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INTELLECTUAL PROPERTY RIGHTS DESIGN AND ACADEMIC INNOVATION: EVIDENCE FROM UNIVERSITY PATENT OWNERSHIP REFORM

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ABSTRACT

China has sought to promote the commercialization of patents at universities, notably through the three rights and mixed ownership reforms. These two reforms adopted different models for the allocation of university patent ownership. The three rights reform completely allocates patent ownership to the universities, while the mixed ownership approach allocates the majority of patent ownership to the inventors upon the generation of outcomes. We empirically tested the effects of the two patent ownership allocation models on the patent performance using Chinese patent data and university statistics. We found that external institutional environment influenced the anticipated outcomes of the reform pilot in both reform models. The three rights reform has a significant impact on patent licensing without affecting the quantity or quality of patents, while the mixed ownership reform has significantly increased patent sales and applications while tilting research and development toward research with relatively low creativity. This paper contributes to the literature on innovation policies governing the conditions for effective institutional changes.

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1. Introduction

Who should own academic inventions—the university or the inventor? The allocation of patent rights in academic institutions lies at the intersection of property rights theory and the economics of innovation. Within the framework of incomplete contracts, the allocation of residual control rights shapes *ex ante* investment incentives when effort is non-contractible (Grossman and Hart, 1986; Hart and Moore, 1990). Applied to academic innovation, two dominant models of university patent ownership have emerged. In Japan and most European countries, ownership is assigned to inventors under the so-called "professors' privilege" (Organization for Co-operation and Development [OECD], 2003). In contrast, the United States adopted the Bayh–Dole Act in the early 1980s, allowing universities to retain patent rights to inventions arising from federally funded research (Hackett and Dilts, 2004).

Empirical evidence on the effects of these ownership regimes remains mixed. Studies examining changes in university patent ownership in the United States, Europe, and elsewhere report inconsistent findings, even within similar ownership frameworks (Henderson et al., 1998; Mowery et al., 2001; Mowery and Sampat, 2004; Mowery et al., 2002; Mowery and Ziedonis, 2002; Sampat, 2006).

Why do seemingly similar university-patent ownership systems produce divergent outcomes? One explanation is that institutional reforms often overlook heterogeneity in the broader environment, limiting their effectiveness. In particular, less attention has been paid to how internal governance structures, administrative discretion, and reform uncertainty mediate the incentive effects predicted by property rights theory. Universities are complex public organizations in which patent ownership determines not only income distribution but also authority over licensing, bargaining and strategic direction. Accordingly, the impact of ownership reform depends not only on the allocation of residual income rights, but also on how control rights are embedded within institutional governance.

Since 2002, China has largely adopted the formal framework of the Bayh–Dole Act. However, this policy transfer has not yielded the intended outcomes: a large share of university patents remains inactive (Gong and Peng, 2018; Luan et al., 2010). Policymakers have attributed this underperformance to the limited autonomy of Chinese universities, which unlike their U.S. counterparts, lack full authority to exercise patent ownership rights.

In response, China initiated a pilot reform in 2011—the "Three Rights Reform" (TRR)—granting central-level public institutions (including universities directly under the Ministry of Education) three key rights over university-owned patents: usus (use), disposal, and fructus (income rights). Implemented in cities such as Beijing, Wuhan, Shanghai, and Hefei, this reform effectively transformed universities' role from nominal to more substantive patent holders.

In parallel, China has explored an alternative model resembling the European "professors' privilege." In 2016, Southwest Jiaotong University (SWJTU) in Sichuan Province introduced a co-ownership model in which patent rights are shared between the university and inventors prior to commercialization. Under this arrangement, 70% of patent ownership is transferred to inventors, converting ex post rewards into ex ante property rights incentives. This shift not only alters the incentive structure but also changes the state-asset nature of university patents, potentially enhancing inventors' participation in commercialization.

Unlike settings where reforms are introduced through comprehensive national legislation, China's reforms have been implemented as pilot programs under heterogeneous institutional conditions. These two pilot reforms provide a unique quasi-natural experiment for examining the effects of different patent ownership regimes within a single country. Our findings show that the two regimes have distinct impacts on patent commercialization, subsequent patenting activity, and research direction—results that diverge from policymakers' expectations. Explaining these outcomes requires attention to the broader institutional environment, including university governance structures, patent management systems, and uncertainty surrounding reform implementation. These factors shape the strategic behaviors of academic inventors and administrators alike.

This paper makes two main contributions. First, demonstrates that the effects of intellectual property rights design are mediated by institutional governance. Ownership regimes operate through university-specific administrative procedures, patent management practices, and varying degrees of reform uncertainty. By embedding ownership reform within these organizational contexts, the analysis moves beyond reduced-form comparisons and identifies the mechanisms through which governance structures shape the effective strength of property rights.

Second, prior studies typically examine uniform ownership changes across countries, making it difficult to identify appropriate control groups and isolate causal effects (Giuri et al., 2013). China's pilot reforms provide within-country variation that mitigates these challenges and allows for more precise causal inference. By distinguishing between university ownership and inventor–university co-ownership, this study offers a sharper empirical test of how residual control rights influence innovation incentives, and helps explain why similar reforms yield heterogeneous outcomes.

The remainder of the article is structured as follows: Section 2 presents the institutional background and research hypotheses; Section 3 provides the data and empirical strategy; and Section 4 presents the empirical results, with robustness tests in Section 5. The final Section 6 gives the conclusions and insights.

2. Conceptual Framework and Hypotheses

2.1 Literature Review

Existing research on the impact of university patent ownership changes in the United States, Europe, and other countries has examined the quantity and quality, research orientation, and commercialization of university patents (Henderson et al., 1998; Mowery et al., 2001; Mowery and Sampat, 2004; Mowery et al., 2002; Mowery and Ziedonis, 2002; Sampat, 2006). However, previous studies have reported inconsistent results for the same university patent ownership. For example, Geuna and Rossi (2011) divided European countries into five groups based on their university patent ownership policies and compared the impact of different patent ownership policies on the numbers of university patents and licenses. They found that the U.S. Bayh–Dole Act model had only a short-term impact on patent growth and that European countries were far weaker in university patent licensing than the United States. Crespi et al. (2010) compared the commercialization rates of patents owned by universities with patents for inventions not owned by universities in six European countries and found no significant differences. Hvide and Jones (2018) found that the number of patent applications and the number of enterprises established by university inventors decreased after the patent ownership at Norwegian universities shifted from scientific inventors to universities. Luan et al. (2010) compared changes in the quantity and quality of university patents before and after the implementation of the Chinese version of the Bayh–Dole Act; they found that although the number of university patent applications significantly increased, there was no significant change in patent quality or commercialization.

Some research has already suggested that these differences in patent performance may be due to differences in the institutional environment outside of the adjustments in patent ownership. Several factors may have affected university patenting and licensing before and after the policy changes. For example, several U.S. policies may have shaped university patent production and commercialization, including enforcement of the Bayh–Dole Act, the 1980 Federal Supreme Court decision in Diamond v. Chakrabarty that allowed patent grants for some biotechnology, the 1982 Federal Circuit Court of Appeals decision on patents (Mowery et al., 2001), and the 1984 passage of Public Act 98-620 that further expanded the scope of university patents (Henderson et al., 1998). Even in the late 1960s, U.S. universities began to establish technology transfer offices and hire professional technology transfer personnel (Mowery and Sampat, 2004). The lack of unified and centralized management in the U.S. university system led to fierce competition among universities for resources, reputation, and students, which encouraged universities to attach greater importance to patent commercialization (Geiger, 1993).

There is generally a lack of clear identification of whether these differences were driven by the institutional environment of the corresponding development trends, legislation and policies related to patent creation and protection, or changes in university patent ownership. The two pilot projects in Chinese universities thus provide an effective comparison of the impacts of university-owned and inventor-owned patent ownership on patent application and commercialization. To identify the real impact of the patent ownership system reform on patent performance more accurately—and to make up for the shortcomings of existing research—we analyzed the institutional factors shaping the impact of patent ownership reform in Chinese universities.

2.2 The Institutional Context: Patent Rights Changes in Chinese Universities

Unlike in the United States, Chinese universities are almost entirely public universities, which are generally under the jurisdiction of national ministries or local governments.[1] Chinese universities also differ from public universities in countries such as the United States. Chinese universities are classified as public institutions (*shiye danwei*), and the university's operating funds mainly come from government allocations, the university's head is a government official who holds an administrative position, so the incentives to commercialize patents are limited. Universities also cannot obtain income from patent commercialization directly.[2] Using university patents also requires following the same procedures needed to use other state-owned assets;[3] the complicated procedures and potential risk of the loss of state assets further hinder university patent commercialization (He and Chen, 2013; Zhu, 2016).

It is, however, true that China has formally copied the content of the Bayh–Dole Act and that patent ownership derived from government-funded research findings was formally granted to

[1] Private universities supplement China's higher education system, with a relatively small number and a low level of education. According to the 2016 National Education Development Statistics Bulletin of the Ministry of Education, there are 2,596 colleges and universities in China, including 742 private colleges. China's colleges and universities have enrolled 671,700 graduate students, of which privately run colleges only admit 715 graduate students, and no private colleges have qualifications for doctoral admissions.

[2] Income from patent commercialization is subject to "two lines of revenue and expenditure" management.

[3] According to the provisions of Article 9 of the "Interim Measures for the Management of the Disposal of State-owned Assets of Central-level Public Institutions," issued by the Ministry of Finance in 2009, university intellectual property, a kind of intangible property, is correspondingly included in the scope of state-owned assets management.

universities.[4] Yet Chinese universities have only obtained nominal patent ownership: The unique organizational nature of Chinese universities means that they lack both the motivation and the ability to commercialize patents.

