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The impact of technological transformation on basic research results: The moderating effect of intellectual property protection

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A B S T R A C T

This study creatively investigates the strategic and substantive innovation transformation of basic research results from the perspective of intellectual property protection. Using Chinese provincial panel data from 2001 to 2018, the relevant empirical research findings are threefold. First, basic research results have a significant role in promoting strategic and substantive innovation, and the level of intellectual property protection has a significant regulatory role. Improved intellectual property protection will weaken the strategic innovation transformation of basic research results and strengthen substantive innovation transformation and a variety of robustness tests support these conclusions. Second, a regional heterogeneity test demonstrates that intellectual property protection has the most significant impact on the technological transformation of basic research results in the eastern region. Third, an industrial heterogeneity test indicates that intellectual property protection significantly enhances the substantive innovation transformation of high-tech enterprises, and the impact on general industrial enterprises is insignificant. The research findings provide a theoretical foundation and empirical evidence for China to improve its intellectual property protection system to facilitate basic research innovation transformation efficiency while comprehensively considering regional and industrial differentiation.

Introduction

A new round of technological revolution and industrial change has been accelerating in the contemporary era, and global economic competition is entering a stage which is dominated by scientific and technological innovation (Ferras-Hernandez & Nylund, 2019). Basic research drives the improvement of a country's independent and original innovation capabilities. China's basic research investment has continued to increase in recent years. According to statistics from the National Bureau of Statistics, the Ministry of Science and Technology and the Ministry of Finance, China's basic research funding in 2021 was 181.7 billion yuan, representing an increase of 23.9 % over the previous year and a 14.1 % growth rate from the previous year. Thanks to the nation's long-term emphasis on basic research, the results of China's basic research have been remarkable. A nation's output of high-quality scientific and technical papers is an important indicator of basic research results. According to *Statistical Data of Chinese S&T Papers* released by the Institute of Science and Technical Information of China, China ranked second in the world in 2019 in terms of the number of high-quality published international papers, the number of highly cited articles and the number of 'hot' papers. However, China's vast high-quality basic research results have not been effectively transformed into practical technologies to advance the technology revolution and industrial change. *The 2021 China Patent Survey Report* issued by the State Intellectual Property Office of China detailed the effective patent implementation rate (10.8 % for universities and 29.6 % for research institutes) and industrialisation rate (2.3 % for universities and 15.9 % for research institutes) of universities and research institutes, indicating a long-term state of marginal transformation of scientific and technological achievements. The purpose of patent applications is to manage the by-products of title and project evaluation rather than industrialise the results (Liu & Xia, 2018). Based on current international circumstances, scientific and technological innovation is the primary battlefield of international game strategy. Strengthening basic research around the country's major strategic needs and transforming it into original innovation capabilities to support innovation-driven development is an urgent need that must be addressed.

As an essential institutional arrangement for stimulating scientific and technological innovation, the impact of intellectual property

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protection on enhancing regional innovation capacities and promoting economic growth has received increasingly widespread research attention. Since the implementation of the *National Intellectual Property Strategy Outline* in 2008, intellectual property protection in China has improved significantly. Data from the China National Intellectual Property Administration show that first instance intellectual property cases in China reached 22000 in 2007 and increased to over 200000 in 2017, and the state's judicial crackdown on intellectual property infringement has increased substantially. Intellectual property protection has a positive impact on technological innovation (Yang, Xiao, & Jiang, 2023). One reason is that the intellectual property protection system can significantly reduce technological innovation subjects' risk. Establishing a complete legal system for intellectual property protection and strict law enforcement to protect the exclusive rights of creators of technological innovations within a certain period of time allows creators to obtain economic benefits and recover investments through transfer or production. Intellectual property protection can also guide the transformation of China's innovation model. In an environment with weak intellectual property protection, a country's independent technological innovation is primarily concentrated among a small number of large enterprises, while most small and medium-sized enterprises rely on imitating innovations from large enterprises' technology and foreign advanced technology to achieve technological upgrading, which slows a country's overall technological innovation and diminishes technological innovation efficiency. Considerable research has been conducted by domestic and foreign scholars regarding the incentive effect of intellectual property protection on technological innovation; however, the kind of incentive effect such protection and enforcement has at different stages of systematic innovation activities remains unclear.

The contributions of this study are in the following areas. First, this study creatively investigates the influencing factors of the technological transformation of basic research results from the perspective of intellectual property protection, explores the constraints to the technological transformation of basic research results from the perspective of institutional environment and analyses regional and industrial heterogeneity. Second, in contrast to previous research, this study categorises the transformation of technological achievements into substantive and strategic innovative technology transformation according to the level of innovation and examines the heterogeneous moderating role of by intellectual property protection at different innovation levels. Finally, this study proposes policy recommendations to promote the transformation of basic research results, arguing that government should increase legislative support, introduce supporting laws and policies and establish a consistent legal environment for the transformation of scientific and technological achievements.

In terms of the structure of the remainder of this paper, the Literature Review section introduces relevant literature regarding innovation theory in basic research and intellectual property protection. The Theories and Hypotheses section presents the study's three hypotheses. The Study Design section details the study's econometric model, data description and variable selection. The Empirical Results and Analysis section discusses the study's findings and implications. The Discussion section distils the contributions and limitations of the study. Finally, the conclusion summarises the findings and proposes future research directions.

Literature review

The research in this study has relevance to two strands of literature; one regarding the theory of innovation in basic research and the other concerning intellectual property protection.

Research on basic research

Existing theoretical literature regarding basic research innovation can be traced back to the linear model of innovation proposed by Bush (1945), which argued that innovation activity presents a linear trajectory formed by the flow of scientific knowledge in which subsequent stages are directly dependent on the research results of the previous steps. Basic research is the foundation of scientific and technological progress, providing resources and tools for producing new knowledge as well as a training ground for researchers in the industry. Bush's dichotomy between basic and applied research was considered to weaken the coherence between national strategic goals and basic science research. Stokes further investigated this issue, proposing Pasteur's quadrant innovation theory (Stokes, 1997), which integrated applied research goals into basic research and constituted a new model of application-oriented basic research. Basic research is at the forefront of the in-depth understanding of innovation and is significantly correlated with corporate research and development (R&D) activities (Lin, Lin, & Song, 2010; Akcigit, Hanley, & Serrano-Velarde, 2021). For instance, Cardamone, Pupo, and Ricotta (2015) found that basic research has significant spillover effects on innovation in manufacturing firms. From the perspective of geographical distance, Bikard and Marx (2020) further noted that basic research not only facilitates the flow of local knowledge, but also expands the scope of academic fields and influences innovative enterprises in distant regions. Basic research provides intellectual capital for technological innovation, which requires experimentation and development in a production process with a certain level of technology (Gersbach, Sorger, & Amon, 2018; Arora, Belenzon, Patacconi, & Suh, 2019). Scholars have continued to enrich the research perspectives regarding the effective integration of basic and applied research, and existing studies have argued that private research funding, responsible research business management and a collaborative system to introduce university research results into performance appraisal systems are essential to advancing the integration of basic research and applied research (Fan, Yang, & Yu, 2021; Kwon, Motohashi, & Ikeuchi, 2021; Siegel, 2022).

Numerous studies have been conducted to assess the economic performance of basic research results, demonstrating a significant impact of basic research on economic development. Prettner and Werner (2016) analysed the long- and short-term effects of basic research on economic growth and static comparative analysis modelling. The authors' results showed that basic research leads to a short-term decline in output growth and applied knowledge. Using panel data for 23 OECD countries over the period 1996–2010, Sun, Wang, and Li (2016) found applied research and experimental development to have a significant impact on short-term productivity growth, while the long-term effects of basic research were more pronounced. Examining panel data for 91 countries between 2003 and 2014, Laverde-Rojas and Correa (2019) determined that scientific productivity in basic science and engineering has a significant positive impact on the economic complexity of countries through university–industry–government interactions that stimulate innovation and business economic growth. Basic research is the primary source of technological progress. With the development of basic science and expedient strategic application of its achievements, economic development can achieve huge benefits (Bush, 1945; Nelson, 1959).

