cheap quality labor), however, the "pollution sanctuary effect" does exist in China because of mass industrialization (Guan et al., 2022). In other words, most foreign investment that comes into China is mainly aimed at circumventing regulations and making profits at the expense of the host country's environment, which increases the cost of managing environmental pollution in China and decreases technological innovation. Gross national product (GNP) growth is significantly lower than GDP in China. Thus, if the revenue gained from the local industries in overseas countries is below the income earned from the international sectors within the nation, GNP becomes lower than the GDP. These variations indicate that the contribution of FDI to the overall Chinese economy for a long time has diverse implications, and there is a possibility that it may be overstated. At present, foreign companies thwart the vast number of domestic small and medium-sized enterprises, reducing their market share through a strong capital and technological advantage base. Suppose the government introduces large amounts of foreign investments hurriedly. In that case, domestic enterprises lose their market share, and their survival and development will be difficult, not to mention the side effect of advanced technological innovation decline.

Therefore, this study expresses that the expansion of FDI may not be conducive to domestic science and technology innovation. A sound IPR protection system and

appropriate protection intensity can promote the rise of domestic technology standards and narrow the gap with developed countries, an important guarantee to achieve sustainable and high-quality development of China's economy. Simultaneously, the strength of IPR protection is also an essential factor affecting FDI. In the context of an open economy, strengthening IPR protection when the technology gap is large will inhibit the positive spillover effect of FDI. China's economic growth model is investment-driven, which has led to a general lack of high-tech talents and highly sophisticated industries, especially in the central and western regions. Despite the government's current policy and financial support for the rapid development of these regions, studies have confirmed that the economic and technological gaps between provinces have not been significantly narrowed (Wan et al., 2022; Zhou et al., 2021). As IPR protection intensity continues to be strengthened, the entry of FDI will be hindered. Second, the biggest beneficiaries of increased IPR protection standards are generally domestic enterprises, whose patents and technological achievements are better protected, thus weakening foreign enterprises' competitiveness and entering FDI activities willingly. Accordingly, the following hypotheses are formulated in this study:

H3a: Strengthening IPR protection intensity will inhibit FDI inflows.
H3b: Expanding FDI inflows are detrimental to domestic science and technology innovation.
H4: FDI inflows play a negative mediating role in the relationship between IPR protection intensity and science and technology innovation.

With the above elaboration, this study is founded on the research framework as shown in Fig. 1:

Materials and Methods

Variable Selection and Data Sources

Independent Variable

This current study employed intellectual property rights protection intensity (IPR) as the independent variable. The neoclassical economic growth theory proposes that

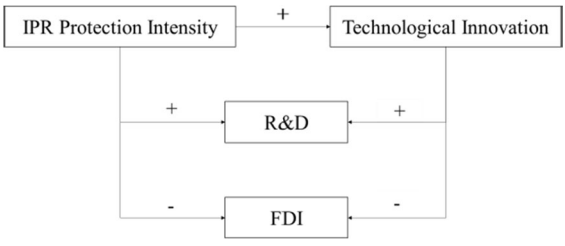

Fig. 1 Research framework

knowledge accumulation and technological advancement are essential to improving efficiency and promoting development. When social and economic development reaches a certain threshold, the fundamental market rules are no longer applicable to the field of knowledge creation and dissemination, thus giving rise to the emergence of intellectual property regulations and systems. By developing relevant systems and strengthening IPR intensity, knowledge innovation, and technological innovation can be promoted to the greatest extent possible, and ultimately, social welfare can be maximized (Arrow, 1962; Hudson & Minea, 2013; Lall, 2003; Naseem et al., 2010; Savitskaya et al., 2010). The IPR protection intensity quantifies the effect of a series of IPR systems and enforcement policy measures, and its measurement is conducive to visualizing the dynamic changes. This study adopted the measurement method proposed by Xu and Shan (2008): $P(t) = L(t)E(t)$, where $P(t)$ denotes IPR protection intensity, $L(t)$ denotes legislation intensity, and $E(t)$ denotes enforcement intensity.

The state mainly carries out China's IPR legislation in a unified manner, and each province (autonomous region and municipality directly under the central government) has some local legislative power, but all of them are further refined based on the national legislation. Therefore, the impact of regional differences on the intensity of IPR legislation is negligible. In this study, the strength of IPR legislation was determined as a constant value across regions. The strength of IPR legislation was measured in terms of the scope of protection, membership of international treaties, exclusion of loss protection clauses, enforcement mechanisms, and duration of protection. This study employed the global patent (GP) algorithm generally adopted by scholars and is mainly measured or judged by the following criteria, as shown in Table 1.

According to the rubric in Table 2, China's IPR legislative intensity score from 2000 to 2019 can be calculated (see Table 3). China's IPR legislative intensity has remained stable at 4.38 since 2008 and has surpassed most countries and regions globally (even leaving some developed countries behind).

The IPR enforcement intensity is influenced by many internal and external factors, such as social and cultural environment, judicial system, social integrity system, and the current state of social development. In addition, the international supervision and control mechanism is an important guarantee to strengthen the enforcement intensity. Accordingly, this study selects four indicators to measure the intensity of local law enforcement: economic development, international supervision, administrative protection, and judicial protection.

Based on the above formula and the IPR legislative intensity and enforcement intensity scores, the IPR protection intensity scores of 21 provinces in China from 2001 to 2019 are calculated. In the heat map of Fig. 2, the darker color represents the higher IPR protection intensity, with Shanghai, Beijing, Tianjin, and Zhejiang having the highest IPR protection intensity scores, followed by Jiangsu and Guangdong.