The first attempt to resolve the difficulties associated with university patent commercialization was the TRR pilot that gave universities real patent rights; with the approval of the State Council, the Ministry of Finance launched a pilot reform in the management of the disposal and revenue rights of scientific and technological achievements of central-level institutions in the Zhongguancun Innovation Pilot Zone in Beijing in May 2011. This reform covered the universities under the jurisdiction of the Ministry of Education in Beijing. In September 2013, the reform pilot was further expanded to universities under the jurisdiction of the Ministry of Education located in Wuhan, Shanghai, and Hefei Independent Innovation Pilot Zone,[5] where pilot units were permitted to decide independently to carry out patent commercialization through transfer, licensing, and share investments under certain criteria. The patent commercialization of the pilot units thus did not require filing with or approval from the competent authority if the value of the patent was less than 8 million yuan, and the pilot units could determine the transaction price through agreement pricing, technology market listing transactions, and auctions, among other avenues. The income from patent commercialization was partially retained by the pilot unit and did not need to be turned over to the treasury. This pilot reform program was initiated at 26 qualifying universities, which were thus granted real patent ownership comprising three elements of property rights: usus (the right to use), disposal (the right to handle), and fructus (the right to the fruits of the property). In October 2015, the TRR was expanded from pilot universities to universities nationwide through the newly revised law on Promoting the Transformation of Scientific

[4] Certain Provisions on the Management of Intellectual Property Rights of Research Results of National Research Program Projects, promulgated in 2002, then confirmed by Science and Technology Progress Law in 2007.

[5] Referring to the Zhongguancun National Innovation Pilot Zone Yearbook 2013, most of the universities in the cities where each pilot zone was located enjoy the policy benefits of the pilot zone in the form of setting up university science and technology parks in the pilot zone, and a search revealed that the pilot zone covers all universities directly under the Ministry of Education in Beijing, Shanghai, Wuhan, and Hefei.

and Technological Achievements. All universities in China are now granted patent ownership, including the aforementioned rights.

The second attempt was an MOR originating from SWJTU, which considered that granting patent ownership to the university alone, while ignoring inventors closely related to the university patents, would not be entirely effective in promoting patent commercialization. In January 2016, SWJTU issued the "Regulations on Patent Management," where *ex-post* inventor cash and equity awards were changed to *ex-ante* patent right incentives, thereby shifting from pure university ownership of patents to mixed ownership for the university and inventor. In this approach, the university and the inventor have a 30% and 70% share of patent ownership, respectively, SWJTU is able to confer patent rights directly upon inventors thanks to the introduction of the "Measures for the Management of Intangible Assets", which stipulated that the university's scientific and technological achievements would no longer be included in the list for state-owned intangible asset management but would be managed as achievements by the university's scientific research management department. Therefore, the inventor acquires the decision-making power and the assurance that they will receive proceeds from the commercialization of the patent.

The MOR of SWJTU was also formally endorsed by the Sichuan Provincial Government. In 2017, the provincial government promoted the replication of SWJTU's MOR pilot across other nine universities in Sichuan. However, based on the information we have collected, the MOR subsequently adopted by the other nine universities exhibit substantive institutional differences from the model implemented at SWJTU.

The MOR implemented by SWJTU can be characterized as a pre-assignment model, under which the allocation and partition of patent rights are completed *ex ante*, prior to commercialization. By contrast, the MOR adopted by the other nine universities follow a commercialization-embedded model, in which ownership partition typically occurs only after a concrete intention to commercialize has emerged. [6] In substance, this latter arrangement resembles an *ex post* equity reward contingent upon successful commercialization.

Notably, these two MOR regimes have co-existed over an extended period. In May 2020, the Ministry of Science and Technology issued the “Pilot Implementation Plan for Granting Researchers Ownership or Long-term Use of Scientific and Technological Achievements on Duty”, under this policy framework, forty universities were selected to participate in the MOR pilot program. The Plan explicitly states that pilot institutions may adopt differentiated incentive arrangements, either granting ownership of scientific and technological achievements prior to commercialization (assignment before commercialization) or providing equity rewards after commercialization (commercialization before reward). This study focuses on the pre-commercialization patent assignment model represented by SWJTU’s MOR reform. Specifically, it examines an institutional arrangement that grants inventors proprietary rights *ex ante*, thereby constituting a property-rights-based incentive mechanism directed at inventors.

2.3 Theoretical Mechanism and Research Hypotheses

Both TRR and MOR involve the redistribution of intellectual property rights that emerged from university research. Reconfiguring ownership affects the costs and benefits of all parties regarding the innovation process, thereby changing the incentives for everyone involved in innovation (Aghion and Tirole, 1994). Universities and inventories are the parties primarily affected by the incentive effects of TRR and MOR. Implementing the TRR has given universities an incentive to reap the benefits of patent commercialization. The right to dispose of and gain benefits from patent commercialization independently allows universities to promote such commercialization. In contrast, the MOR

[6] Taking Sichuan University as an example, in the “Public Notice of Determination of Ownership of Scientific and Technological Achievements of Sichuan University” issued on January 2, 2018, a total of nine patents involving five scientific and technological achievements were divided and confirmed, but within a reasonable period of time to confirm the rights of the above patents, there was no information on the transfer of rights in SIPO’s patent search system. Refer to Institute of Science and Technology Development of Sichuan University: Public notice on the recognition of the ownership of scientific and technological achievements of Sichuan University, January 2, 2008. https://kyy.scu.edu.cn/info/2266/4969.htm.

encourages inventors to participate actively in patent commercialization. The difference is that TRR is an *ex-post* incentive for inventors in patent commercialization, while MOR is an *ex-ante* incentive. TRR thus directly incentivizes universities, while MOR directly incentivizes inventors.

On the face of it, whether it is an ex-post incentive for inventors or an ex-ante allocation of rights, the potential gains can promote patent commercialization. The key point, however, is that the institutional environment affects the role of these incentives.

In theory, patents owned by the state reduce universities' risk aversion when engaging in patent commercialization. Since the state bears the consequences of losses during the commercialization of university patents, universities may, akin to the 'tragedy of the commons', be less concerned about the potential risk of patent loss and thus more inclined to commercialize their patents. However, the actual outcome may differ.

Chinese public universities constitute a distinctive category of public institutions (*shiye danwei*) within the state administrative system. Their research achievements are legally classified as state-owned assets and are therefore incorporated into the regulatory framework of state asset supervision. University administrators are embedded in a hierarchical bureaucratic structure with differentiated administrative ranks, which shapes the institutional logic of patent governance in Chinese universities as one that prioritizes asset preservation and risk avoidance. Under this governance structure, Chinese universities may strategically restrain patent commercialization activities in order to mitigate the perceived risk of state asset loss. As bureaucratic actors, university administrators face career incentives tied to political evaluation and promotion within the administrative hierarchy. If patents are transferred at prices subsequently deemed too low, such transactions may be interpreted ex post as causing a loss of state-owned assets, thereby exposing administrators to disciplinary or political accountability risks and potentially undermining their prospects for future advancement. Therefore, the theory of the "tragedy of the commons" may not apply to university patents in China, which makes it difficult for the TRR to effectively incentivize patent commercialization—apart from licensing that do not involve the transfer of patent rights.

From the perspective of TRR's impact on inventors, although the TRR requires universities to reward inventors with a certain percentage of their income after patent commercialization, inventors are aware of the institutional difficulties in commercializing university patents and would not expect to commercialize their patents by transfer or equity investment. According to relevant survey data, the ratio of patent licensing in universities is only 3.4%, and the commercialization rate is 4.1% (SIPO, 2018). This extremely low rate of commercialization leaves inventors with no incentive to participate in this process. As a result, it is difficult for TRR to create effective incentives for inventors.

In MOR, since SWJTU's reform of managing university patents without treating them as state-owned assets, the university can assign the majority of patent rights to the inventor *ex ante* without institutional or political constraint, which not only alleviates concerns about the loss of state assets, but also incentivizes the inventor to promote patent commercialization and reap the rewards. Inventor involvement plays an important role in the commercialization of immature university patents, which are often in the early experimental stage that is still remote from commercial application. Thus, the tacit knowledge of patent implementation makes it difficult to achieve commercial application without the active participation of inventors. Because they gain ownership of a majority share of the patent prior to commercialization, they gain the decision-making power to commercialize it. Their participation in commercialization then facilitates the connection with an enterprise's technical staff, thereby shortening the patented technology cycle from theory to practical application and increasing the probability of successful commercialization. However, institutional factors may still have an impact on the strategic choices of inventors: The inconsistency between the MOR and the provisions of the current legal system may cause inventors to doubt the sustainability of the MOR, leading them to choose more short-sighted forms of commercialization.

Commercializing patents involves either selling or licensing the patent, where selling is a one-shot ownership transfer, and licensing grants either exclusive or non-exclusive patent use rights, which can generate sustainable benefits. How should universities and inventors choose their patent commercialization strategy? Essentially, selling and licensing are two ways of allocating the risk of uncertainty between the parties to a transaction. For patents with a high degree of technical uncertainty, the patentee may prefer to sell the patent, while for patents with a lower risk of technical uncertainty and higher quality, the patentee may prefer to license (Jeong et al., 2013).

However, the institutional environment associated with different enforcement agents may affect patent commercialization strategies that are supposed to be determined by the uncertainty of the patented technology. For the TRR, the main factor affecting the decision of the university as a patent owner is the risk of losing state assets. Although Chinese public universities have acquired real patent ownership, these patents are legally still state-owned assets, and university administrators are still liable for the loss of state-owned assets if the value of the patents depreciates during commercialization. Because patent licensing involves only the transaction of patent usage rights, it does not lead to the loss of state assets, thus becoming the only viable form of patent commercialization under TRR. For the MOR, although the vast majority of the patent rights are granted to the inventor prior to commercialization, the stability of these rights can affect the inventor's decision to commercialize the patent. Due to the controversial legality of the MOR, there is a high degree of uncertainty regarding the patent rights obtained by the inventor. This risk of uncertainty, coupled with the inventor's lack of ability to manage the commercialization of the patent, could add to a preference to obtain immediate income in the form of a one-shot patent transfer rather than the long-term stable benefits of patent licensing. We thus develop the following hypothesis:

Hypothesis 1: The TRR and MOR incentivize universities and inventors, respectively, to implement patent commercialization. However, under the influence of the institutional environment related to the pilot reform, the two differ in the manifestations of patent commercialization, with the TRR favoring the promotion of patent licensing and the MOR favoring the promotion of patent sales.