Research on intellectual property protection

The second strand of literature examines the influence of intellectual property protection on innovation activities from the perspective of adequate protection. First, this research has examined the measurement of intellectual property protection. Rapp and Rozek (1990) were the first scholars to quantitatively analyse intellectual property protection. Ginarte and Park (1997) improved on this approach, producing that GP index to examine patent protection and categorise the associated indicators into protection coverage, membership in international treaties, and protection of loss of rights, enforcement measures and duration of protection. The GP index effectively overcame the shortcomings of the Rapp and Rozek (1990) approach, becoming an internationally accepted indicator. Although China has a relatively complete legal system for intellectual property protection that is uniformly implemented throughout the country, legislation and law enforcement are not synchronised and the degrees of legal implementation related to intellectual property rights in different regions differ, resulting in uneven intellectual property protection in China (Ang, Cheng, & Wu, 2014; Fang, Lerner, & Wu, 2017). Therefore, scholars have proposed modifying the GP index by considering different dimensions of 'enforcement strength' (Lin, Lin, & Song, 2010; Liu, Mu, Hu, Wang, & Wang, 2018).

Considerable research has also been conducted regarding the impact of intellectual property protection on innovation activities. The internationalisation of enterprise R&D is an important approach for promoting innovation. Stronger intellectual property protection in a host country encourages more internationalised projects in enterprise R&D (Nasirov, Gokh, & Filippaios, 2022). In addition, strengthening intellectual property protection in developing countries will help attract investment from multinational companies and further drive technological innovation in developing countries through technology diffusion (Lai, 1998; Maskus & Penubarti, 1995). Intellectual property protection regimes promote innovation by protecting innovations from imitation and giving firms a temporary technological advantage. Liu, Mu, Hu, Wang, and Wang (2018) and Kanwar and Evenson (2003) argued that the non-competitive and non-exclusive nature of innovation allows intellectual property protection to promote technological innovation by facilitating investment in R&D. Some scholars have proposed a non-linear theory regarding the relationship between intellectual property protection and innovation quality, arguing that the effect between the two is an inverted U shape. Furukawa (2010) argued that there is threshold inflection point between intellectual property protection and innovation quality, in which an increased level of intellectual property protection to the left of the inflection point raises innovation quality, whereas overemphasised intellectual property protection inhibits innovation quality (Gangopadhyay & Mondal, 2012). Various factors can influence the impact of intellectual property protection on innovation. For example, China's intellectual property protection is relatively weak, and corporate legal knowledge regarding intellectual property protection is particularly crucial to advancing the impact of intellectual property rights on corporate innovation performance (Zhao, Tan, & Zhong, 2022) and different types of intellectual property rights also exert a differential impacts on corporate innovation (Teixeira & Ferreira, 2019; Grimaldi, Greco, & Cricelli, 2021).

The above review indicates that the existing literature has only examined the fundamental role of basic research in innovation activities and the economic benefits it can generate. According to endogenous economic growth theory, basic research itself cannot directly promote economic development and it must be transformed into technological innovation to achieve technological progress and drive economic development. In comparison, minimal research has focused on the technological transformation of basic research results. Furthermore, the existing literature lacks investigations which integrate intellectual property protection into the technical transformation of basic research results. The effect of intellectual property protection in systematic innovation activities remains unclear, and whether intellectual property protection can promote the technological transformation of basic research results in China requires further examination.

Theories and hypotheses

Analysis of the moderating effect of intellectual property protection on the technology translation of basic research

Linear and non-linear innovation models emphasise that innovation necessitates basic research as support, but improving original innovation capabilities not only requires a considerable investment in basic research, but it also requires the establishment of a mutually supporting legal and policy system. Intellectual property protection has a significant role in the transformation of basic research results as an important policy support for practical innovation. Basic research has the nature of a public good (Nelson, 1959; Arrow, 1962). The main body of basic research includes state-funded researchers whose research results are predominantly shared in the form of published scholarly articles, which, once published publicly can be referenced and used by others (Akcigit, Hanley, & Serrano-Velarde, 2021). As a result, the incentive mechanism that drives the researchers' motivation is the recognition of the priority of knowledge creation, and the subsequent recognition of peers. Notably, this dynamic indicates a lack of motivation for further technological transformation to monetise and obtain economic benefits through patented intellectual property rights. Furthermore, China's intellectual property protection system requires improvement. The technological transformation of basic research results requires considerable financial support, and a weak intellectual property protection system can lead to stolen technology for investment projects or competitors directly imitating innovations, which can discourage scientific researchers from transforming technological research results. In the long run, the technological transformation of China's basic research has entered a vicious circle, as researchers invest great effort to obtain basic research results and publish them in peer-reviewed papers as indicators of completed scientific research projects to obtain career promotion, tenure evaluations and scientific research funding, completing closed loop basic research and moving on to new rounds of basic research activities; however, a lack of follow-up technology transformation of basic research results remains. Therefore, strengthening China's intellectual property protection is expected to significantly stimulate the high-level technological transformation of basic research results, fully leverage the positive regulatory role of intellectual property protection in the process of high-tech transformation of basic research results and guide the scientific research incentive mechanism from the traditional single-track system of publishing papers to the dual-track system of reputational and intellectual property economic benefits. Demonstrating the thesis of this theory will improve the efficiency of technology transformation and the expedient application of basic research. Since patent grants require continued testing and annual fees, patentees decide whether to continue to pay annual fees to maintain patent rights or to cease payments, letting patent rights end according to the actual circumstances of the technical value of the patent and potential market benefits. The purpose of strategic innovation is more to cater to local government policies to obtain tax incentives and other benefits, rather than industrialisation, the level of innovation is low and strengthening intellectual property protection will cause the innovation subject to abandon low-yield strategic innovation to seek substantive innovation. Based on this, we propose H1.

H1. Basic research promotes technological innovation, and intellectual property protection has a heterogeneous regulatory influence on the strategic and substantive innovation transformation of basic research.

Analysis of the difference in the regulating effect of intellectual property protection

A significant gap between knowledge and talent pools is evident in different regions of China (Zhang & Bai, 2022), and regions' diverse industrial capabilities and uneven implementation of intellectual property protection causes intellectual property protection to have a heterogeneous regulatory role in the technological transformation of basic research results. The eastern region is highly developed economically, with a large concentration of universities and research institutes, and intensity of academic research can significantly increase the innovation spillover from universities to enterprises (Kantor & Whalley, 2014). Additionally, the talents cultivated by scientific research institutes flow to enterprises, enhancing the convergence of basic research results and enterprise innovation and promoting the technological transformation of basic research results (Davis & Dingel, 2019). Furthermore, in the stage of basic research transformation, regional industrialisation capacity and intellectual property protection also have significant regulatory roles. First, the technological transfer of regional basic research results must be combined with local industrial development to achieve economic benefits expediently (Meyer-Krahmer & Schmoch, 1998; Carayol & Matt, 2004). The strength of regional intellectual property protection also has a significant regulatory role. Although the same set of laws related to intellectual property protection apply across the Chinese mainland, due to widely differing economic, cultural and judicial environments and uneven intellectual property protection between regions, a significant trend of strong east and west weakness exists for intellectual property protection (Yang, Xiao, & Jiang, 2023). In summary, the eastern region has abundant basic research and innovation resources, strong industrialisation capabilities and a high-level intellectual property protection system, and the government can build an institutional bridge for intellectual property protection to help research results cross the valley of death and realise commercialisation and industrialisation. Therefore, under the positive regulation of intellectual property protection, the eastern region has a relatively efficient capability to transform basic research results and high technical level and the regulatory role of intellectual property protection gradually decreases in eastern, central and western regions.