Dependent and Control Variables

Dependent Variable Technology innovation (LnTEC): This study intends to use the number of granted invention patents in each region to measure technological innovation. Compared with design patents and utility model patents, invention patents can

Table 1 Criteria for Judging IPR Legislation Intensity. Source: own research

Criteria	Content	Score
Protection scope	Utility model patent, pharmaceutical patent, chemicals, food patent, plant and animal species, microbiology, and medical device patents	1/7
International treaty membership	<Paris convention on the protection of industrial property>, <patent cooperation treaty>, <international union for the protection of new varieties of plants> (UPOV)	1/3
Exclusion of loss of protection clause	No implementation requirements, compulsory licensing, no invalidation	1/3
Execution mechanism	A pre-action injunction, help infringement, reverse onus	1/3
Protection period	Whether the patent protection period reaches 20 years	Yes,1 No, 0

Table 2 IPR legislation intensity score. Source: own research

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Score	3.38	3.71	3.71	4.05	4.05	4.05	4.05	4.05	4.38	4.38
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Score	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38

better be measured by technological innovation capability. Therefore, the number of granted invention patents is used as a dependent variable, denoted by LnTEC.

Control Variables Industry structure (IND): industrial structure is one of the most critical external factors affecting technological innovation. At present, the increasing share of tertiary industry in China and the gradual shift of the center of gravity of the industrial structure have created a favorable development environment for modern industries located at the high end of the value chain, such as intellectual property, information services, and R&D and design, which are conducive primarily to promoting technological innovation. The industrial structure is expressed as the share of the tertiary sector in the region's GDP and is denoted by IND.

Urbanization (URB): Urbanization has a specific influence on the R&D and innovation capacity of the selected regions. Higher urbanization means better infrastructure, a higher level of public service development, smoother technology and knowledge dissemination channels, and a more mature innovation environment. In addition, regions with a high level of urbanization are more attractive for investment in high-technology enterprises. The agglomeration of high-technology industries brings scale effects conducive to enhancing the region's innovation capacity. The urbanization level is measured by the share of the urban population in the total population of each region, which is expressed as URB.

Education level (EDU): The higher education level means that the intellectual capital and talents in the region are relatively more concentrated, the regional innovation atmosphere is more robust, the R&D strength is stronger, and the number of high-quality patents is higher. However, the increase in the number of patent applications will also bring more potential patent disputes, so better IPR protection measures and reasonable IPR protection intensity are needed. In this study, the level of education is selected as the control variable, and the ratio of regional financial expenditure on education to total financial expenditure is used to measure, which is expressed as EDU.

Intermediate Variables

Research and development investment (R&D): A mature and perfect intellectual property protection system and a moderate IPR protection intensity can guard the legitimate rights and interests of property owners and stimulate the awareness of IPR protection and innovation motivation of regions and enterprises,

Table 3 Indicators. Source: own research

Indicator	Implication	Scoring standard
Economic development	Per capita GDP	If the per capita GDP exceeds US$2000, the score is 1; If the per capita GDP is less than US$ 2000, the score is the ratio of the per capita GDP to US$ 2000
International supervision	WTO member countries	China joined the WTO in 2001 and considering the time lag, the score is 0 before 2005 and 1 after 2005
Administrative protection	Legislation time	When the legislative time is more than 100 years, the score is 1; if shorter than 100 years, the score is the ratio of the legislative time to 100 years. This study's legislation time to date is 67 years, and a score of 0.67
Judicial protection	Lawyers as a percentage of the total population	If the proportion of lawyers in the total population exceeds five to ten thousandths, the score is 1; if less than five to ten thousandths, the score is the ratio of the actual ratio to five ten thousandths

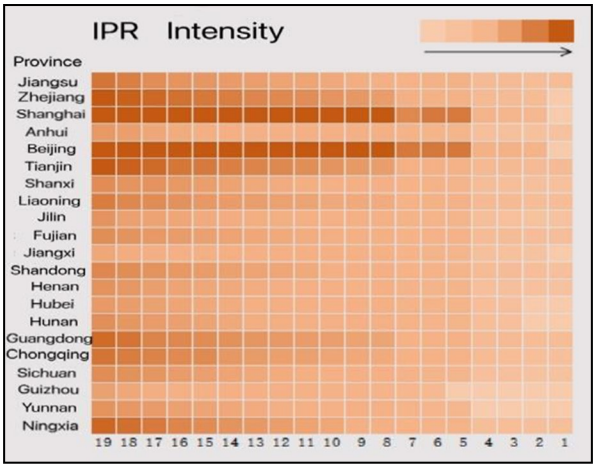

Fig. 2 Heat map of IPR intensity. Source: own research

leading to a sustainable increase in R&D investment. As the core part of science and technology investment, the increase in R&D investment leads to the corresponding increase in the number of high-quality invention patents granted. In this study, R&D investment is selected as a mediating variable to study the intensity of IPR protection and the amount of granted invention patents, measured by the proportion of R&D investment to fiscal expenditure.

Foreign direct investment inflows (FDI): IPR protection intensity is conducive to safeguarding the market interests of domestic enterprises but will instead weaken the willingness of foreign capital inflow, which in turn inhibits the efficiency of the FDI technology spillover mechanism. It is realized that increasing the degree of IPR protection will hinder the positive spillover effect of FDI. Therefore, this study chooses FDI inflow as a negative mediating variable and measures FDI inflow by the proportion of actual utilized foreign investment to the region's GDP.