The foundation of university patent commercialization lies in the sustained improvement of both the quantity and quality of university patents. The number of patent applications filed by universities is primarily determined by three factors: the cost of patenting, the expected allocation of innovation returns, and the perceived certainty of patent commercialization. TRR and MOR predominantly affect the latter two dimensions—namely, the allocation of residual income rights and the certainty of commercialization outcomes.

Under TRR, universities obtain stronger rights of patent disposition and revenue retention, which in principle could incentivize them to promote patent applications. However, the decision to file patents is ultimately made at the inventor level. Because inventors are entitled only to *ex post* monetary rewards contingent upon successful commercialization, their expected returns remain highly uncertain. Given the low probability of patent commercialization in Chinese universities, inventors lack credible expectations of stable returns. Consequently, TRR provides limited incentives for increasing the number of university patent applications.

By contrast, under MOR, inventors acquire a substantial share of patent ownership—typically 70 percent—prior to commercialization. This *ex ante* allocation of property rights primarily allocates innovation returns to inventors, thereby strengthening their incentives to file patent applications. Moreover, because university patents are no longer administered as state-owned assets under MOR, inventors are able to exercise greater control over the commercialization process. This institutional change enhances inventors' expectations regarding the certainty of commercialization outcomes. Taken together, these mechanisms imply that MOR is more likely to stimulate an increase in university patent applications. We thus develop the following hypothesis:

Hypothesis 2: The TRR and MOR exert differential effects on the number of university patent applications. While the TRR provides limited incentives for increasing patent filings, the MOR is capable of effectively stimulating growth in university patent applications.

The purpose of promoting the commercialization of university patents is to ensure that university research outcomes are widely applied in the market, which would prevent innovative technologies from being underutilized. However, it is important to acknowledge that universities should also conduct fundamental research that is of great value but is difficult to commercialize. If there are too many incentives for universities or inventors to commercialize patents, could this lead to a shift in the focus of university research from fundamental research to applied research that is easier to commercialize? Previous studies have examined the impact of implementing the Bayh–Dole Act on universities' research orientation and found that applied research significantly increased after the Act was implemented (Morgan et al., 1997). The logic is that the Act shifted ownership of state-funded research projects from the state to universities, which have an incentive to promote patent commercialization and increase revenues. Inventors can then share the commercialization benefits. University researchers are then more inclined to invest their energy in applied research that is likely to yield benefits (Thursby et al., 2007).

However, although the TRR has enabled universities to obtain real patent rights, university researchers still understand that the nature of university patents as state assets makes university administrators unwilling to bear the risk of losing those assets that arise from patent commercialization. Chinese universities also have a very low rate of patent commercialization; based on previous experiences, university researchers do not expect to benefit significantly from patent commercialization. The likelihood of obtaining a substantial return from patent commercialization is minimal. It is thus difficult for TRR to alter the orientation of research in Chinese universities without a change in the institutional systems.

The MOR, meanwhile, changes the incentives of inventors, who in turn make decisions about the research orientation. When inventors choose their research orientation, applied research has a shorter commercialization period and lower risk than basic research. Coupled with the uncertainty of the pilot reform itself, inventors may have an incentive to devote more energy to applied research that could facilitate patentable results, thereby obtaining the benefits of commercialization faster. We thus formulate the following hypothesis:

Hypothesis 3: Both in terms of the institutional environment of Chinese universities and the impact on incentive recipients, the TRR may not change the research orientation of Chinese universities. However, the MOR encourages inventors to shift their research orientation toward projects that require a lower level of innovation and are more likely to yield applicable findings.

3．Data Sources and Empirical Strategy

3.1 Data Sources

We empirically tested our research hypotheses with a unique dataset we assembled from various sources. The research data included both patent and university data. The TRR pilot, which is examined in this study, began in February 2011 and ended in November 2015. Meanwhile, the MOR pilot started in January 2016 and was expanded in October 2020 to cover a broader scope. Consequently, this study's observation period spans from 2008 to 2020.The patent data were published by State Intellectual Property Office(SIPO) from 2008 to 2020; these data contained information about the applicant, application date, grant date, and legal status changes, such as the transfer and license for each patent. Because this study focused on the commercialization of patents with higher innovation value, we studied invention patents for which universities applied independently. The university data came from the "Compilation of Scientific and Technological Statistics of Colleges and Universities (2009–2018),"[7] which includes relevant statistical data on research projects, investment in sci-tech funds, number of R&D personnel, the number of graduate students and the research orientation of various universities. It should be noted that our sample only included Chinese universities directly under the jurisdiction of the Ministry of Education. There are 76 such universities, including arts, languages, finance, and others. Some of these universities indicated they produced almost no scientific achievements. To ensure that the universities in the control group matched the treatment group as well as possible, we excluded the 16 arts, language, and financial institutions, all of which filed fewer than 600 patents from 2012 to 2019, and limited the total sample size to 60 universities. Although these 60 universities make up only 5.32% of the total number of Chinese universities, they account for 31.43% of the number of R&D personnel, 51.29% of the R&D funding allocation, 52.31% of the R&D

[7] The compilation provides college-level data from 2008 to 2017. From 2018, the compilation no longer provides university-level data. Therefore, estimates were calculated based on the growth rates observed in the preceding year for the control variables concerning R&D personnel, the number of graduate students, and investment in science and technology funds for 2018 and 2019.

expenditure, and 34.74% of the number of patents granted in Chinese universities.[8] Thus, these universities represent the highest level of Chinese research universities, which makes the findings here salient to better understand the operation of patent commercialization for core innovations in the context of reform. The statistical descriptions of the data used in this paper are presented in Table 1.

Table 1. Descriptive Statistics

Variable	Obs.	Mean	Std.dev.	Min	Max
Ln (Patent licenses)	788	0.482	0.923	0	4.787
Ln (Patent transfers)	780	2.266	1.382	0	5.849
Ln (Patent sales revenue)	600	7.572	2.786	0	13.327
Ln (Patent applications)	720	6.225	1.101	0	9.044
Proportion of funding allocated to basic research	600	0.362	0.187	0.020	0.984
Ln (R&D personnel)	720	7.085	0.707	5.537	9.152
Ln (graduate students)	720	8.084	0.752	3.523	9.748
Ln (sci-tech funds)	720	13.496	0.874	10.718	15.889
Ln (Marketization Index)	720	2.166	0.167	1.421	2.442

3.2 Empirical Strategy

3.2.1 Difference-in-Difference

An important advantage of the reform examined in this study is that the TRR started in only a set of universities. This provides us with a "treatment group" affected by the policy change and a "control group" that was not affected; this allowed us to apply the difference-in-difference (DID) method to estimate the impact of changes in university patent ownership on patent commercialization and production. If the treatment and control group samples are sufficiently similar and meet the parallel-trend assumption, the DID method can detect the net effects of the policy change. Both the treatment and control universities were under the jurisdiction of the Ministry of Education,[9] thus representing

[8] The above data are from the 2015 Compendium of Science and Technology Statistics for Higher Education Institutions, reflecting the data of Chinese universities in 2014. See Appendix Table 1 for detailed comparative information.

[9] There are 75 universities under the jurisdiction of the Ministry of Education. This paper excluded 15 universities with fewer than 600 patents.

the highest caliber of Chinese universities; this ensured that the treatment and control samples were as similar as possible.

In the DID model, we controlled the variables related to human and physical capital, and external institutional environment that has been marketized. We added fixed effects at the university and time levels to control for the influence of factors that do not change by the university or over time. The two-way fixed-effect panel model based on the DID was developed as follows:

$$Y_{i,t} = \beta\, \mathrm{TRR}_{i,t} + \gamma' X_{i,t-1} + \eta_i + \mu_t + \varepsilon_{i,t} \tag{1}$$

where $TRR_{i,t}$ represents the 26 universities in the TRR; its value is equivalent to the interaction term used to capture the net effects of policy in the DID model. That is, when the university belonged to the treatment group and the pilot reform had been launched, $TRR_{i,t}$ was 1, otherwise it was 0. The TRR was first implemented in February 2011 at 12 universities under the jurisdiction of the Ministry of Education in Beijing and then extended in November 2013 to 14 universities under the same jurisdiction in Wuhan, Shanghai, and Hefei. In this study, we designate 2011 and 2014 as the respective implementation years for the first and second waves of the TRR pilot. By October 2015, through the amendment of the Law on Promoting the Transformation of Scientific and Technological Achievements, the relevant policies of the reform began to be implemented nationwide, thereby ending the pilot program. β shows the effect of reforms on the outcome variable. University-fixed effects η_i and time-fixed effects μ_t were included to address other unobserved university and time variations, while $\varepsilon_{i,t}$ is the random error.

$Y_{i,t}$ is the measurement of patent commercialization, patent application and research orientation, where patent commercialization was proxied by the frequency of selling and licensing. To measure the level of patent sales, we used the number of patent transfers, where the number of patent transfers is the number of patent transfers registered in the SIPO, and the revenue from the sale of patents as proxy variables, and research orientation was proxied by the share of basic research in the university's

R&D investment.