Compared with industrial enterprises, high-tech enterprises[1] engage in higher investment in basic research, faster technological change and more radical innovation, and intellectual property protection has a more important role in the transformation of basic research achievements of high-tech enterprises. The essence of basic research transformation is the combination of scientific research and market demand, and a huge gap remains between public research institutions' R&D projects and the R&D needs of industry (Liu & White, 2001). Companies are in the utility-driven Pasteur's quadrant and therefore have a greater incentive to transfer technology for basic research. Chinese enterprises' low investment in basic research could lead to the transformation of inefficient basic research results, and long-standing intellectual property challenges have an important role in this. First, absorbing common knowledge created by other scientific research units for applied research or transforming basic research results generated within the enterprise itself requires knowledge absorption capacity and a solid knowledge reserve. Compared with industrial enterprises above the designated size, high-tech enterprises invest larger basic research expenditure, which enables them to understand basic external knowledge. Only when users are capable of understanding information can it be absorbed to stimulate innovation (Escribano, Fosfuri, & Tribó, 2009; Martinez-Senra, Quintas, Sartal, & Vazquez, 2015). As competition in high-tech industries intensifies, technological advancement accelerates. The first-mover advantage of leading technology in a short period of time is extremely likely to establish a monopoly advantage that is difficult for late-comer companies to achieve. Thus, intellectual property protection is particularly important for high-tech industries where high levels of investment in basic research aims to achieve technological advantage and monopoly status. Second, high-tech companies must conduct cutting-edge basic research internally, while also grasping increasingly diverse and advanced market needs externally. The Pasteur's quadrant proposed by Stokes (1997) differs from Bohr's quadrant of pure basic research and Edison's quadrant of pure applied research (Stokes, 1997), which reference a utility-driven basic research with a goal-oriented approach to advancing through basic research. Enterprises are the core subjects that combine the 'two skins' of science and technology and economy. However, the disclosure of a certain degree of details of patent applications and technology applications makes it difficult for enterprises to prevent competitors from violating intellectual property rights, and strengthening intellectual property protection reduces the risk of this infringement, increases the expected return of R&D investment and encourages enterprises to conduct independent basic research transformation and introduce basic research for technology transformation (Arrow, 1962). Finally, high-tech sectors are more prone to producing breakthrough innovation from individual firms than traditional industries, and intellectual property protection has a greater role in radical innovation (Nasirov, Gokh, & Filippaios, 2022). Improving the level of intellectual property protection in a country will significantly promote the efficiency of enterprises' basic research results transformation, this promotional effect has industrial heterogeneity and the effect on high-tech industries is more significant. The foundation of basic research achievements in high-tech industries is larger, the degree of market demand diversification is higher and technological sensitivity is stronger, which leads to a stronger positive adjustment effect of intellectual property protection on high-tech enterprises in the transformation of basic research technology. According to this, we propose H2 and H3.

H2. The moderating effect of intellectual property protection on the transformation of basic research achievements is heterogeneous and positively regulates the transformation of technological achievements in the eastern region.

H3. The regulating effect of intellectual property protection on the transformation of basic research achievements has industrial heterogeneity and positively regulates the transformation of technological achievements in high-tech industries.

Study design

Econometric model construction

This study first analyses the panel data conducting unit root, cointegration and fixed-effect tests. The Hausman results show that the p-value is less than 0.01, strongly rejecting the null hypothesis and a fixed-effect model is adopted. Therefore, to analyse the influencing factors of the technology transformation of basic research results, this study constructs the following econometric model:

$$Innovation_{it} = \beta_0 + \beta_1 BP_{it} + \beta_j Controls_{jit} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

where the subscripts i and t respectively represent the region and year, *Innovation* denotes the technological innovation in region i in year t, BR_{it} represents the basic research results in region i in year t and *Controls* is a set of control variables. This study uses a fixed-

[1] High-tech industries include pharmaceutical, electronics and communications equipment, computer and office equipment, medical equipment and instrumentation and information chemicals manufacturing, with technological innovation as a core feature of all five industries. Regarding industrial enterprises, in 1998, the National Bureau of Statistics divided the scope of industrial statistics into above- and below-scale. Industrial enterprises above designated size, in 1998–2006, referred to all state-owned and non-state-owned industrial legal person units with main annual business income of 5 million yuan or more. From 2007 to 2010, the statistical scope was adjusted to industrial legal entities with main annual business income of 5 million yuan and above. Since 2011, the statistical scope has been industrial legal entities with main annual business income of 20 million yuan and above.

effects model, passing the Hausman test. μ_i represents unobserved factors that do not vary over time, δ_t controls for time fixed effects and ε_{it} is a random disturbance term.

To further examine whether intellectual property protection has a significant moderating role in the technological transformation of basic research results we reference Wen, Chang, Hau, and Liu (2004) and Wen, Hau, and Chang (2005) to construct the moderating effect models. The study introduces the level of regional intellectual property protection (IPR_{it}) and the cross-product term between primary research results and intellectual property protection ($BR_{it} \times IPR_{it}$) based on Eq. (1), to explore the moderating role of IP protection as follows:

$$Innovation_{it} = \beta_0 + \beta_1 BR_{it} + \beta_2 IPR_{it} + \beta_3 BR_{it} \times IPR_{it} + \beta_j Controls_{jit} + \mu_i + \delta_t + \varepsilon_{it} \quad (2)$$

By determining the coefficient β_1 in the empirical results of Eq. (1), we can test whether basic research results can promote technological innovation in China to realise the technological transformation of basic research results. By determining the regression coefficient of Eq. (2), the effect of basic research results on technological innovation is obtained by $\beta_1 + \beta_3 IPR_{it}$, where the coefficient β_3 of the cross-product term measures the size of the moderating impact of intellectual property protection. If the estimated result β_3 is significantly positive, this indicates that increasing the level of intellectual property protection facilitates the technological transformation of basic research results. In contrast, if the estimated β_3 outcome is significantly negative, it indicates that increasing intellectual property protection inhibits the technological transformation of basic research results.

Data description and variable selection

Explained variables

To quantify technological innovation ($Innovation_{it}$), existing studies have generally adopted the number of patents as a measure of regional innovation performance (Chen, Liu, & Ge, 2021). As the number of patent applications lag, the number of patents granted better ensures the quality of technological innovation; thus, this study uses the number of regional patents granted as a proxy variable for technological innovation (Hagedoorn & Cloodt, 2003). To mitigate the impact of differences in population size in different provinces on the measurement of basic research results, population size is used for standardisation to eliminate scale effects. In addition, considering that some innovations are generated in response to national innovation subsidy policies (Chen, Liu, Suárez Serrato, & Xu, 2021), technological innovation is divided into strategic ($Strategy_{it}$) and substantive ($Substant_{it}$) forms. Strategic innovation caters to government policies by releasing innovation signals and is realised in the form of minor, low-technology level innovation, which is measured by the number of utility model and design patents. In contrast, substantial innovation drives technological progress and represents high-tech level innovation, which is measured by the number of invention patents.

Core explanatory variables

Regarding the indicators of primary research results (BR_{it}), existing studies have generally chosen fundamental research R&D funding investment to measure regional basic research intensity (Sun, Wang, & Li, 2016). As an R&D activity requiring high investment, R&D capital investment can enhance the level of regional basic research to a certain extent. However, due to the long cycle of basic research, no synchronisation exists between R&D investment and the output of basic research results. This study examines the technological transformation of basic research results and published scientific and technical articles are the main output form of basic research results. As basic public knowledge, academic research is a significant contributor to technological innovation (Mansfield, 1991). Therefore, this study adopts the number of scientific and technical articles included in regional SCI, EI and CPCI-S search tools as the metric of basic research results, which is standardised to regions' population size.