Data Source

Population, GDP, foreign direct investment, granted invention patents, tertiary industry share urbanization level, education level, and investment in science and technology research and development in fiscal expenditures are obtained from the China Statistical Yearbook, local statistical yearbooks, and data published in the official website of the National Bureau of Statistics, and the number of lawyers is obtained from the China Lawyers Statistical Yearbook. Due to the imperfect statistical system and incomplete yearbooks in some regions, the sample was selected from 21 provinces, including Jiangsu, Zhejiang, Shanghai, Anhui, Beijing, Tianjin, and Hebei, and the time range was 2007–2019.

Research Model

This study investigates the magnitude of the effect of the intensity of IPR protection on the number of patent applications for inventions using a panel model with the following general form:

$$y_{it} = \partial_i + X_{it}\beta_i + u_{it}, i = 1,2,\ldots.,N;t = 1,2,\ldots.,T \tag{1}$$

where y_{it} is the dependent variable, ∂_i is the intercept term, β_i is the regression coefficient of the independent variable X_{it}, and u_{it} is the random error term. In testing the above hypotheses, this study added mediating variables and control variables as shown in the following models:

$$LnTECT_{it} = C_{11} + \alpha_{11}IPR_{it} + \sum_{k=1}^{3} y_{k1} + \varepsilon_{it} \tag{2}$$

Model (1) aims to verify the correlation between IPR protection intensity and technological innovation.

$$\mathrm{IPR_{it}} = \mathrm{C_{12}} + \beta_{12}\mathrm{R\&D_{it}} + \sum_{\mathrm{k=1}}^{3} \gamma_{\mathrm{k2}}\mathrm{X_k} + \varepsilon_{\mathrm{it}} \tag{3}$$

Model (2) aims to verify the relationship between IPR protection intensity and R&D investment.

$$LnTEC_{it} = C_{13} + \gamma_{11}R\&D_{it} + \sum_{k=1}^{3} \gamma_{k3}X_k + \varepsilon_{it} \tag{4}$$

Model (3) aims to verify the impact of R&D investment on technological innovation.

The mediating effect exists only when IPR protection intensity is positively correlated with technological innovation and R&D, and R&D is also positively correlated with technological innovation. Therefore, model (4) is built to simultaneously test the effect of IPR protection intensity and R&D on technological innovation. Similarly, model (5) is the effect of IPR protection intensity and FDI inflow on technological innovation at the same time. Based on models (4) and (5), model (6) is built to test further the mechanism of the interaction between R&D input and FDI on technological innovation.

$$LnTEC_{it} = C_1 + \alpha_1 IPR_{it} + \beta_1 R\&D_{it} + \sum_{k=1}^{3} \gamma_k X_k + \varepsilon_{it} \tag{5}$$

$$LnTEC_{it} = C_2 + \alpha_2 IPR_{it} + \beta_2 FDI_{it} + \sum_{k=1}^{3} \delta_k X_k + \mu_{it} \tag{6}$$

Table 4 Descriptive statistics. Source: own research

Variable	Min	Max	Mean	Std. Dev	VIF
LnTEC	3.466	10.998	8.041	1.490	
IPR	9.515	16.078	13.467	1.230	5.15
R&D	0.01	0.07	0.024	0.016	3.53
EDU	0.11	0.22	0.167	0.025	1.46
URB	0.28	0.9	0.577	0.145	5.83
IND	0.31	0.84	0.476	0.102	3.32
FDI	0	0.330	0.063	0.069	1.12
Sample	273				

Table 5 Correlation analysis. Source: own research

	IPR	LnTEC	R&D	EDU	URB	IND	FDI
IPR	1						
LnTEC	0.641**	1					
R&D	0.694**	0.658**	1				
EDU	−0.364**	0.033	−0.028	1			
URB	0.858**	0.620**	0.784**	−0.309**	1		
IND	0.819**	0.525**	0.646**	−0.373**	0.756**	1	
FDI	−0.130*	0.052	−0.142*	0.164**	−0.047	−0.162**	1

NB: ***, **, and * signify $p<0.01$; $p<0.05$; and $p<0.1$

$$LnTEC_{it} = C_3 + \alpha_1 IPR_{it} + \beta_1 R\&D_{it} + \beta_2 FDI_{it} + \theta R\&D_{it} \times FDI_{it} + \sum_{k=1}^{3} \delta_k X_k + \sigma_{it} \quad (7)$$

Results

Descriptive Statistical Analysis

As can be seen from Table 4, the standard deviations of technological innovation (LnTEC) and intellectual property protection intensity (IPR) both exceeded 1, indicating that the variability of invention patent applications and IPR was large in each province. The variance inflation factors of all variables are less than 10, and therefore, no multicollinearity is considered between the variables.

Correlation Analysis

Since the correlations between the variables could not be determined, this study used SPSS 23.0 software to conduct correlation tests to examine the closeness of the

relationships. The results of the analysis are shown in Table 5. First, LnTEC is significantly and positively correlated with IPR, so hypothesis H1 is initially verified. Second, IPR is significantly and positively correlated with R&D inputs at the 5% level, confirming H2a. Third, LnTEC is significantly and negatively correlated with FDI inflows at the 10% level, confirming hypothesis H3b.

Regression Model

Considering the provincial differences and preventing potential endogeneity issues, this study used Stata 16.0 to build a fixed-effects model for regression testing, and the regression results are shown in Table 6 below.

In Model 1, the effect of IPR on LnTEC is significantly positive at the 1% level (see Table 6), i.e., IPR positively affects LnTEC, again confirming hypothesis 1. Since the regression coefficients of the independent variables are significant, mediating variables can be introduced (Baron & Kenny, 1986; Judd & Kenny, 2016; Liu et al., 2008). From the regression coefficient of control variables, improving education, increasing urbanization, and optimizing industrial structure help promote technological innovation. In Model 2, the regression coefficient of R&D investment is 1.932 (see Table 6), which means that increasing R&D investment can stimulate innovation and thus produce more high-quality invention patents, positively promoting technological innovation, and hypothesis H2b is verified. Model 3 represents the mediating role of R&D in the relationship between IPR and LnTEC, and the inclusion of the R&D input variable changes the IPR coefficient to 0.258, which is significant at the $p < 0.01$ level. Therefore, strengthening IPR protection intensity is expected to yield a friendly innovation environment and motivate each subject to increase R&D investment actively.