The selection of universities participating in the TRR pilot may be non-random. The selection was probably influenced by university characteristics and institutional environment, thus making the model estimation results biased by whether the university enters the pilot variable $\mathrm{TRR}_{i,t}$ associated with the random error term $\varepsilon_{i,t}$. To obtain unbiased estimates of the coefficients of β in Model (1), a vector of university characteristics variables and institutional environment variable $X_{i,t-1}$ was included to mitigate the possible bias in estimates due to the endogeneity of the TRR pilot selection. Because there is no relevant document specifying the selection criteria for universities to enter the TRR pilot, we conjectured that the R&D personnel, the number of graduate students, investment in sci-tech funds, the number of patent applications, and the Marketization Index,[10] which measures the depth and quality of the marketization process may be determinants of whether a university was included. To verify whether these university characteristics were the main influencing factors, logit models were constructed (Lu et al. 2013) to estimate the probability of universities being included in the 2011 and 2013 TRR pilots, with the university characteristics prior to the implementation of the TRR as explanatory variables, and whether the universities would be selected for the TRR pilot as the dependent variable. The results from Appendix Table 2 reveal that the selection of TRR pilot universities was influenced by the R&D personnel, investment in sci-tech funds, the number of patent applications and the level of marketization. Therefore, a first-order lagged term of these variables should be included in the regression model to control for possible endogeneity in the selection of universities participating in the TRR.

3.2.2 Synthetic Control Method

To evaluate the impact of the MOR implemented by SWJTU in January 2016. Given only one treated unit, conventional panel data approaches such as DID are unlikely to yield credible causal

[10] Data for 2016 and earlier are from Wang Xiaolu et al: China Sub-Provincial Marketisation Index Report (2016). In consideration of extant studies, data for the period 2017-2019 were obtained on the basis of the average growth rate of the total marketisation index in each region over the years.

estimates, as their validity relies on large-sample properties and strong assumptions regarding average parallel trends across treated and control groups.

To address this limitation, we adopt the Synthetic Control Method (SCM) proposed by Abadie and Gardeazabal (2003) and further developed by Abadie et al. (2010, 2015). SCM is particularly well suited for policy evaluations involving one treated unit and a well-defined intervention, as it constructs a data-driven counterfactual by optimally weighting untreated units to closely match the treated units' pre-intervention characteristics and outcome trajectories. We compare the patent commercialization, patenting and research direction of SWJTU adopted MOR with that of a weighted combination of other universities chosen to resemble the characteristics of SWJTU before MOR.[11] We conceptualize such a weighted average of other Chinese universities as a "synthetic" SWJTU without MOR, against which we can compare the actual SWJTU with MOR.

Predictor selection in the SCM is designed to capture stable pre-treatment structural characteristics of universities while ensuring close alignment of outcome dynamics prior to the policy intervention. In constructing the synthetic counterpart for SWJTU, we select predictors that reflect long-run research capacity, institutional status, and regional innovation conditions, rather than variables potentially affected by the reform itself. Specifically, we include the pre-intervention averages of the number of R&D personnel and enrolled graduate students, which proxy for the scale of research inputs and human capital endowments and evolve slowly over time. We also control for whether a university belongs to the national "985 Project", capturing persistent differences in institutional quality, resource access, and administrative support that are largely time-invariant. Regional location is incorporated to account for systematic spatial heterogeneity in innovation ecosystems, technology markets, and policy environments. Most importantly, following standard practice in the synthetic control literature, several pre-treatment lags of the outcome variables are

[11] Sichuan University was excluded from the donor pool primarily because it was designated as one of ten MOR pilot institutions by the Sichuan Provincial Government in 2017. Although Sichuan University's MOR differs from that of SWJTU, we removed this sample to avoid other potential unobserved differences.

included to ensure a close match between SWJTU and its synthetic control in terms of pre-reform patent strategy. This predictor set allows the synthetic control to credibly approximate SWJTU's counterfactual evolution in the absence of the MOR, thereby strengthening the causal interpretation of the estimated treatment effects.

4 Empirical Findings

4.1 Impact of TRR on University Patent Commercialization and Production

The direct purpose of the TRR was to promote universities' patent commercialization. The Columns (1) and (2) of Tables 2 show the effects of TRR on patent licensing and transfers. We found that TRR had a significant positive impact on the number of patent licenses at the 5% level, but no significant impact on patent transfers. The estimated coefficient on the policy indicator is 0.294. Given the log-linear specification, this implies that TRR increased university patent licensing by approximately 34%. In magnitude terms, the effect corresponds to roughly 0.32 standard deviations of the dependent variable, indicating a quantitatively meaningful shift. Although the TRR has exerted a positive influence on patent licensing, Columns (3) and (4) of Table 2 indicate that TRR has not significantly impacted the number of patent applications filed by universities or their research directions.

Table 2 *The Effects of TRR on Patent Commercialization and Production in Universities*

	(1)	(2)	(3)	(4)
	Ln (Patent licenses)	Ln (Patent transfers)	Ln (Patent applications)	Proportion of funding allocated to basic research
TRR	0.294**	-0.149	-0.087	0.006
	(0.124)	(0.207)	(0.080)	(0.025)
Ln (R&D personnel)	-0.301	-0.178	-0.054	0.013
	(0.247)	(0.249)	(0.117)	(0.040)
Ln (graduate students)	0.250	-0.002	0.070	0.011
	(0.232)	(0.207)	(0.069)	(0.024)
Ln (sci-tech funds)	0.136	0.120	0.100	-0.027
	(0.208)	(0.361)	(0.132)	(0.059)
Ln (patent applications)	0.272*	0.344**		0.025
	(0.157)	(0.150)		(0.026)

Marketization Index	-1.466* (0.810)	0.944 (1.399)	0.414 (0.400)	-0.341* (0.188)
Year FE	Yes	Yes	Yes	Yes
University FE	Yes	Yes	Yes	Yes
Obs.	420	420	420	420
Adjusted R^2	0.667	0.606	0.936	0.695

Note. All University Characteristics variables are first-order lagged terms. Standard errors are clustered by the university in parentheses. ***Significant at 1%, **at 5%, *at 10%.

4.2 Impact of MOR on University Patent Commercialization and Production

4.2.1 Impact of MOR on University Patent Commercialization

We employ the synthetic control method (SCM) to evaluate the effect of the MOR reform on university patent commercialization. We begin by examining patent licensing outcomes. As shown in Figure 1, although the synthetic control provides a satisfactory pre-treatment fit, no persistent divergence emerges following the implementation of MOR in 2016. The gap between SWJTU and its synthetic counterpart alternates in sign across post-treatment years, the post-reform trajectory does not exhibit a clear and sustained upward shift relative to the counterfactual benchmark.

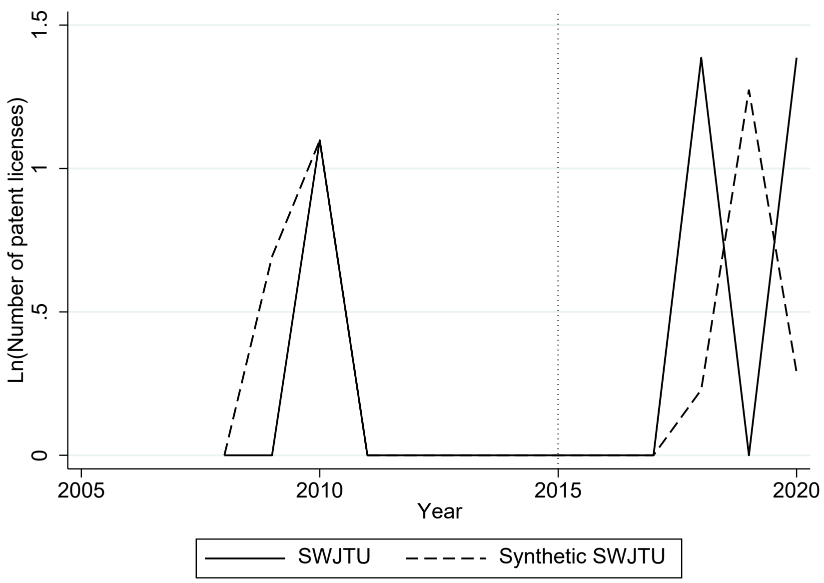


Figure 1. *Patent Licenses Trends: SWJTU and Synthetic SWJTU*

Further observation of the impact on patent transfers, Figure 2 plots the evolution of the outcome variable—log patent transfers—for the SWJTU and its synthetic counterpart. The pre-treatment fit is close: during the pre-reform period (2010–2014), the gap between the treated unit and the synthetic control fluctuates narrowly around zero, indicating that the synthetic control closely reproduces the treated unit's pre-intervention trajectory.[12]

Following the reform in 2016, a sizable and persistent divergence emerges. Averaging across 2016–2020, the estimated post-treatment effect is approximately 1.4 log points. Interpreting magnitudes in levels, this implies that patent transfers at the SWJTU are on average about 4 times higher than the counterfactual implied by the synthetic control. The absence of mean reversion suggests that the MOR induced a structural shift rather than a short-run transitory response. The evidence indicates that the MOR generated a large and sustained increase in patent transfer activity relative to the counterfactual path.

It is worth noting that an increase in the number of patent transfers does not necessarily reflect genuine commercialization based on market forces. Since SWJTU's MOR pilot stipulated that "for existing patents and patent applications, the university shall reward inventors by changing the registered patent right holder," the reform required filing ownership amendments with the SIPO, replacing "SWJTU" with "SWJTU+ inventor(s)" as the legal right holder. Consequently, an increase in patent transfers may partly reflect intra-organizational ownership adjustments implemented to fulfil reform requirements. In this institutional context, changes in transfer counts could conflate administrative re-registration with economically significant technology transactions.

[12] The synthetic SWJTU was composed of four universities: Huazhong Agricultural University, Jilin University, Wuhan University of Technology, and Zhejiang University (with weights 0.626, 0.317, 0.045, and 0.012, respectively).