Moderating variables

Intellectual property protection (IPR_{it}): the GP index proposed by Ginarte and Park (1997) is the mainstream measurement index for existing research on intellectual property protection. However, the GP index does not include the strength of intellectual property enforcement in its considerations. Park (2008) asserted that the GP index evaluates the strength of a country's intellectual property protection. Drawing on existing research by domestic scholars, this study introduces regional intellectual property enforcement strength to the GP index and measures the level of intellectual property protection in each region of China. Since China joined the WTO in 2001, the nation established a set of intellectual property protection systems in alignment with international standards, implementing the amended *Patent Law of the People's Republic of China*, this study selects data from 2001 to 2018 to measure the level of intellectual property protection. The specific method is as follows:

$$IPR_{it} = F_{it} \times GP_t \quad (3)$$

where IPR_{it} represents the level of intellectual property protection in year t in region i, F_{it} represents the intellectual property enforcement strength in region i in year t and GP_t represents the GP index in year t, as proposed by Ginarte and Park (1997). For the F_{it} of law enforcement in various regions, this study draws on and expands the measurement of law enforcement strength from the following three aspects (Lin, Lin, & Song, 2010; Liu, Mu, Hu, Wang, & Wang, 2018). First, the level of social legalisation, which is measured by the proportion of lawyers in the region. Second, the efficiency of government enforcement, which is measured by the settlement rate of patent infringement cases. Third, infringement acceptance outcomes, which are measured by the 1−patent infringement rate (i.e. one minus the number of patent infringement disputes accepted by a provincial intellectual property office in the year divided by the cumulative number of patents granted in the province up to that year). The extreme value standardisation method is also used to standardise each index in a dimensionless way to facilitate appropriate data comparison.

Control variables

R&D personnel input (H). R&D personnel investment is a crucial factor in promoting technological innovation (Griffith, Redding, & Reenen, 2004). Basic research and its practical technology translation is a systematic innovation activity. Compared with applied research and experimental development, basic research requires training and investment in a large number of highly skilled R&D personnel to advance original innovation, and the US National Science Foundation (NSF) references personnel training as an important indicator when assessing the performance of basic research projects. Based on this, this study selects the number of R&D personnel in the region as measurement (Griffith, Redding, & Reenen, 2004), standardising it for population size.

R&D capital investment (RD). Basic research activities have a long development cycle and require specialised laboratories and precision research equipment and is an innovation activity that requires considerable capital investment. Bush (1945) demonstrated that government investment in basic research could lead to significant technological innovation, persuading the US government to establish the NSF. Nelson (1959) and Arrow (1962) argued that the output of basic research is a public good and therefore prone to risk and market failure; thus, basic research must be funded by the government. Therefore, this study uses the ratio of regional fiscal expenditure to GDP to measure R&D investment.

Technology trading (Trad). The technology trading market is closely related to technological innovation and represents an important market factor. A sound technology trading market can coordinate technology supply and demand and promote the circulation and application of intellectual property rights (Hayter, Rasmussen, & Rooksby, 2020). In this study, the proportion of technology market turnover in each region to local GDP is selected to measure the level of technology transactions (Hayter, Rasmussen, & Rooksby, 2020).

Economic development (GDP). According to existing research, heterogeneous innovation activities should be used to achieve technological progress at different levels of economic development (Acemoglu, Aghion, & Zilibotti, 2006). Developed regions are close to the frontier of technology; thus, basic research and its transformation should be emphasised, while the technological level of less developed regions is generally low, and absorption of technology diffusion should be the primary approach for advancing technological progress. This study references Acemoglu, Aghion, and Zilibotti (2006), using regional per capita GDP as a measure of regional economic development.

Description of the data time window

The data in this study covers the period from 2001 to 2018 for several reasons. First, China joined the WTO in 2001 and subsequently established a system of intellectual property protection in alignment with international standards, implementing the amended *Patent Law of the People's Republic of China* in July 2001; thus, it is of considerable practical importance to select 2001 as the starting point for the data. Second, China's intellectual property protection efficiency suffered a serious setback in 2018 with the outbreak of the China–US trade war. Furthermore, following the outbreak of COVID-19, China resolutely and decisively adopted a series of protective public health measures, including closing cities, suspending work and production and other provisions, to effectively curb the pandemic's spread. Objectively, these actions also led to a relative slowdown in China's technological innovation. Pandemic prevention policy was strictly implemented for three years, and was only fully liberalised in 2022; thus, activities such as patent applications in 2019 and beyond will undoubtedly be lower than in previous years. Therefore, to comprehensively consider realistic factors, timeliness is abandoned, and 2018 is referenced as the end point of the data window in this study to improve the credibility of the empirical results.

Descriptive statistics

The data on the number of regional patents granted and published articles are obtained from *China Statistical Yearbook on Science and Technology*. The data for the measurement of intellectual property protection enforcement are obtained from the *Law Yearbook of China*, the *China Social Statistics Yearbook* and the China Intellectual Property Protection Bureau. The number of lawyers per province was not published in the *China Lawyers Yearbook* in 2008, 2009 and 2012, and this study completes the data using interpolation. The remaining data are obtained from the *China Statistical Yearbook*, the *China Statistical Yearbook on Science and Technology*, the *Educational Statistics Yearbook of China*, the EPSDATA database and various regional statistical yearbooks. Because of severe missing data on Tibet, this region is excluded from the measurement. A descriptive statistical analysis of the study's variables is presented in Table 1.

Table 1 shows that the mean value of strategic innovation is 4.527, which is much higher than the average value of substantive innovation of 0.92, indicating that the phenomenon of pursuing quantity while ignoring quality is widespread, and the standard deviation of strategic innovation (7.115) is also much greater than that of substantive innovation (2.152), indicating that the level of strategic innovation varies considerably across different regions. Similarly, the mean value of regional basic research is 2.966, the standard deviation is 6.094, the minimum value is 0.015 and the maximum value is 52.93, demonstrating that investment in basic research also varies widely across regions. The average value of intellectual property protection enforcement intensity in each region is 2.634, the standard deviation is 0.437, the minimum value is 0.434 and the maximum value is 4.09, also indicating that the level of intellectual property protection varies considerably across provinces. The analysis of the control variables is not repeated.

Table 1
Descriptive statistics of variables.

Variables	Sample size	Mean	SD	Minimum	Maximum
Innovation	540	5.447	8.775	0.13	57.333
Strategy	540	4.527	7.115	0.091	43.938
Substant	540	0.920	2.152	0.007	21.810
BR	540	2.966	6.094	0.015	52.930
IPR	540	2.634	0.437	0.434	4.090
H	540	0.285	0.317	0.017	2.396
RD	540	0.205	0.094	0.077	0.627
Trad	540	0.101	0.209	0.001	1.602
GDP	540	3.416	2.587	0.300	15.309

Empirical results and analysis

Baseline regression analysis

The results of the study's baseline regressions are presented in Table 2. In column (1), the coefficient estimate of BR is 1.337 and is significant at the 1 % level, indicating that increasing the output of basic research results significantly improves the level of regional technological innovation. In columns (4) and (5), the coefficient estimates of BR for strategic and substantial innovations are 0.813 and 0.524, respectively, which pass the 1 % significance test. This indicates that for every 1 % increase in regional basic research results, regional strategic and substantive innovation increase by 0.813 and 0.524, respectively, and a higher amount of basic research results generates increased technological innovation. Basic research results have a strong role in promoting the transformation of low- and high-level innovation. The coefficients of BR are improved after adding a set of control variables to columns (2), (5) and (8), and all the coefficient estimates of BR are significant at the 1 % level except column (5), which passes the 10 % significance level test. This once again confirms the fundamental position of basic research in the innovation system, which constitutes the cognitive starting point of scientific development and technological progress and is the source of knowledge for all technological innovation. China has become the frontier of science and technology in some fields, entering a 'no man's land', which cannot be transformed based on existing foreign basic research results.

Further examining the moderating effect of intellectual property protection on the technological transformation of basic research, the estimated coefficient of the cross-product term (BR $\times$ IPR) in column (3) is insignificant. A possible rationale for this phenomenon is that technological innovations are divided into strategic and substantive categories, and intellectual property protection exerts differential moderating effects on heterogeneous innovations. Considering the estimated coefficients of BR $\times$ IPR in columns (6) and (9) reveals that the estimated coefficient of strategic innovation is significantly negative at the 1 % level, while the estimated coefficient of substantive innovation is significantly positive at the 1 % level, indicating that strengthening intellectual property protection weakens the positive

Table 2
Moderating effect of technology transfer of basic research results and intellectual property protection.