The more R&D investment, the more patent output, and the level of technological innovation also rises, and hypothesis H2 holds. The dependent variable of Models 7 and 8 is IPR. As seen in Model 8, the regression coefficient of FDI

Table 6 Regression model. Source: own research

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
	LnTEC						IPR	
C	−3.159	−1.177	−3.129	−1.110	−3.061	−3.144	9.221	7.616
IPR	0.257***		0.258***		0.256***	0.256***		
R&D		1.932	2.219				3.399	
FDI				−0.749	−0.692			−0.225
R&D × FDI						−38.766		
EDU	0.284	−2.160	0.216	−2.057	0.309	0.542	−3.173**	−9.239***
URB	11.463***	13.973***	11.324***	14.097***	11.4821***	11.545***	4.459***	10.209***
IND	2.256**	3.092***	2.259**	2.962***	2.144**	2.183**	4.458***	3.193***
Province & Year Fixed								
F	399.12	366.79	318.46	368.44	319.59	321.33	276.75	227.29
Adj R^2	0.9512	0.9476	0.9511	0.9478	0.9512	0.9515	0.8022	0.9175

NB: ***, **, and *signify $p < 0.01$; $p < 0.05$; $p < 0.1$

is − 0.225 (see Table 6), which means that strengthening IPR intensity reduces FDI inflows. Combined with Model 4, the large inflow of FDI also hurts the number of domestic invention patent applications. In Model 5, the regression coefficient of IPR decreases to 0.256 compared to Model 1, and the regression coefficient of FDI is − 0.692 (see Table 6). Therefore, it can be concluded that FDI plays a negative mediating role in the relationship, and IPR is positively promoting technological innovation, and hypothesis H3 is confirmed. Reasons for these results are that large numbers of FDI not based on transferring knowledge and technology are often invested in industries at the low end of the industrial chain, mainly energy and labor-intensive industries.

This kind of foreign capital inflow does not advance technology but causes enormous environmental pollution. As a result, the government had to invest numerous financial resources and formulate related environmental policies to combat pollution, and enterprises had to transfer part of the funds originally used for research and development experiments to compensate for the damage caused by the manufacturing process. The strict control of environmental laws and the reduction of R&D funds invariably set shackles on the development of the industry, and technological innovation is negatively affected. In addition, although FDI can bring more cutting-edge and advanced technologies and ideas by changing the competitive environment and driving the flow of R&D potential, the over-reliance on FDI in the country can also reduce the innovation capacity and pull down the innovation standard.

Furthermore, this study uses the number of domestic patent applications instead of invention patent applications as an indicator to measure the level of technological innovation. The results obtained are consistent with the earlier results obtained, and the findings still hold.

Table 7 Regression results are divided into three regions. Source: Own research

	Eastern			Central			Western		
Variable	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15
C	− 3.742	− 3.176	− 3.431	− 4.209	− 3.423	− 4.164	− 4.591	− 4.348	− 4.813
IPR	0.161	0.133	0.140	0.413***	0.259	0.374*	0.516***	0.436***	0.534***
R&D	20.8443			17.585			3.355		
FDI		− 1.256			− 3.428			2.002	
R&D × FDI			− 39.974			136.871			− 32.5
EDU	4.011	− 2.611	− 2.452	4.029	4.358	3.433	2.664	2.124	3.310
URB	− 6.812***	11.974***	12.177***	13.629***	17.090***	15.202***	3.276	4.302*	3.177*
IND	1.834	4.775***	4.746***	− 3.098*	− 3.508**	− 3.123	6.624***	7.099***	6.701***
F	25.75	122.84	123.07	164.64	153.73	150.08	93.83	98.60	94.17
Adj R^2	0.5162	0.9131	0.9132	0.9124	0.9402	0.9389	0.9504	0.9525	0.9505

NB: ***, **, and *signify $p < 0.01$; $p < 0.05$; $p < 0.1$

Heterogeneity Test

Considering the regional technology gap due to geographic location, this study further divided the sample into Eastern, Central, and Western regions for analysis. The results are shown in Table 7 below.

As shown in Table 7, the increase in IPR contributes to technological innovation, which is particularly significant in the Western region; R&D plays a positive mediating role in the relationship between IPR and positively contributing to technological innovation. In Model 8 and Model 11, the coefficient of FDI is negative, which indicates that FDI does not favor technological innovation in the eastern and central regions. In Model 14, the coefficient of FDI is 2.002, which suggests that in the Western region, the level of innovation is positively influenced by FDI. Therefore, it is necessary to expand the scale of investment in the western region to introduce advanced technology. It is also worth noting that the interaction coefficients of FDI and R&D are less than 0 in Models 6, 9, and 15, which means that the current FDI introduction and R&D investment in China are unbalanced and unreasonable. For regions that can achieve significant technological breakthroughs in the short term, R&D investment should be increased; however, for regions with complex development and backward technology, FDI introduction should be the focus of work, and the two should cooperate and coordinate to better serve the flourishing development of China's science and technology innovation.