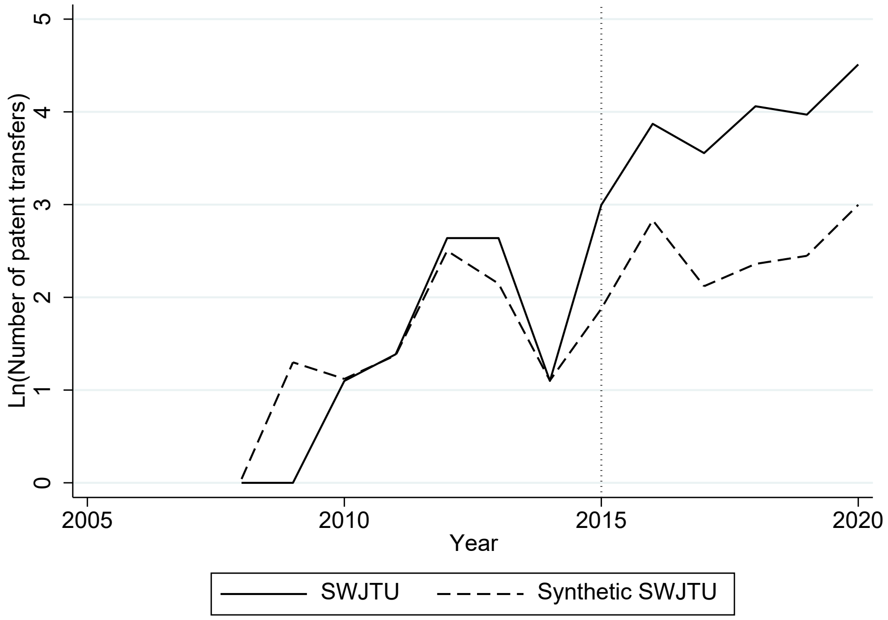


Figure 2. *Patent Transfer Trends: SWJTU and Synthetic SWJTU*

The revenue generated from patent sales is a more appropriate outcome measure of whether MOR effectively enhances the university's external technology transfer. Figure 3 reports the synthetic control estimates for log patent sale revenue.[13] The synthetic control analysis for patent sales revenue reveals a sustained post-reform divergence. While the pre-treatment trajectories are reasonably well aligned, SWJTU's patent sales revenue exceeds its synthetic counterpart beginning in 2016, with the gap widening over time. The post-reform gap in log patent sales revenue reaches approximately 2–3 log points by 2016–2017. This magnitude corresponds to an order-of-magnitude increase relative to the synthetic counterfactual.

[13] The synthetic SWJTU was composed of five universities: University of Electronic Science and Technology, Northeast Normal University, Beijing Normal University, China University of Geosciences, Beijing and China University of Mining & Technology, Beijing (with weights 0.319, 0.305, 0.244, 0.096 and 0.036, respectively).

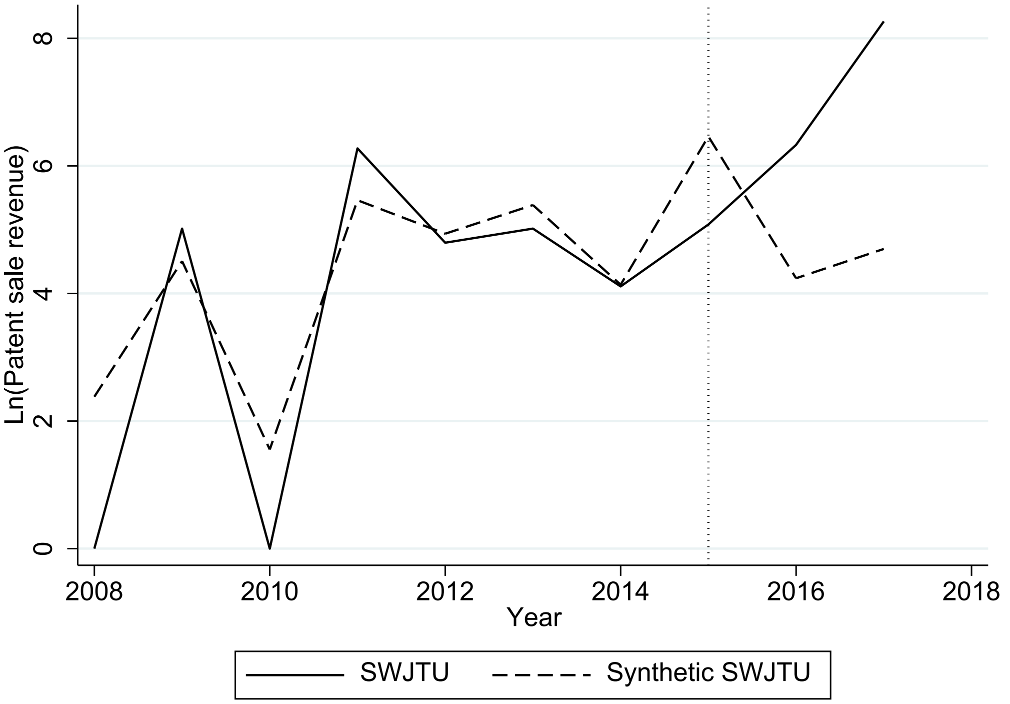


Figure 3. *Patent Sale Revenue Trends: SWJTU and Synthetic SWJTU*

These findings support Hypothesis 1. The significant positive impacts of TRR and MOR on patent commercialization demonstrate the effectiveness of both pilots in providing incentives for rights holders to commercialize their patents by granting ownership to universities and inventors, respectively. However, the TRR and MOR produced different strategies for commercializing their patents. The impact of TRR on patent commercialization was apparent only for patent licensing, while the impact of MOR appeared only for sales. These differences can be reasonably explained in terms of the institutional environment. Although the TRR has had a similar effect on patent commercialization as the implementation of the Bayh–Dole Act in the United States, the motivation behind it was different. The possible reason for the license-based commercialization of Chinese university patents is that under the state asset management system, university administrators are concerned about the risk of losing state assets due to the transfer of patents. Patent commercialization in the U.S. is dominated by licensing because universities generally seek to generate sustainable and stable income. For MOR, the risk of policy uncertainty makes inventors more willing to obtain immediate benefits in the form of patent sales.

4.2.2 Impact of MOR on University Patent Application

We further examine the impact of MOR on the number of patent applications. Figure 4 reports the synthetic control estimates for log patent applications.[14] The pre-treatment fit is close: over the period 2009–2015, the SWJTU and its synthetic counterpart track each other closely, and the pre-reform gap remains small and does not exhibit systematic trends. This suggests that the synthetic control provides a reasonable approximation to the counterfactual trajectory in the absence of the MOR.

Following the implementation of the MOR in 2016, the SWJTU begins to diverge gradually from its synthetic control. The estimated treatment effect—measured as the difference in log patent applications between the SWJTU and its synthetic counterpart—is close to zero in the first post-treatment year (approximately 0.05 log points), increases modestly in 2016–2017 (around 0.2–0.25 log points), and becomes more pronounced after 2018 (reaching roughly 0.6–0.65 log points by the end of the sample). Averaged over the post-reform period, the estimated effect is approximately 0.35 log points. Interpreted in levels, this corresponds to an increase of about 42% in patent applications relative to the synthetic counterfactual.

[14] The synthetic SWJTU was composed of five universities: University of Science and Technology Beijing, Southwest University, China University of Petroleum (East China), China University of Mining & Technology, Beijing and Wuhan University of Technology (with weights 0.364, 0.269, 0.196, 0.112 and 0.06, respectively).

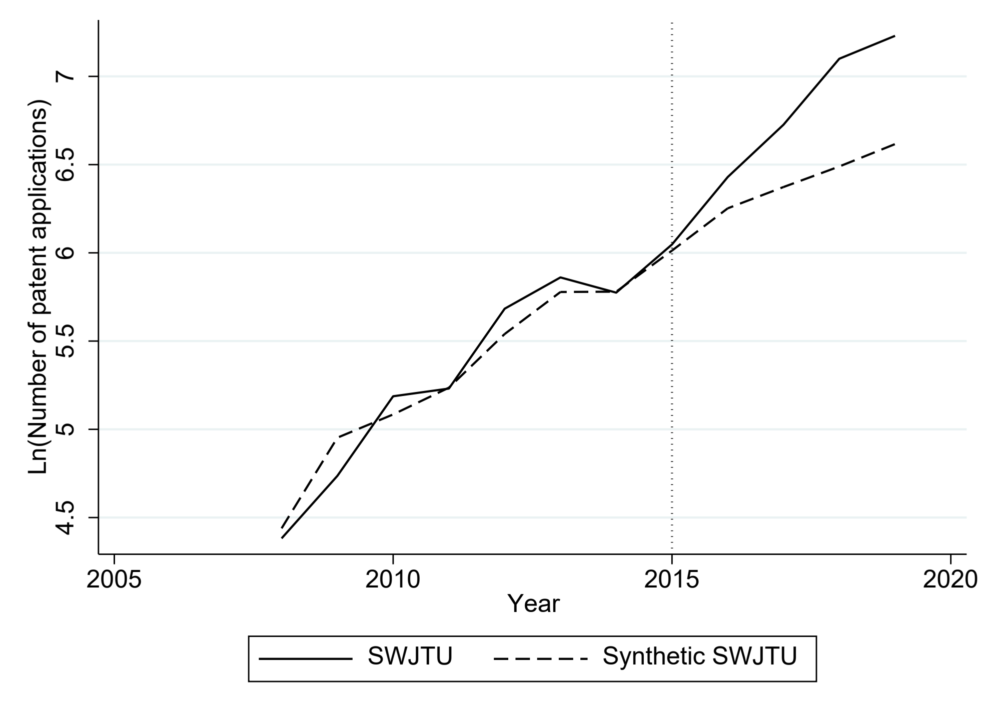


Figure 4. *Patent Application Trends: SWJTU and Synthetic SWJTU*

The above findings provide empirical support for Hypothesis 2. Under the TRR, universities obtain stronger rights over patent disposition and residual income retention. However, inventors are entitled only to ex post rewards contingent upon successful commercialization. Given the extremely low probability of patent commercialization within Chinese universities, inventors face limited prospects of stable or predictable returns. As a result, TRR does not substantially strengthen inventors' *ex ante* incentives to increase patenting activity. In contrast, under the MOR, inventors are granted a substantial share of patent ownership prior to commercialization. This reallocation of residual control rights enables inventors to play a leading role in the commercialization process and enhances the credibility and certainty of expected returns. By internalizing a greater portion of the upside gains at the outset, inventors face stronger marginal incentives to engage in patenting. Consequently, MOR is more effective in stimulating an increase in university patent applications.