Variables	(1) Innovation	(2) Innovation	(3) Innovation	(4) Strategy	(5) Strategy	(6) Strategy	(7) Substant	(8) Substant	(9) Substant
BR	1.337***	0.659***	1.045**	0.813***	0.194*	1.163**	0.524***	0.466***	−0.118
	(18.485)	(5.355)	(2.033)	(12.174)	(1.712)	(2.476)	(47.740)	(21.695)	(−1.384)
IPR			0.648			0.866*			−0.218**
			(1.129)			(1.652)			(−2.294)
BR × IPR			−0.094			−0.234**			0.140***
			(−0.786)			(−2.145)			(7.071)
H		5.317***	5.000***		6.095***	5.152***		−0.778***	−0.153
		(3.671)	(3.212)		(4.582)	(3.623)		(−3.080)	(−0.591)
RD		−7.679	−6.415		−8.228	−5.598		0.549	−0.817
		(−1.375)	(−1.124)		(−1.604)	(−1.074)		(0.563)	(−0.862)
Trad		4.909	4.337		5.598**	3.897		−0.689	0.440
		(1.625)	(1.359)		(2.018)	(1.336)		(−1.309)	(0.831)
GDP		2.920***	2.895***		2.622***	5.184		0.298***	0.303***
		(11.142)	(10.997)		(10.893)	(23.546)		(6.525)	(6.943)
_cons	−0.150	−3.276***	−5.008**	0.169	−2.927***	−5.259***	−0.320***	−0.350*	0.251
	(−0.217)	(−2.694)	(−2.569)	(0.265)	(−2.620)	(−2.952)	(−3.047)	(−1.650)	(0.774)
Individual Fixed	fixed	fixed	fixed	fixed	fixed	fixed	fixed	fixed	Fixed
Time Fixed	fixed	fixed	fixed	fixed	fixed	fixed	fixed	fixed	Fixed
R^2	0.6840	0.7871	0.7878	0.5895	0.7263	0.7299	0.8753	0.8890	0.8998
N	540	540	540	540	540	540	540	540	540

Note: ***, ** and * represent significance at 1 %, 5 % and 10 % levels, respectively; t-values are in parentheses.

correlation between basic research results and strategic innovation and strengthens the positive correlation between basic research results and substantive innovation. The intent of strategic innovation is generally to meet local government policies to obtain tax incentives (Chen, Liu, Suárez Serrato, & Xu, 2021) rather than industrialising or marketising innovations, which results in generally low economic benefits, considering that granting patents requires testing and annual payments. It is challenging to motivate innovation agents engaged in low level of technological innovation to apply for patents under a more robust level of intellectual property protection. In contrast, innovation agents engaged in substantive innovation often achieve substantial economic benefits during the period of patent exclusivity. Stronger intellectual property protection will significantly increase agents' monopoly income and mitigate the annual patent fee, thus incentivising innovation agents to conduct high-tech basic research technology transformation, which will improve the level of regional intellectual property protection. This can help discourage innovation agents from releasing false innovation signals to cater to government policies and will help guide the technological transformation of basic research results to substantial innovation at a high-tech level. With the combined effects, a high level of intellectual property protection will strengthen a region's overall innovation capacity. These findings verify the hypothesis H1, confirming that basic research significantly promotes the transformation of technological achievements, intellectual property protection has a heterogeneous regulatory role and strengthened intellectual property protection weakens the positive correlation between basic research results and strategic innovation and strengthens the positive correlation between basic research results and substantive innovation.

Regional heterogeneity analysis

China's regional development is currently uncoordinated, and there are significant differences in basic research capabilities, economic development and intellectual property protection in eastern, central and western regions. A combination of various factors may lead to regional heterogeneity in the moderating effect of intellectual property protection. This study analyses the regional heterogeneity of the moderating impact of intellectual property protection for two types of technological innovation. The intersection item BR × IPR in column (1) and column (2) in Table 3 reveals that the estimated coefficient of strategic innovation in the eastern region is significantly negative at the 5 % level, and the estimated coefficient of substantive innovation is significantly positive at the 5 % level, which is basically consistent with the baseline research conclusions. As for the findings for central and western regions, although the sign of the estimated coefficient is consistent with that in the eastern region, the significance level does not pass the 10 % significance test and the significance level is low.

This demonstrates significant stepwise regional heterogeneity in the moderating effect of intellectual property protection on the transformation of basic research achievements, indicating that strengthening intellectual property protection will weaken strategic technological innovation transformation of basic research achievements in the eastern region and strengthen substantive technological innovation transformation basic research achievements. However, no significant effect is found in the central and western regions. Once again, this suggests significant stepwise regional heterogeneity in the moderating effect of intellectual property protection on the transformation of basic research results. The reason that intellectual property protection significantly inhibits the transformation of strategic innovation of basic research results in the eastern region could be that after the establishment of the intellectual property protection system, the cost of hiring professional lawyers to seek judicial or administrative protection is relatively high (Sey, Lowe, & Poole, 2010) and compared with substantive innovation with high innovation content and high economic returns after commercialisation, enterprises are willing to appropriately abandon strategic innovations with low economic returns. Among the reasons that intellectual property protection strengthens the positive relationship between basic research results and substantive innovation in the eastern region, the eastern region has a relatively high level of economic development, sufficient funds to support basic research activities and a higher level of basic research results. At the same time, the agglomeration of scientific research institutes, universities and enterprises in the eastern region is conducive to the agglomeration of innovation resources (Guo, Jiang, Xu, & Yang, 2023), and the strong intellectual property protection system further enhances the efficiency of using innovation resources. Furthermore, the large number of research institutes, universities and enterprises in the eastern region nurtures a large population of innovative talents, and the exchange and mobility of talents amplifies the public knowledge pool effect and promotes the transformation of basic research results. Second, the eastern region hosts a considerable number of high-tech industries, and collaborative industry–university–research innovation effectively realises the

Table 3
Regional heterogeneity in the moderating effect of intellectual property protection.

Variables	East		Central		West	
	(1) Strategy	(2) Substant	(3) Strategy	(4) Substant	(5) Strategy	(6) Substant
BR	1.874**	0.077	0.043	0.079	1.283***	0.141**
	(2.024)	(0.434)	(0.050)	(0.404)	(2.726)	(2.043)
IPR	2.870	−0.456	1.152***	−0.123	0.287	0.003
	(1.628)	(−1.343)	(2.798)	(−1.317)	(1.359)	(0.101)
BR × IPR	−0.495**	0.087**	−0.135	0.027	−0.027	0.035
	(−2.377)	(2.160)	(−0.493)	(0.443)	(−0.166)	(1.486)
H	5.861**	−0.349	16.280***	2.457***	5.117*	0.696*
	(2.494)	(−0.771)	(7.350)	(4.911)	(1.835)	(1.709)
RD	−34.731**	−2.756	−5.278	−8.441***	1.608	−0.711**
	(−1.980)	(−0.816)	(−0.581)	(−4.110)	(0.715)	(−2.164)
Trad	14.049**	1.103	7.392***	2.463***	−6.554***	−0.349
	(2.382)	(0.971)	(2.789)	(4.113)	(−4.311)	(−1.570)
GDP	2.360***	0.308***	0.187	−0.280***	0.121	0.014
	(4.492)	(3.041)	(0.406)	(−2.695)	(0.806)	(0.645)
_cons	−11.393**	0.678	−5.325***	0.949***	−1.656	0.007
	(−2.108)	(0.651)	(−3.368)	(2.658)	(−1.540)	(0.042)
Individual fixed	fixed	Fixed	fixed	fixed	fixed	fixed
Time fixed	fixed	Fixed	fixed	fixed	fixed	fixed
R^2	0.8051	0.9235	0.8940	0.8792	0.8630	0.9217
N	198	198	144	144	198	198

Note: ***, ** and * represent significance at 1 %, 5 % and 10 % levels, respectively; t-values are in parentheses.

complementary advantages of innovation subjects, causing the eastern region to have a higher conversion rate of basic research results. Strong local industrialisation can quickly realise economic benefits, and a relatively high level of local intellectual property protection can better protect innovations. Notably, intellectual property protection has no significant impact on the technological transformation of basic research results in central and western regions. A possible rationale for this is that it is not intellectual property protection that restricts the technological transformation of basic research results in the central and western regions. Enterprises are the primary driver of innovation. *The National Enterprise Innovation Survey Yearbook 2019* shows that the proportion of enterprises that achieve innovation in China decreases on the order of eastern, central and western regions. Advancing innovation in central and western regions may require related support policies and other aspects to clear obstacles for enterprise innovation. The empirical results verify hypothesis H2, confirming that the moderating effect of intellectual property protection on the transformation of basic research results has noteworthy regional heterogeneity. Specifically, intellectual property protection has a significant positive regulatory effect on strategic and substantive innovation in the eastern region but exerts no significant impact on central and western regions.