Discussion

In this section, we delve into a detailed discussion of the findings derived from our study on the interplay between intellectual property rights (IPR) protection, research and development (R&D) investment, foreign direct investment (FDI) and their collective influence on technological innovation within the regional context of China. By examining these relationships, we aim to provide nuanced insights into the strategic implications of IPR frameworks for fostering innovation and economic growth.

Firstly, our analysis reveals a significant positive correlation between the increased intensity of IPR protection and domestic technological innovation, as evidenced by the surge in invention patent applications. This finding underscores the critical role of robust IPR frameworks in creating an environment conducive to innovation. Strengthening IPR enforcement emerges as a pivotal strategy for incentivizing firms to invest in R&D activities, thereby fostering a culture of innovation and knowledge creation. Drawing on the assertions of Chu et al. (2018), our findings reinforce the notion that stronger IPR protections are associated with higher levels of innovation. By providing legal safeguards for intellectual property, stringent IPR regimes not only incentivize firms to invest in innovation but also facilitate knowledge dissemination and technology transfer, driving sustained economic growth.

However, our study also uncovers a complex relationship between intensified IPR protection and FDI entry. Contrary to conventional wisdom suggesting that stringent IPR regimes attract more FDI by safeguarding intellectual property, our findings indicate a nuanced scenario within the Chinese context. Heightened IPR protection

acts as a double-edged sword, deterring FDI entry while simultaneously fostering domestic innovation. This finding challenges prior perspectives, such as those posited by Campi and Dueñas (2019), which suggested a direct positive correlation between stringent IPR regimes and FDI attraction. Instead, our analysis underscores the need for policymakers to strike a delicate balance between reinforcing IPR enforcement and attracting foreign investment.

Furthermore, our study highlights the mediating role of FDI in the relationship between IPR protection intensity and technological innovation. While intensified IPR protection fosters domestic innovation, the influx of FDI tends to mitigate this positive impact. This suggests a trade-off between strengthening IPR frameworks and leveraging foreign investment for innovation-driven growth. Contrary to the findings of Cai et al. (2019), which suggested a positive impact of FDI on R&D efforts in host countries, our analysis unveils a nuanced dynamic within the Chinese context. The adverse interaction between FDI and R&D investment underscores the challenges of aligning foreign investment strategies with local innovation agendas.

Notably, our study highlights regional disparities in China's innovation ecosystem, with the Western region exhibiting a more pronounced effect of FDI compared to the Eastern and Central regions. This geographical dimension adds depth to our understanding of how regional characteristics influence the effectiveness of FDI in stimulating innovation. By pinpointing specific regional sensitivities to FDI within the context of IPR protection strategies, our findings contribute valuable insights to regional innovation system theory. Policymakers can leverage this knowledge to tailor targeted interventions aimed at promoting inclusive innovation across all regions of China (Wang et al., 2021).

In essence, our discussion underscores the intricate dynamics at play in strategizing IPR frameworks for enhanced innovation within China's regional context. By recognizing the multifaceted nature of these relationships, policymakers can devise informed strategies to foster a vibrant innovation ecosystem that drives sustainable economic growth.

Conclusion and Suggestions

The study's examination of intellectual property rights (IPR) protection, research and development (R&D) investment, and foreign direct investment (FDI) within the regional context of China reveals several critical insights and strategic recommendations for policy and innovation management. These conclusions provide a basis for actionable strategies aimed at enhancing China's position in the global innovation landscape.

Firstly, the positive impact of IPR protection intensity on domestic technological innovation is a central finding, emphasizing the need for robust legal frameworks that not only protect intellectual properties but also encourage investment in innovation. China's progress in refining its IPR laws should continue with a focus on enforcement and compliance, ensuring that innovations are safeguarded, which in turn incentivizes further R&D activities. Learning from the effective

practices of regions like the Yangtze River Delta can provide valuable strategies for nationwide implementation.

Secondly, while increased IPR protection can deter FDI entry, our findings highlight the importance of nuanced policy frameworks that can balance the dual goals of attracting FDI and boosting domestic innovation. Policies should aim to attract high-quality FDI that complements domestic technological capabilities and contributes positively to the national innovation system. This involves not only refining the IPR regime but also improving other business environment factors that make China an attractive destination for foreign investors.

Furthermore, the study reveals the negative interaction between FDI and R&D in influencing the number of invention patent applications, suggesting that FDI does not always correlate with an increase in domestic innovation capabilities. It is crucial for policymakers to understand the conditions under which FDI can be beneficial and to craft policies that align foreign investments with local R&D activities, thus mitigating any adverse effects on domestic innovation. The pronounced regional disparities in how FDI influences innovation suggest the need for regional-specific strategies. Authorities should consider initiatives that encourage the redistribution of high-tech industries and talent to less developed areas, particularly the Western region, to help bridge the gap in innovation capabilities across China. Such strategies could include financial incentives, infrastructural improvements, and targeted educational programs to cultivate local talent.

Lastly, to ensure the continuity of innovation and its benefits to the economy, China needs to invest in cultivating a generation of high-tech talents who can drive future innovations. This involves not only providing educational opportunities but also creating an ecosystem that supports the commercialization of innovations and the transformation of scientific achievements into marketable solutions.

In conclusion, while China has made significant strides in improving its IPR protection and fostering innovation, there remains a complex interplay between IPR, FDI, and R&D that requires careful policy consideration. By addressing these dynamics thoughtfully, China can enhance its technological innovation capacity and strengthen its position as a leader in the global knowledge economy.

Acknowledgements This study was supported by the Key Research Base of Universities in Jiangsu Province for Philosophy and Social Science "Research Center for Green Development and Environmental Governance."

Author Contribution Conceptualization and acquisition of data: Mingxing Li, Xiaomeng Chi; study design: Hongzheng Sun, Mengjuan Zhang; analysis and interpretation: Saifullah; writing and reviewing: Fredrick Oteng Agyeman.