4.2.3 Impact of MOR on University Research Orientation

We examine the impact of MOR on the research orientation of universities. Figure 5 reports synthetic control estimates for the share of R&D expenditure allocated to basic research.[15] The SWJTU and its synthetic counterpart track each other closely in the pre-reform period. Prior to 2015, differences between the two series are small and do not display systematic trends, indicating that the synthetic control provides a reasonable approximation to the counterfactual allocation path absent the MOR. Following the implementation of the MOR in 2016, the trajectories diverge. The share of funding allocated to basic research in SWJTU is about 10%-23% lower than that of the synthetic control. In magnitude, this represents a non-trivial reallocation of research funds away from basic research relative to the synthetic counterfactual.

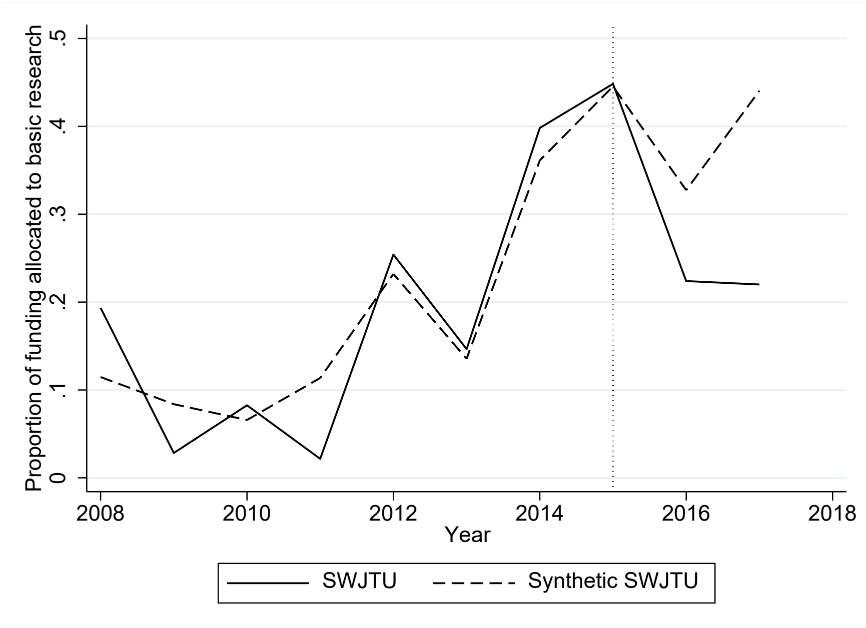


Figure 5. *Funding Allocation Trends: SWJTU and Synthetic SWJTU*

These results confirmed Hypothesis 3. Because the TRR has failed to motivate Chinese university researchers in the absence of reward expectations, it has failed to change the research orientation of university researchers. However, under the MOR, universities sharing patent ownership with inventors helped the latter to take the initiative to promote commercialization. The uncertainty of MOR has also encouraged inventors to shift their research orientation to research with lower levels of

[15] The synthetic SWJTU was composed of five universities: China University of Mining & Technology, Beijing, China Pharmaceutical University, Beijing Jiaotong University, China University of Mining and Technology and Zhejiang University (with weights 0.516, 0.239, 0.112, 0.096 and 0.037, respectively).

innovation with short-term cycles and faster payoffs.

5. Robustness Test

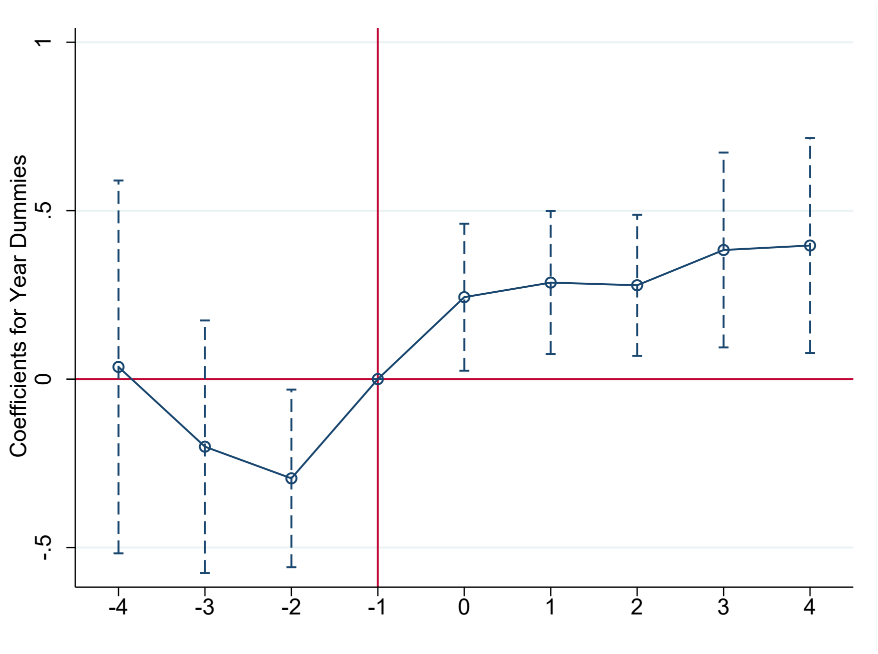
5.1 Parallel Trend Test

A potential challenge to the DID regression estimations is that the treatment and control groups must be comparable before TRR implementation. To investigate this, we compared the coefficients before and after the implementation to test the parallel time trends before reform implementation and the impact after the reform. We used the model:

$$Y_{it} = \sum_{j=-4, j\neq -1}^{n} \theta_j T_{it}^{j} + \lambda X_{i,t-1} + \eta_i + \mu_t + \varepsilon_{it} \tag{2}$$

where T_{it}^{j} is a series of dummy variables, T_{it}^{j}=1 when *j*>0 if university *i* is a university participating in the TRR and is in the *j*th year after being listed, and T_{it}^{j}=1 when *j*<0 if university *i* is a university that will participate in the TRR and is in the *j*th year before being listed. We used the year prior to the university's participation in the TRR as the base year, so $j \neq -1$. The coefficient θ_j indicates whether there is a significant difference in the trend of the patent licensing between the treated and control groups in the year *j* after (or the year before) the university's participation in TRR. Other variables are the same as in Model (1).

Based on Model (2), we constructed a parallel-trends test chart of whether there was a between-group difference in the logarithm of the number of patent licenses, where the control group was the period before policy implementation. Figure 6 illustrates that the estimate of θ_j is not significantly different from 0 when $j<0$; with the exception that the patent licenses of the TRR universities were significantly lower than the control group universities when $j=-2$, there was no significant difference in the number of patent licenses between TRR universities and other universities in the control group. After the implementation of the reform, we found that the number of patent licenses was significantly higher for TRR universities than for the control group, and the policy effects of TRR on patent licensing gradually increased over time.



Note: Period −1 is the control group, and the results for each of the other times are relative to period −1.

Figure 6. *Parallel-Trends Test of Patent Licenses: TRR versus Universities in the Control Group*

5.2 PSM-DID

Although the treatment and control groups were universities under the jurisdiction of the Ministry of Education, the 26 pilot universities involved in TRR may differ tremendously from other universities; we therefore used propensity score matching (PSM) with DID to further verify the impact of TRR. Because we had a panel of universities observed over time, matching was implemented year-by-year using lagged covariates. After estimating the propensity score with the probit model, treatment universities were matched with control universities using kernel-based matching. After the matching procedure, the pre-existing observed differences between treatment and control groups were expected to be substantially ameliorated. Before continuing, the balancing property of the propensity score was tested in the annual sub-samples, and the results showed that the balance characteristics were satisfied.[16] After retaining the samples that satisfied the common support assumption, we applied the

[16] The results of the balance test are shown in Appendix Table 3.

DID model to further verify the true effects of the TRR. The DID model is shown in Equation (1). The results are shown in Column (1) of Table 3. We found that the magnitude of the effect was similar to the results using the DID method.

Table 3 *The Effects of TRR*

Variables	Ln (Patent licenses)	
	(1) PSM-DID	(2) Staggered DID(ATT)
Policy	0.286** (0.126)	0.720*** (0.2)
Ln (R&D personnel)	-0.182 (0.267)	Yes
Ln (graduate students)	0.221 (0.245)	Yes
Ln (sci-tech funds)	0.194 (0.182)	Yes
Ln (patent applications)	0.293* (0.163)	Yes
Marketization Index	-1.301 (0.877)	Yes
Year FE	Yes	
University FE	Yes	
Obs.	391	420
Adjusted R^2	0.668	

5.3 Staggered DID Robustness Estimation

In the traditional two-way fixed DID model, the coefficient estimates may be biased due to the problem of a "bad control group." This issue arises because, with staggered treatment timing, samples that received treatment earlier can serve as control groups for those treated later. However, the earlier-treated group already reflects the treatment effect in their outcome variables, which leads to biased estimates (Goodman-Bacon, 2021). To address this potential issue, we adopted the average treatment effect on the treated method proposed by Callaway and Sant'Anna (2021) for robust estimation. The specific results are shown in Column (2) of Table 3. We found that the results are consistent with the earlier findings from the baseline research. The dynamic trend of the heterogeneous robust estimators is illustrated in Figures 7; the estimated coefficients for different samples are not significant before the implementation of the TRR, which meets the parallel trends assumption. The treatment effect becomes gradually significant after the TRR is implemented, which indicates that the main results are robust.