Industry heterogeneity analysis

Basic research has different effects on heterogeneous industries, particularly on technology-intensive enterprises. Previous research has concluded that basic research makes a long-term contribution to industrial total factor productivity (Sun, Wang, & Li, 2016), while a comprehensive policy portfolio of government basic research has a significant influence on promoting innovation in high-tech industries (Yi, Murphree, Meng, & Li, 2021). However, comparative analyses of the role of basic research in high-level and high-tech industries and the moderating role of intellectual property protection in the transformation of results between industries are lacking. To address the lack of research, this study conducts an industrial heterogeneity analysis. The estimated coefficients of BR in columns (1) and (3) in Table 4 both pass the 1 % significance level test, at 0.295 and 0.220, respectively, indicating that for every 1 % increase in regional basic research achievements, high-level and high-tech industrial enterprises' technological innovation will respectively increase by 0.295 and 0.220. This shows that increased basic research results will enhance the high-level technological transformation of industrial enterprises and high-tech industrial enterprises. The cross-product item BR × IPR in Table 4 shows that the estimated coefficient of column (2) did not pass the 10 % significance level, indicating that the level of intellectual property protection has no significant moderating effect on the basic research technology transformation of industrial enterprises. In contrast, the estimated coefficient of the cross-product item in column (4) is significantly positive at the 5 % significance level, indicating that strengthened intellectual property protection will raise the positive correlation between the basic research achievements and substantive innovation in high-tech industrial enterprises. These findings demonstrate industrial heterogeneity in the high-level technological transformation of basic research results, indicating that intellectual property protection only strengthens the positive correlation between basic research results and substantive innovation in high-tech industries. The most important characteristic of high-tech industries is that technological innovation is a core business component, and original innovation is the fundamental driver of high-tech industry development (Yap & Rasiah, 2017). Compared with traditional industrial enterprises, high-tech industries have a richer pool of basic research results, and long-term investment in basic research establishes strong capabilities to absorb external knowledge, resulting in certain advantages in independently transforming basic research results and applying common knowledge. High-tech enterprises are also at the forefront of market demand and have a greater incentive to conduct applied research in response to diverse market needs to generate greater economic returns. Therefore, demand for the transformation of basic research results is stronger, and high-level intellectual property protection further strengthens high-tech industrial enterprises' technological transformation practices. This empirical result verifies hypothesis H3, confirming that the moderating effect of intellectual property protection on the transformation of basic research results has significant industrial heterogeneity. Specifically, intellectual property protection has a significant positive regulatory effect on the substantive innovation of high-tech industrial enterprises but no significant impact on the substantive innovation of industrial enterprises on regulations.

Table 4
Industry heterogeneity in the moderating effect of intellectual property protection.

Variables	Enterprise above designated size		High-tech industry enterprises	
	(1) Substant	(2) Substant	(3) Substant	(4) Substant
BR	0.295***	0.494	0.220***	−0.270
	(3.209)	(1.156)	(4.221)	(−1.160)
IPR		1.597***		0.183
		(2.914)		(0.600)
BR × IPR		−0.049		0.115**
		(−0.499)		(2.154)
H	4.924***	4.764***	1.898***	2.625***
	(3.577)	(3.149)	(3.090)	(3.821)
RD	4.409	5.953	0.843	−0.249
	(0.881)	(1.187)	(0.340)	(−0.098)
Trad	2.128	1.877	1.288	2.822*
	(0.890)	(0.701)	(1.007)	(1.966)
GDP	1.708***	1.657***	0.622***	0.588***
	(7.944)	(7.726)	(5.643)	(5.298)
_cons	−7.706***	−12.095***	−2.307***	−2.675***
	(−5.876)	(−6.053)	(−4.161)	(−2.648)
Individual fixed	Fixed	fixed	fixed	fixed
Time fixed	Fixed	fixed	fixed	fixed
R^2	0.7143	0.7227	0.5158	0.5236
N	330	330	420	420

Note: ***, ** and * represent significance at 1 %, 5 % and 10 % levels, respectively; t-values are in parentheses.

Endogeneity problems and treatment

The findings of this study may be influenced by endogeneity from two-way causality between technology transformation innovation and basic research. Technology transformation is not only the result of basic research, and technological progress achieved by stronger technology transformation in a region may enhance the efficiency of basic research to some extent. This study uses a one-period lag of basic research results as an instrumental variable (IV), conducting a two-stage least squares (2SLS) regression to address the endogeneity issue. For robustness, the study also uses the limited information maximum likelihood method (LIML), which is more insensitive to weak IVs, for the regression. The F value in the first stage and the Wald test in the second stage are both more significant than their critical values, indicating no weak IV problem. The results are shown in Table 5. According to the estimation results of IVs, the impact of basic research results on technology transformation innovation remains consistent with the baseline regression considering the endogeneity problem of two-way causality.

Robustness tests

To further examine the reliability of the baseline results, this study conducts a robustness check from two perspectives. First, as there may be a certain time lag in the technological transformation of basic research results, the core explanatory variable basic research results are regressed with a one-period lag, presenting the regression in Table 6. Second, to exclude the policy effects before and after the *Outline of National Intellectual Patent Strategy* was announced and implemented in China in 2008, the study adjusts the time window of the sample data to 2008–2018 for re-estimation. The regression results are shown in Table 7. The coefficients, signs and significance levels of the critical variables in the two robust regressions are essentially the same as the benchmark regressions, indicating that the earlier estimates remain robust, supporting the baseline analytical conclusions.

Discussion

The empirical model in this study examines the moderating effect of intellectual property protection on the strategic and substantive innovation transformation of basic research results, also investigating regional and industrial heterogeneity in the regulatory role of intellectual property protection and proposes countermeasures and suggestions to promote the technological transformation of basic research results according to the research conclusions.

This study integrates intellectual property protection, basic research and technological innovation into a single research framework, examines the effects of basic research results on the heterogeneity of substantive and strategic innovation and the moderating role of intellectual property protection and analyses regional and industrial heterogeneity. The findings not only fully support Bush (1945), demonstrating that basic research is the source of technological innovation, but also fully analyses the stimulating role of intellectual property protection in different stages of systematic innovation activities.

This study distinguishes technological innovation into strategic and substantive forms and analyses the heterogeneous moderating role of intellectual property protection in the high- and low-level transformation of basic research results on the basis of existing research. At the same time, heterogeneity analyses of the regulatory effect of intellectual property protection according to each regions' economic development level and different characteristics of each industry is also conducted.

This study proposes countermeasures and suggestions to promote the technological transformation of basic research results. Combined with the study's research conclusions and the practical problems that

Table 5
Two-stage least squares regression with limited information maximum likelihood regression for instrumental variables (second stage).