Funding This study is financed by the National Natural Science Foundation of China (72174076 and 71974081).

Data Availability Data for the study is available and will be supplied upon request.

Declarations

Conflict of Interest The authors declare no competing interests.

Ethical Approval Not applicable.

References

Al-kalouti, J., Kumar, V., Kumar, N., Garza-Reyes, J. A., Upadhyay, A., & Zwiegelaar, J. B. (2020). Investigating innovation capability and organizational performance in service firms. *Strategic Change, 29*(1), 103–113. https://doi.org/10.1002/jsc.2314

Androschuk, G. (2021). Global innovation index 2020: Who will finance innovations. *Law and innovations, 1*(33), 7–13. https://doi.org/10.37772/2518-1718-2021-1(33)-1

Appelbaum, R. P., Cao, C., Han, X., Parker, R., & Simon, D. (2018). *Innovation in China: Challenging the global science and technology system*. John Wiley & Sons.

Arora, A., Fosfuri, A., & Gambardella, A. (2008). Markets for technology in the knowledge economy. *International Social Science Journal, 54*(171), 115–128. https://doi.org/10.1111/1468-2451.00363

Arrow, K. (1962). Economic welfare and the allocation of resources for invention. *National Bureau of Economic Research*. http://www.nber.org/chapters/c2144

Azembila, A. B., Ma, Z., Li, M., Aganda, A. O., Amowine, N., & Hu, W. (2020). Assessing the asymmetric linkages between foreign direct investments and indigenous innovation in developing countries: A non-linear panel auto-regressive distributed lag approach. *South African Journal of Economic and management Sciences*, *23*(1). https://doi.org/10.4102/sajems.v23i1.3496

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*(6), 1173–1182. https://doi.org/10.1037//0022-3514.51.6.1173

Barrios, S., & Strobl, E. (2002). Foreign direct investment and productivity spillovers: Evidence from the Spanish experience. *Weltwirtschaftliches Archiv, 138*(3), 459–481. https://doi.org/10.1007/bf02707949

Brander, J. A., Cui, V., & Vertinsky, I. (2017). China and intellectual property rights: A challenge to the rule of law. *Journal of International Business Studies, 48*(7), 908–921. https://doi.org/10.1057/s41267-017-0087-7

Bruno, R. L., Crescenzi, R., Estrin, S., & Petralia, S. (2021). Multinationals, innovation, and institutional context: IPR protection and distance effects. *Journal of International Business Studies, 53*(9), 1945–1970. https://doi.org/10.1057/s41267-021-00452-z

Cai, H., Boateng, A., & Guney, Y. (2019). Host country institutions and firm-level R&D influences: An analysis of European Union FDI in China. *Research in International Business and Finance, 47*, 311–326. https://doi.org/10.1016/j.ribaf.2018.08.006

Campi, M., & Dueñas, M. (2019). Intellectual property rights, trade agreements, and international trade. *Research Policy, 48*(3), 531–545. https://doi.org/10.1016/j.respol.2018.09.011

Changyu, S. (2021). Upholding development of intellectual property with Chinese characteristics. *China National Intellectual Property Administration*. https://english.cnipa.gov.cn/art/2021/2/19/art_1340_156782.html

Chen, Y., Jiang, H., Liang, Y., & Pan, S. (2022). The impact of foreign direct investment on innovation: Evidence from patent filings and citations in China. *Journal of Comparative Economics, 50*(4), 917–945. https://doi.org/10.1016/j.jce.2022.05.005

Chu, A. C., Fan, H., Shen, G., & Zhang, X. (2018). Effects of international trade and intellectual property rights on innovation in China. *Journal of Macroeconomics, 57*, 110–121. https://doi.org/10.1016/j.jmacro.2018.05.003

De Massis, A., Di Minin, A., Marullo, C., Rovelli, P., Tensen, R., Carbone, A., & Crupi, A. (2020). How the "EU innovation champions" successfully absorbed and reacted to the shock caused by the COVID-19 pandemic. JRC Working Papers on Corporate R&D and Innovation. https://joint-research-centre.ec.europa.eu/publications/how-eu-innovation-champions-successfully-absorbed-and-reacted-shock-caused-covid-19-pandemic_en

Ding, L., & Xue, P. (2023). Incentives or disincentives? Intellectual property protection and FinTech innovation - Evidence from Chinese cities. *Finance Research Letters*, *58*. https://doi.org/10.1016/j.frl.2023.104451

Enkel, E., & Sagmeister, V. (2020). External corporate venturing modes as new way to develop dynamic capabilities. *Technovation*, *96–97*. https://doi.org/10.1016/j.technovation.2020.102128

Feng, W., & Li, J. (2021). International technology spillovers and innovation quality: Evidence from China. *Economic Analysis and Policy, 72*, 289–308. https://doi.org/10.1016/j.eap.2021.09.003

Feziwe, L. K., Abdultaofeek, A., Emmanuel, A., Israel, E. A., Bethel, M. M., & Vikash, J. (2021). Digital innovations for post-CoViD-19 pandemic recovery. *2021 International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems (icABCD)*, 1–6. https://doi.org/10.1109/icABCD51485.2021.9519378

Gmeiner, R., & Gmeiner, M. (2021). Encouraging domestic innovation by protecting foreign intellectual property. *International Review of Law and Economics*, *67*. https://doi.org/10.1016/j.irle.2021.106000

Guan, Y., Zhai, Z., Wang, Y., Wu, D., Yu, L., & Lei, Z. (2022). Foreign direct investment, environmental regulation, and haze pollution: Empirical evidence from China. *Environmental Science and Pollution Research, 29*(18), 27571–27584. https://doi.org/10.1007/s11356-021-17841-4