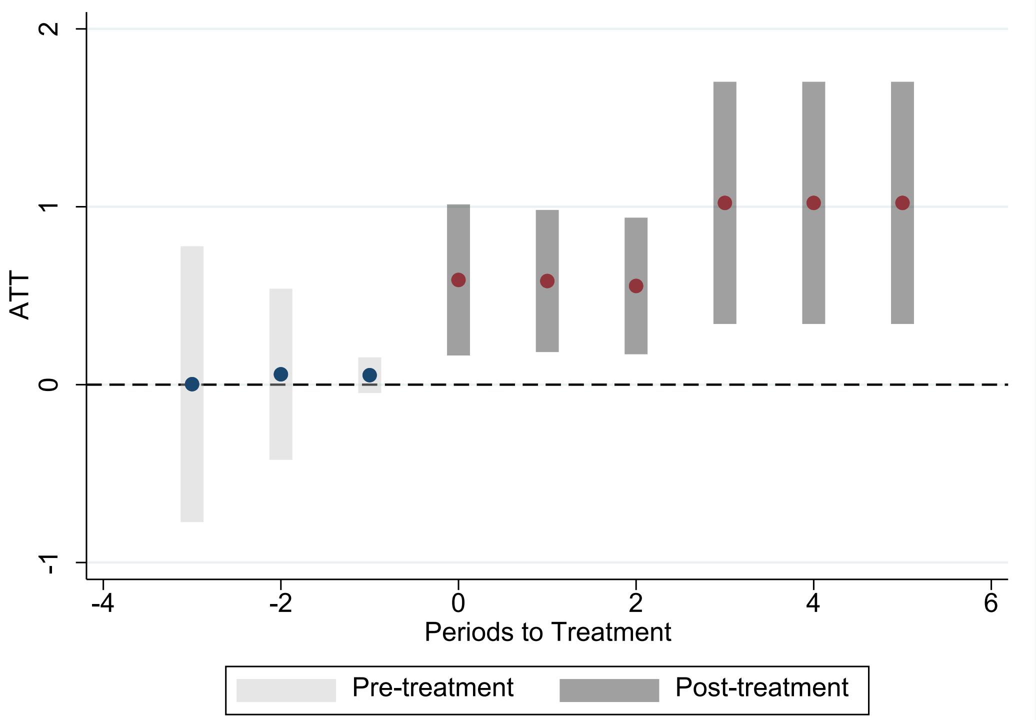


Figure 7. *Dynamic Effects Trend of Patent Licenses: TRR versus Universities in the Control Group*

5.4 Further Restricting the Sample and Adding Control Variables

This paper studied universities directly under the Chinese Ministry of Education, and although this group of universities represents the highest level of university innovation in China, they still differ in aspects such as R&D investment and size. For this reason, we further restricted the study sample to the universities directly under the Ministry of Education that took part in the 985 project, all of which are comprehensive or science and technology-based universities with comparable conditions and sizes. This made the samples in the treatment and control groups more comparable. Among the universities studied in this paper, 32 are Project 985 universities. The results from Column (1) of Table 4 show that the results based on DID still support the conclusion that TRR has a significant and positive impact on the number of patent licenses.

Based on the sample of 985 universities, we further add the patent-related policies autonomously adopted by universities during the sample observation period as control variables, thus examining the impact of TRR on patent licensing while controlling for the impact of the patent policies implemented by universities. We divided the university's patent policies into five categories. Equity share denotes the share of equity between the university and the inventor after the patent has been funded as equity. Royalty share denotes the share of revenue from patent transfer and licensing between the university and the inventor. Patent subsidy represents whether the university subsidizes the patent application fee. Tenure denotes whether patent authorization and commercialization are the basis for the appointment and assessment of professors. Bonus denotes the reward of the university to the inventor after the patent is granted. We constructed the above five policy variables at the university-annual level. When these variables are 0, it means that the university has not adopted such policies. When equity share and royalty share are greater than 0 and less than 1, it indicates the investor obtains a share of equity or royalties from the patent. When the other three policy variables are 1, it means that the university has adopted the policy. From Column (2) of Table 4, it can be seen that the TRR still has a significant and positive impact on patent licensing after controlling for policy variables at the university level.

Table 4. *The Effects of TRR on Patent Licensing in Universities*

Variables	985 Universities	985 Universities (including university-level patent policies)
Policy	0.545*** (0.195)	0.517*** (0.165)
Equity share		-0.258 (0.318)
Royalty share		-0.034 (0.398)
Patent subsidy		0.135 (0.279)
Tenure		-0.256 (0.370)
Bonus		0.088 (0.295)
University Characteristics	Yes	Yes
Year FE	Yes	Yes
University FE	Yes	Yes
Obs.	210	210
Adjusted R^2	0.759	0.756

Note: The five categories of university patent-related policy information in Column (2) were obtained from Yi and Long (2021).

5.4 Placebo Test for SCM

To evaluate the significance of the results from SCM, we pose the question of whether our results could be occurred by chance. How often would we obtain these results if we had chosen a university at random instead of using SWJTU? To verify the robustness of the results, we used placebo tests. Based on methods used by Abadie and Gardeazabal (2003) and Abadie et al. (2010), we ran placebo studies by applying SCM to a university that did not implement the MOR during our study's sample period—that is, the treatment status was assigned to one control university as if it had implemented MOR in the intervention year. This procedure was then repeated for all control universities in the original donor pool. Placebo effects were calculated as gaps between the outcome values of a placebo university and its synthetic objects. If the placebo studies showed that the gap estimated for SWJTU was unusually large relative to the gaps for the universities that did not implement MOR, this would further support the credibility of our results.

The placebo test also has an applicable premise; SCM requires that each university's synthetic object have a good fit before MOR implementation. If a university had a poor fit before MOR implementation—that is, the pre-intervention mean-squared prediction error (MSPE) was quite different from that of SWJTU—then even a large difference in predictors obtained after MOR implementation would not reflect the true effects. We therefore conducted the placebo tests suggested by Abadie et al. (2010), excluding universities that had a pre-MOR MSPE more than two times that of SWJTU's, which allowed us to focus exclusively on those universities that fit almost as well as SWJTU in the period prior to MOR.

After obtaining all placebo estimates, the time trends of the estimated treatment effects and placebo effects were compared graphically. If the treatment effects for SWJTU were larger than most placebo effects, they may be considered plausible. Figures 8-9 display the results of patent sales; the gray lines represent the MOR effect on number of patent transfers and revenue generated from patent sales for each university in the control group respectively, while the solid black line denotes the effect for SWJTU. As shown in Figures 8-9, the effect line for SWJTU is, in general, large relative to the distribution of the control universities' lines after MOR implementation, which demonstrates the significant positive impact of MOR on patent sales. The placebo test results were thus consistent with the previous findings.

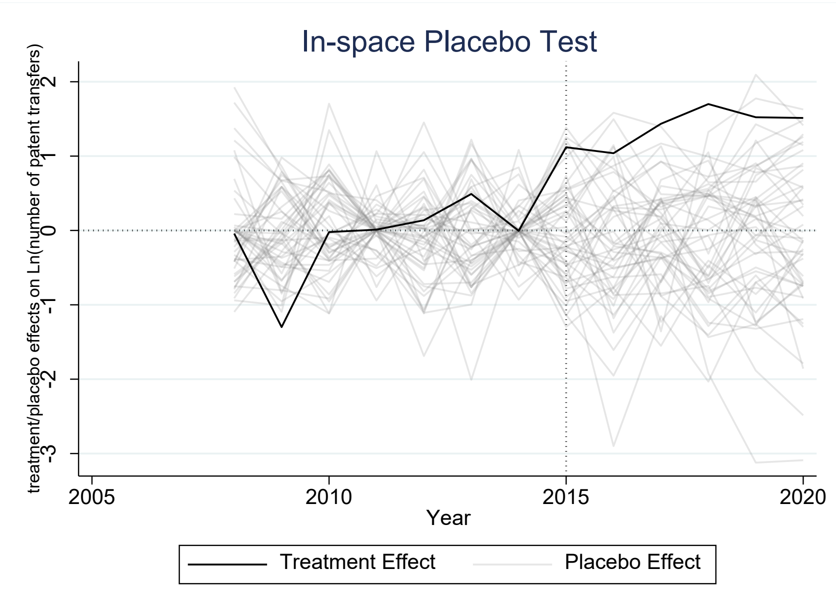


Figure 8. *Logarithm of Patent Transfer Gaps in SWJTU and Placebo Gaps in Control Universities (Excludes Universities with Pre-MOR MSPE Two Times Higher Than SWJTU's)*