	IV-2SLS			IV-LIML		
Variables	Innovation	Strategy	Substant	Innovation	Strategy	Substant
BR	0.716***	0.947***	0.534***	0.716***	0.947***	0.534***
	(5.28)	(8.91)	(22.87)	(5.28)	(8.91)	(22.87)
Control variables	Control	Control	Control	Control	Control	Control
_cons	−19.195***	1.295	−4.651***	−19.195***	1.295	−4.651***
	(−5.65)	(0.38)	(−7.94)	(−5.65)	(0.38)	(−7.94)
Individual fixed	fixed	fixed	Fixed	fixed	Fixed	fixed
Time fixed	fixed	fixed	Fixed	fixed	fixed	fixed
R^2	0.891	0.829	0.947	0.891	0.829	0.947
N	510	510	510	510	510	510

Note: ***, ** and * represent significance at 1 %, 5 % and 10 % levels, respectively; z values are in parentheses.

Table 6
Robustness tests of core explanatory variables with one lagged period.

Variables	(1) Innovation	(2) Innovation	(3) Innovation	(4) Strategy	(5) Strategy	(6) Strategy	(7) Substant	(8) Substant	(9) Substant
BR	1.445***	0.687***	0.991*	0.870***	0.174	1.145**	0.575***	0.512***	−0.153
	(17.543)	(4.986)	(1.676)	(11.472)	(1.378)	(2.117)	(46.054)	(21.406)	(−1.566)
IPR			1.100*			1.297**			−0.197*
			(1.705)			(2.200)			(−1.847)
BR × IPR			−0.075			−0.235*			0.160***
			(−0.543)			(−1.861)			(6.994)
Control variables	Control	Control	Control	Control	Control	Control	Control	Control	Control
_cons	−0.177	−3.641***	−6.549***	0.176	−3.017**	−6.500***	−0.353***	−0.624***	−0.049
	(−0.255)	(−2.821)	(−3.073)	(0.276)	(−2.545)	(−3.337)	(−3.361)	(−2.783)	(−0.139)
Individual Fixed	fixed	fixed	fixed	fixed	fixed	Fixed	fixed	fixed	fixed
Time Fixed	fixed	fixed	fixed	fixed	fixed	Fixed	fixed	fixed	fixed
R^2	0.6792	0.7828	0.7842	0.5851	0.7206	0.7250	0.8744	0.8880	0.8990
N	510	510	510	510	510	510	510	510	510

Note: ***, ** and * represent significance at 1 %, 5 % and 10 % levels, respectively; t-values are in parentheses.

Table 7
Robustness tests adjusting the time window.

Variables	(1) Innovation	(2) Innovation	(3) Innovation	(4) Strategy	(5) Strategy	(6) Strategy	(7) Substant	(8) Substant	(9) Substant
BR	1.546***	0.785***	1.364**	0.915***	0.244*	1.051	0.631***	0.542***	0.313**
	(15.298)	(5.300)	(1.969)	(9.689)	(1.738)	(1.609)	(36.000)	(19.963)	(2.470)
IPR			1.948**			2.237***			−0.289*
			(2.193)			(2.673)			(−1.781)
BR × IPR			−0.137			−0.191			0.054*
			(−0.870)			(−1.284)			(1.857)
Control variables	Control	Control	Control	Control	Control	Control	Control	Control	Control
_cons	−1.429**	−8.893***	−14.337***	−0.226	−6.896***	−13.188***	−1.202***	−1.997***	−1.149*
	(−2.330)	(−4.211)	(−4.427)	(−0.395)	(−3.449)	(−4.321)	(−11.301)	(−5.163)	(−1.939)
Individual Fixed	fixed	fixed	fixed	fixed	fixed	fixed	fixed	fixed	fixed
Time Fixed	fixed	fixed	fixed	fixed	fixed	fixed	fixed	fixed	fixed
R^2	0.7117	0.7735	0.7773	0.6072	0.6830	0.6912	0.8727	0.8886	0.8906
N	330	330	330	330	330	330	330	330	330

Note: ***, ** and * represent significance at 1 %, 5 % and 10 % levels, respectively; t-values are in parentheses.

require urgent attention in China, this study advocates aspects of policy investment in basic research and improving the intellectual property protection system, which has important practical value for promoting the transformation of basic research results and improving the stability and competitiveness of industrial and supply chains.

This study has some notable deficiencies. First, to mitigate the effects of exogenous shocks, the time span of the research sample is from 2001 to 2018, which could not include most recent years. The impact of the China–US trade war and the COVID-19 pandemic on China's innovation efficiency cannot be completely excluded, which may pollute the data in 2019 and beyond; thus, it can only be discarded. This undoubtedly introduces certain limitations in the study of the impact of intellectual property protection on innovation efficiency in recent years. Second, the measure of intellectual property protection level employed is based on a mainstream measurement index of existing research on intellectual property protection using a modified GP index. However, since the level of intellectual property protection cannot be measured objectively, both the GP index and the modified GP index are somewhat subjective. This is because most of the specific indicators that constitute the intellectual property protection index are the result of subjective selection, particularly the F value in the revised GP index. Some differences in the revised GP of future scholars may arise.

Conclusion

To promote the technological transformation of basic research achievements in China and explore the influence of intellectual property protection, this study empirically examines the moderating effect of intellectual property protection on the technological transformation of basic research achievements based on the moderating effect model and provincial panel data in China from 2001 to 2018 and further analyses regional and industrial heterogeneity. The relevant results are threefold. (1) Overall, the baseline research results reveal a strong promotional effect on strategic and substantive innovation, while intellectual property protection has a significant negative regulating effect on strategic innovation and a significant positive regulatory effect on substantive innovation. This conclusion holds after conducting IV 2SLS regression, LIML regression and a series of robustness tests. (2) The regional heterogeneity analysis demonstrates a significant stepwise regional heterogeneous difference in the regulatory effect of intellectual property protection on research results transformation, indicating that it significantly inhibits strategic technological innovation transformation of basic research results in the eastern region, and significantly promotes the substantial innovative technology transformation of basic research results; however, no significant effect is found on central and western regions. (3) The industrial heterogeneity analysis shows that basic research results are conducive to substantial technology transformation of heterogeneous industries; however, intellectual property protection only has a significant positive regulatory role for high-tech industries.

This study presents a comprehensive investigation at theoretical and practical levels, and the following explorations can be conducted in future research. This study examines the moderating role and heterogeneity analysis of intellectual property protection in the process of technology transformation of basic research results, providing rigorous empirical evidence; however, how to improve the quality of China's basic research results and realise subsequent technology application after technology transformation to improve economic benefits necessitates further study, presenting a direction worthy of in-depth future research.