Gupta, A. (2001). Excelling in R&D. *Journal of Product Innovation Management, 18*(2), 123–124. https://doi.org/10.1016/s0737-6782(01)00082-0

Hasan, I., & Kobeissi, N. (2012). Innovations, intellectual protection rights and information technology: An empirical investigation in the MENA region. *Electronic Commerce Research, 12*(4), 455–484. https://doi.org/10.1007/s10660-012-9100-1

Hepburn, C., Qi, Y., Stern, N., Ward, B., Xie, C., & Zenghelis, D. (2021). Towards carbon neutrality and China's 14th five-year plan: Clean energy transition, sustainable urban development, and investment priorities. *Environmental Science Ecotechnology, 8*, 100130. https://doi.org/10.1016/j.ese.2021.100130

Holtzman, Y., & McManus, T. (2008). Innovation in research and development: Tool of strategic growth. *Journal of Management Development, 27*(10), 1037–1052. https://doi.org/10.1108/02621710810916295

Hossain, M. S. (2021). Merger & Acquisitions (M&As) as an important strategic vehicle in business: Thematic areas, research avenues & possible suggestions. *Journal of Economics and Business*, *116*. https://doi.org/10.1016/j.jeconbus.2021.106004

Huang, D., Zhong, S., Tang, J., & Zhao, J. (2021). Impact of foreign direct investment on the haze pollution in various cities: Evidence from China. *Growth and Change, 52*(4), 2016–2039. https://doi.org/10.1111/grow.12557

Hudson, J., & Minea, A. (2013). Innovation, intellectual property rights, and economic development: A unified empirical investigation. *World Development, 46*, 66–78. https://doi.org/10.1016/j.worlddev.2013.01.023

Hurmelinna-Laukkanen, P., Sainio, L., & Jauhiainen, T. (2008). Call for papers: Outsourcing R&D for efficient innovation. *R&D Management, 38*(2), 278–289. https://doi.org/10.1111/j.1467-9310.2008.00513.x

Jordaan, J. A. (2017). Producer firms, technology diffusion and spillovers to local suppliers: Examining the effects of foreign direct investment and the technology gap. *Environment and Planning a: Economy and Space, 49*(12), 2718–2738. https://doi.org/10.1177/0308518x17731942

Judd, C. M., & Kenny, D. A. (2016). Process analysis. *Evaluation Review, 5*(5), 602–619. https://doi.org/10.1177/0193841x8100500502

Klein, M. A. (2018). Foreign direct investment and collective intellectual property protection in developing countries. *Journal of Economic Behavior & Organization, 149*, 389–412. https://doi.org/10.1016/j.jebo.2018.01.008

Kowalski, A. M. (2020). Dynamics and factors of innovation gap between the European Union and China. *Journal of the Knowledge Economy, 12*(4), 1966–1981. https://doi.org/10.1007/s13132-020-00699-1

Lall, S. (2003). Indicators of the relative importance of IPRs in developing countries. *Research Policy, 32*(9), 1657–1680. https://doi.org/10.1016/s0048-7333(03)00046-5

Landoni, P., Dell'era, C., Frattini, F., Messeni Petruzzelli, A., Verganti, R., & Manelli, L. (2020). Business model innovation in cultural and creative industries: Insights from three leading mobile gaming firms. *Technovation*, *92–93*. https://doi.org/10.1016/j.technovation.2019.102084

Lee, M., Alba, J. D., & Park, D. (2018). Intellectual property rights, informal economy, and FDI into developing countries. *Journal of Policy Modeling, 40*(5), 1067–1081. https://doi.org/10.1016/j.jpolmod.2018.07.003

Levin, R. C., Cohen, W. M., & Mowery, D. C. (1985). R&D Appropriability, opportunity, and market structure: New evidence on some schumpeterian hypotheses. *The American Economic Review, 75*, 20–24.

Li, S., & Alon, I. (2019). China's intellectual property rights provocation: A political economy view. *Journal of International Business Policy, 3*(1), 60–72. https://doi.org/10.1057/s42214-019-00032-x

Lin, H., & Long, C. X. (2021). Do discretion criteria for patent administrative law enforcement encourage innovation among firms? *China Economic Quarterly International, 1*(2), 160–175. https://doi.org/10.1016/j.ceqi.2021.05.001

Lin, W. (2022). Automated infrastructure: COVID-19 and the shifting geographies of supply chain capitalism. *Progress in Human Geography, 46*(2), 463–483. https://doi.org/10.1177/03091325211038718

Liu, S., Du, J., Zhang, W., Tian, X., & Kou, G. (2021). Innovation quantity or quality? The role of political connections. *Emerging Markets Review*, *48*. https://doi.org/10.1016/j.ememar.2021.100819

Liu, Y., Lu, H., & Hu, J. (2008). IT capability as moderator between IT investment and firm performance. *Tsinghua Science and Technology, 13*(3), 329–336. https://doi.org/10.1016/s1007-0214(08)70053-1

Majeed, M. T., & Ahmad, E. (2007). FDI and exports in developing countries: Theory and evidence. *The Pakistan Development Review, 46*(4II), 735–750. https://doi.org/10.30541/v46i4IIpp.735-750

Mothe, C., & Nguyen-Thi, T. U. (2021). Does age diversity boost technological innovation? Exploring the moderating role of HR practices. *European Management Journal, 39*(6), 829–843. https://doi.org/10.1016/j.emj.2021.01.013