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References

Acemoglu, D., Aghion, P., & Zilibotti, F. (2006). Distance to frontier, selection, and economic growth. *Journal of the European Economic association, 4*(1), 37–74.
Akcigit, U., Hanley, D., & Serrano-Velarde, N. (2021). Back to basics: Basic research spillovers, innovation policy, and growth. *The Review of Economic Studies, 88*(1), 1–43.
Ang, J. S., Cheng, Y., & Wu, C. (2014). Does enforcement of intellectual property rights matter in China? Evidence from financing and investment choices in the high-tech industry. *The Review of Economics and Statistics, 96*(2), 332–348.
Arora, A., Belenzon, S., Patacconi, A., & Suh, J. (2019). The changing structure of American innovation: Some cautionary remarks for economic growth. NBER, 25893
Arrow, K. J. (1962). Economic welfare and the allocation of resources for invention. *The Rate and Direction of Inventive Activity*, 609–626.
Bikard, M., & Marx, M. (2020). Bridging academia and industry: How geographic hubs connect university science and corporate technology. *Management Science, 66*(8), 3425–3443.
Bush, V. (1945). *Science, the endless frontier: A report to the president*. Washington: United States Government Printing Office.
Carayol, N., & Matt, M. (2004). Does research organization influence academic production? *Research Policy, 33*(8), 1081–1102.
Cardamone, P., Pupo, V., & Ricotta, F. (2015). University technology transfer and manufacturing innovation: The case of Italy. *Review of Policy Research, 32*(3), 297–322.
Chen, F., Liu, H., & Ge, Y. (2021). How does integration affect industrial innovation through networks in technology-sourcing overseas M&A? A comparison between China and the US. *Journal of Business Research, 122*, 281–292.
Chen, Z., Liu, Z., Suárez Serrato, J. C., & Xu, D. Y. (2021). Notching R&D investment with corporate income tax cuts in China. *American Economic Review, 111*(7), 2065–2100.
Davis, D. R., & Dingel, J. I. (2019). A spatial knowledge economy. *American Economic Review, 109*(1), 153–170.
Escribano, A., Fosfuri, A., & Tribó, J. A. (2009). Managing external knowledge flows: The moderating role of absorptive capacity. *Research Policy, 38*(1), 96–105.
Fan, X., Yang, X., & Yu, Z. (2021). Effect of basic research and applied research on the universities' innovation capabilities: The moderating role of private research funding. *Scientometrics, 126*(7), 5387–5411.
Fang, L. H., Lerner, J., & Wu, C. (2017). Intellectual property rights protection, ownership, and innovation: Evidence from China. *The Review of Financial Studies, 30*(7), 2446–2477.
Ferras-Hernandez, X., & Nylund, P. A. (2019). Clusters as innovation engines: The accelerating strengths of proximity. *European Management Review, 16*(1), 37–53.
Furukawa, Y. (2010). Intellectual property protection and innovation: An inverted-U relationship. *Economics Letters, 109*(2), 99–101.
Gangopadhyay, K., & Mondal, D. (2012). Does stronger protection of intellectual property stimulate innovation? *Economics Letters, 116*(1), 80–82.
Gersbach, H., Sorger, G., & Amon, C. (2018). Hierarchical growth: Basic and applied research. *Journal of Economic Dynamics and Control, 90*, 434–459.
Ginarte, J. C., & Park, W. G. (1997). Determinants of patent rights: A cross-national study. *Research policy, 26*(3), 283–301.
Griffith, R., Redding, S., & Reenen, J. V. (2004). Mapping the two faces of R&D: Productivity growth in a panel of OECD Industries. *Review of Economics and Statistics, 86*(4), 883–895.
Grimaldi, M., Greco, M., & Cricelli, L. (2021). A framework of intellectual property protection strategies and open innovation. *Journal of Business Research, 123*, 156–164.
Guo, D., Jiang, K., Xu, C., & Yang, X. (2023). Geographic clusters, regional productivity and resource reallocation across firms: Evidence from China. *Research Policy, 52*,(2) 104691.
Hagedoorn, J., & Cloodt, M. (2003). Measuring innovative performance: Is there an advantage in using multiple indicators? *Research policy, 32*(8), 1365–1379.
Hayter, C. S., Rasmussen, E., & Rooksby, J. H. (2020). Beyond formal university technology transfer: Innovative pathways for knowledge exchange. *The Journal of Technology Transfer, 45*(1), 1–8.
Kantor, S., & Whalley, A. (2014). Knowledge spillovers from research universities: Evidence from endowment value shocks. *The Review of Economics and Statistics, 96*(1), 171–188.
Kanwar, S., & Evenson, R. (2003). Does intellectual property protection spur technological change? *Oxford Economic Papers, 55*(2), 235–264.
Kwon, S., Motohashi, K., & Ikeuchi, K. (2021). Chasing two hares at once? effect of joint institutional change for promoting commercial use of university knowledge and scientific research. *The Journal of Technology Transfer, 47*(4), 1242–1272.
Lai, E. L. C. (1998). International intellectual property rights protection and the rate of product innovation. *Journal of Development economics, 55*(1), 133–153.
Laverde-Rojas, H., & Correa, J. C. (2019). Can scientific productivity impact the economic complexity of countries? *Scientometrics, 120*(1), 267–282.
Lin, C., Lin, P., & Song, F. (2010). Property rights protection and corporate R&D: Evidence from China. *Journal of Development Economics, 93*(1), 49–62.
Liu, C., & Xia, G. (2018). Research on the dynamic interrelationship among R&D investment, technological innovation, and economic growth in China. *Sustainability, 10*(11), 4260.
Liu, X., & White, S. (2001). Comparing innovation systems: A framework and application to China's transitional context. *Research Policy, 30*(7), 1091–1114.
Liu, Z., Mu, R., Hu, S., Wang, L., & Wang, S. (2018). Intellectual property protection, technological innovation and enterprise value—An empirical study on panel data of 80 advanced manufacturing SMEs. *Cognitive Systems Research, 52*, 741–746.
Mansfield, E. (1991). Academic research and industrial innovation. *Research Policy, 20*(1), 1–12.
Martinez-Senra, A. I., Quintas, M. A., Sartal, A., & Vazquez, X. H. (2015). How can firms' basic research turn into product innovation? The role of absorptive capacity and industry appropriability. *IEEE Transactions on Engineering Management, 62*(2), 205–216.
Maskus, K. E., & Penubarti, M. (1995). How trade-related are intellectual property rights? *Journal of International economics, 39*(3-4), 227–248.
Meyer-Krahmer, F., & Schmoch, U. (1998). Science-based technologies: University —industry interactions in four fields. *Research Policy, 27*(8), 835–851.
Nasirov, S., Gokh, I., & Filippaios, F. (2022). Technological radicalness, R&D internationalization, and the moderating effect of intellectual property protection. *Journal of Business Research, 145*, 215–227.
Nelson, R. R. (1959). The simple economics of basic scientific research. *Journal of Political Economy, 67*(3), 297–306.
Park, W. G. (2008). International patent protection: 1960−2005. *Research policy, 37*(4), 761–766.
Prettner, K., & Werner, K. (2016). Why it pays off to pay us well: The impact of basic research on economic growth and welfare. *Research Policy, 45*(5), 1075–1090.
Rapp, R. T., & Rozek, R. P. (1990). Benefits and costs of intellectual property protection in developing countries. *J. World Trade, 24*, 75.
Sey, A., Lowe, B., & Poole, N. (2010). The use of intellectual property protection by micro, small, and medium-scale enterprises: A case study of Ghana. *Enterprise Development and Microfinance, 21*(1), 67–83.
Siegel, D. S. (2022). Two cheers for RRBM, pasteur's quadrant, and an application of RRBM to the commercialization of science and technology transfer. *Journal of Management Studies, 59*(6), 1643–1650.
Stokes, D. E. (1997). *Pasteur's quadrant: Basic science and technological innovation*. Brookings Institution Press.
Sun, X., Wang, Y., & Li, M. (2016). The influences of different R&D types on productivity growth in OECD countries. *Technology Analysis & Strategic Management, 28*(6), 651–663.
Teixeira, A. A. C., & Ferreira, C. (2019). Intellectual property rights and the competitiveness of academic spin-offs. *Journal of Innovation & Knowledge, 4*(3), 154–161.
Wen, Z., Chang, L., Hau, K. T., & Liu, H. (2004). Testing and application of the mediating effects. *Acta Psychologica Sinica, 36*(5), 614–620.
Wen, Z., Hau, K. T., & Chang, L. (2005). A comparison of moderator and mediator and their applications. *Acta Psychologica Sinica, 37*(2), 268–274.
Yang, J., Xiao, M. Y., & Jiang, M. B. (2023). Intellectual property right protection, technological innovation and return to capital in China. *Science Research Management, 44*(02), 137–145.
Yap, X. S., & Rasiah, R. (2017). Catching up and leapfrogging in a high-tech manufacturing industry: towards a firm-level taxonomy of knowledge accumulation. *Knowledge Management Research & Practice, 15*(1), 114–129.
Yi, J., Murphree, M., Meng, S., & Li, S. (2021). The more the merrier? Chinese government R&D subsidies, dependence, and firm innovation performance. *Journal of Product Innovation Management, 38*(2), 289–310.
Zhang, J., & Bai, K. R. (2022). Basic research in Chinese universities and enterprise innovation. *Economic Research Journal, 57*(12), 124–142.
Zhao, X., Tan, J., & Zhong, S. (2022). An institutional view on the leverage of external patent law expertise and patenting performance: Insights from China. *Journal of Innovation & Knowledge, 7*(4), 100263.