Mtar, K., & Belazreg, W. (2020). Causal nexus between innovation, financial development, and economic growth: The case of OECD countries. *Journal of the Knowledge Economy, 12*(1), 310–341. https://doi.org/10.1007/s13132-020-00628-2

Naseem, A., Spielman, D. J., & Omamo, S. W. (2010). Private-sector investment in R&D: A review of policy options to promote its growth in developing-country agriculture. *Agribusiness, 26*(1), 143–173. https://doi.org/10.1002/agr.20221

Noon, P., De Vita, G., & Appleyard, L. (2018). What do we know about the impact of intellectual property rights on the foreign direct investment location (country) choice? A review and research agenda. *Journal of Economic Surveys, 33*(2), 665–688. https://doi.org/10.1111/joes.12292

Piper, W. E., Ogrodniczuk, J. S., Lamarche, C., & Joyce, A. S. (2006). Use of the social relations model by group therapists: Application and commentary. *International Journal of Group Psychotherapy, 56*(2), 191–209. https://doi.org/10.1521/ijgp.2006.56.2.191

SÁIz, P., & Castro, R. (2017). Foreign direct investment and intellectual property rights international intangible assets in Spain over the long term. *Enterprise & Society*, *18*(4), 846–892. https://www.jstor.org/stable/26568140

Santoro, G., Bresciani, S., & Papa, A. (2020). Collaborative modes with cultural and creative industries and innovation performance: The moderating role of heterogeneous sources of knowledge and absorptive capacity. *Technovation*, *92–93*. https://doi.org/10.1016/j.technovation.2018.06.003

Savitskaya, I., Salmi, P., & Torkkeli, M. (2010). Barriers to open innovation: Case China. *Journal of Technology Management & Innovation, 5*(4), 10–21. https://doi.org/10.4067/s0718-27242010000400002

Steinbock, D. (2019). U.S.-China trade war and its global impacts. *China Quarterly of International Strategic Studies, 04*(04), 515–542. https://doi.org/10.1142/s2377740018500318

Tin, L. (2020). China's IP protection development is widely acknowledged. Lung Tin IP Attorneys. http://www.lungtin.com/Content/2020/03-02/1040021289.html

Tou, Y., Watanabe, C., & Neittaanmäki, P. (2020). Fusion of technology management and financing management - Amazon's transformative endeavor by orchestrating techno-financing systems. *Technology in Society*, *60*. https://doi.org/10.1016/j.techsoc.2019.101219

Tsai, K. H., & Wang, J. C. (2004). The R&D performance in Taiwan's electronics industry: A longitudinal examination. *R&D Management, 34*(2), 179–189. https://doi.org/10.1111/j.1467-9310.2004.00332.x

Wan, Q., Chen, J., Yao, Z., & Yuan, L. (2022). Preferential tax policy and R&D personnel flow for technological innovation efficiency of China's high-tech industry in an emerging economy. *Technological Forecasting and Social Change*, *174*. https://doi.org/10.1016/j.techfore.2021.121228

Wan, Q., Yuan, L., Yao, Z., & Xu, Y. (2021). Impact of intellectual property protection on the innovation efficiency in China's hi-tech industry. *Technology Analysis & Strategic Management, 35*(1), 107–122. https://doi.org/10.1080/09537325.2021.1968372

Wang, C. C., & Wu, A. (2016). Geographical FDI knowledge spillover and innovation of indigenous firms in China. *International Business Review, 25*(4), 895–906. https://doi.org/10.1016/j.ibusrev.2015.12.004

Wang, Y.-F., & Chen, Y.-J. (2017). The causes and economic consequences of patent litigation. *Asian Economic and Financial Review, 7*(11), 1123–1143. https://doi.org/10.18488/journal.aefr.2017.711.1123.1143

Wang, Y., Hu, H., & Zhang, L. (2021). Intellectual property rights protection, social network and new venture performance. *Management Review, 33*(3), 129–137. https://doi.org/10.6049/kjjbydc.2020010203

Xiao, Q.-L., Wang, Y., & Zhou, W.-X. (2021). Regional economic convergence in China: A comparative study of nighttime light and GDP. *Frontiers in Physics*, *9*. https://doi.org/10.3389/fphy.2021.525162

Xu, C., & Shan, X. (2008). Constructing of the index system and verification for the intensity of intellectual property protection in China. *Studies in Science of Science, 26*(4), 715–723.

Zhou, X., Cai, Z., Tan, K. H., Zhang, L., Du, J., & Song, M. (2021). Technological innovation and structural change for economic development in China as an emerging market. *Technological Forecasting and Social Change*, *167*. https://doi.org/10.1016/j.techfore.2021.120671

Authors and Affiliations

Xiaomeng Chi[1,4] · Mingxing Li[1,2] · Hongzheng Sun[1] · Saifullah[1] · Mengjuan Zhang[1,3] · Fredrick Oteng Agyeman[1]

✉ Saifullah
hakrosaifullah2@gmail.com

Xiaomeng Chi
2272210055@stmail.ujs.edu.cn

Mingxing Li
mingxingli6@ujs.edu.cn

Hongzheng Sun
2212010056@stmail.ujs.edu.cn

Mengjuan Zhang
mengjuan.zhang@cranfield.ac.uk

Fredrick Oteng Agyeman
freddrickotengagyeman2@gmail.com

[1] School of Management, Jiangsu University, Zhenjiang 212013, China

[2] Research Center for Green Development and Environmental Governance, Jiangsu University, Zhenjiang 212013, China

[3] Centre for Competitive Creation Design, Cranfield University, Bedfordshire MK43 0AL, UK

[4] Engineering Management, Jiangsu University Cranfield Tech Futures Graduate Institute, Zhenjiang 212013, China