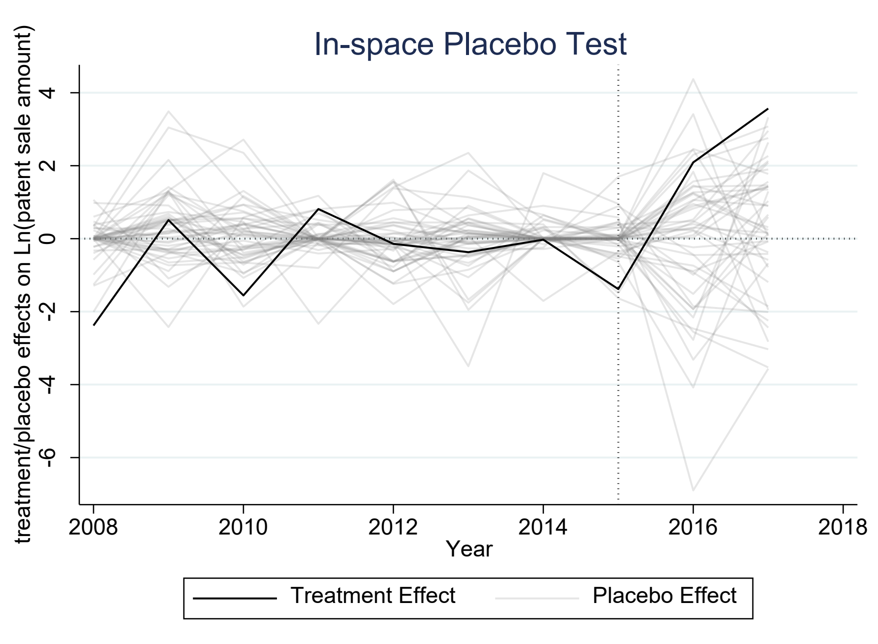


Figure 9. *Logarithm of Patent sale revenue Gaps in SWJTU and Placebo Gaps in Control Universities (Excludes Universities with Pre-MOR MSPE Two Times Higher Than SWJTU's)*

Figure 10 displays the result of patent application. The gray lines represent the MOR effect on the number of patent applications for each university in the control group respectively, while the solid black line denotes the effect for SWJTU. As shown in Figure 10, the effect line for SWJTU is, in general, large relative to the distribution of the control universities' lines after MOR implementation, which demonstrates the significant positive impact of MOR on patent applications.

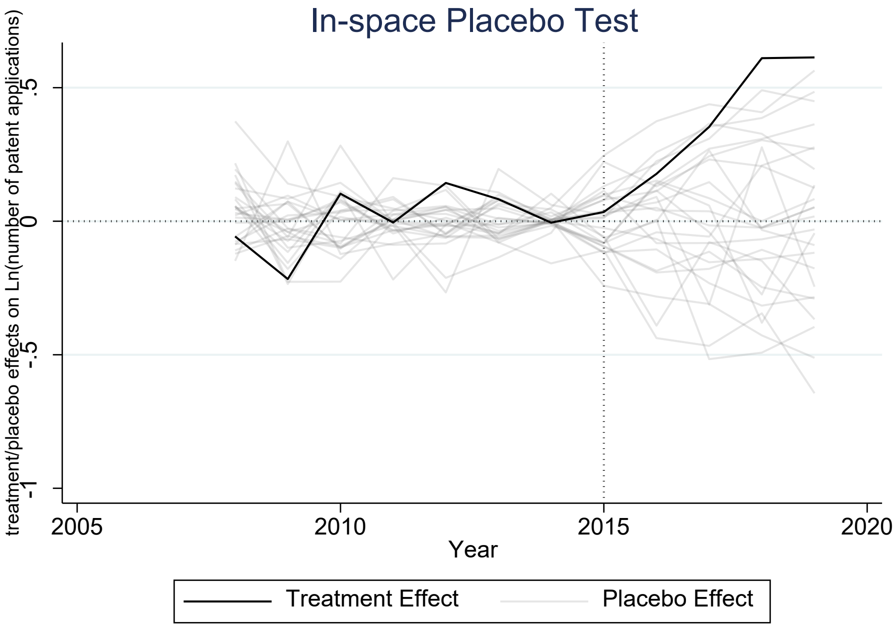


Figure 10. *Logarithm of Patent Application Gaps in SWJTU and Placebo Gaps in Control Universities (Excludes Universities with Pre-MOR MSPE Two Times Higher Than SWJTU's)*

Figure 11 displays the result of research direction. The gray lines represent the MOR effect on ratio of funding allocated to basic research for each university in the control group respectively, while the solid black line denotes the effect for SWJTU. As shown in Figure 11, the effect line for SWJTU is, in general, large relative to the distribution of the control universities' lines after MOR implementation, which demonstrates the significant negative impact of MOR on funding allocated to basic research.

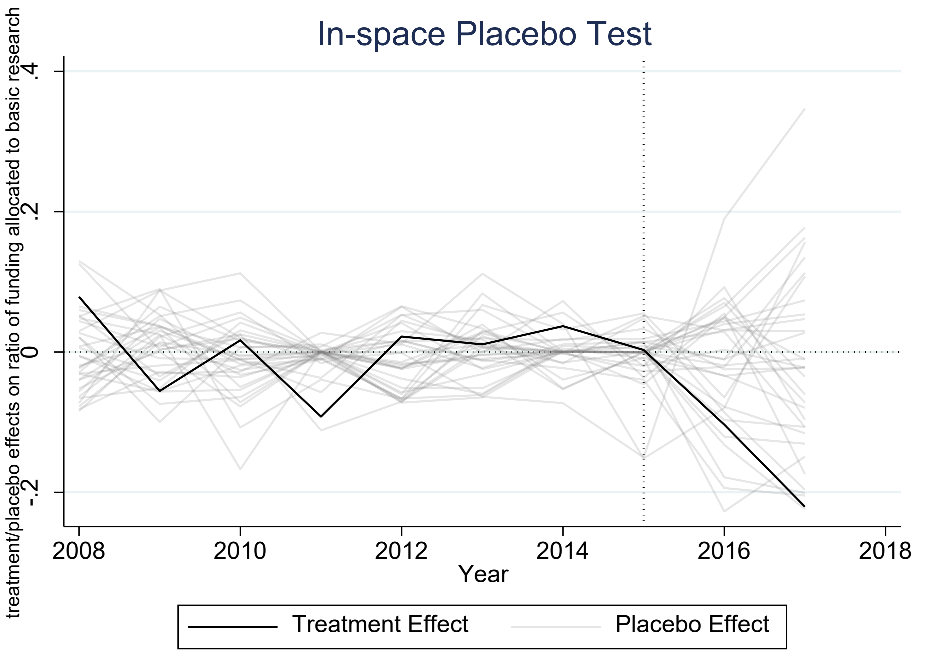


Figure 11. *Ratio of funding allocated to basic research Gaps in SWJTU and Placebo Gaps in Control Universities (Excludes Universities with Pre-MOR MSPE Two Times Higher Than SWJTU's)*

6. Discussion and Conclusions

The TRR and MOR are important explorations made in a typical emerging market, China, to promote patent commercialization in universities. Our results revealed that the two opposite models for the allocation of university patent ownership produce different outcomes, with TRR favoring an increase in the number of patent licenses and MOR favoring an increase in patent sales. As the two main models for patent commercialization, the choice between licensing or sales should have been made by the implementing entity based on the quality and other characteristics of the patent. However, the different impact of TRR and MOR on patent commercialization is actually due to the special institutional environment in China. When university patents are managed as state-owned assets, Chinese universities can only commercialize their patents through patent licensing to avoid the risk of losing state-owned assets. The uncertainty of MOR, meanwhile, made inventors more willing to obtain short-term income through patent sales, so the impact of MOR was only reflected in increasing the patent sales.

The TRR and MOR also have different effects on the patent application and research orientation of universities. For the TRR, researchers are aware that university patents managed as state-owned assets are less likely to be commercialized. This makes it difficult to motivate inventors to apply the patents and change their research orientation. In contrast, the MOR grants inventors a larger share of patent rights, thereby incentivizing inventors to apply for patents. However, due to inconsistencies between the form of patent rights granted to inventors under MOR and the provisions of the existing legal system, the uncertainty of MOR also makes researchers more focused on short-term gains, which tends to shift their R&D projects to low-level applied research.

It is thus difficult to make a judgment call on which of these two models is more conducive to promoting patent commercialization. On the one hand, under both TRR and MOR, the impact on patent commercialization is constrained by institutional factors. These limitations prevent rights holders from selecting the appropriate commercialization method based on the characteristics of the patent. On the other hand, although the number of patent applications has increased under the MOR, universities' R&D investment has been steered towards low-level incremental innovations.

These findings remind us that when formulating policies, policy-makers should pay close attention to the influence of the institutional context on outcomes. Problem-solving needs to start with the external institutional environment. For the TRR and MOR, the nature of Chinese universities as public institutions, the state asset management system for university patents and the institutional stability represent significant institutional constraints. To this end, the following strategies are recommended for policymakers:

First, whether we choose TRR or MOR, only by clarifying that university patents are not managed as state-owned assets can a stable and effective incentive for patent commercialization be provided.

Second, the legal issues related to MOR must be clarified as soon as possible to ensure the stability of ownership, so university patent inventors can form long-term stable expectations. This would allow inventors to conduct relevant basic and applied research according to their real needs, rather than being pushed into short-term, profit-driven research.

Finally, university researchers are often poor at patent commercialization operation and management; they often sell patents to save time and effort. While giving the vast majority of ownership rights to inventors, universities should also take an active role. University technology managers should fully leverage their role. If universities can establish professional technology transfer teams to manage patents and connect patent commercialization channels to continuously improve patent maturity (Choudhury, Khanna, and Makridis, 2020), enterprises would be more willing to cooperate with universities to facilitate patent licensing. Patent licensing could then become a stable source for nurturing universities' R&D.

In summary, institutional change does not operate in isolation. To achieve the desired effect, it is necessary to analyze whether the institutional changes are consistent with the relevant regulative, normative, and cognitive-cultural institutional environment. This paper is therefore related to the broader IP policy debate that blind harmonization of IP worldwide without considering national context could lead to frustrated expectations of innovation boosts (Qian, 2007, 2009). In cases of inconsistency, our research suggests ways to adjust and adapt to achieve the expected effect of the institutional changes. As long as the relevant institutional obstacles and uncertain expectations are addressed effectively, it is believed that both the TRR and MOR can effectively incentivize patent commercialization and promote a virtuous cycle of university innovation and commercialization. While the findings of this study are based on the reform context of patent ownership in Chinese universities, they are also applicable to countries similar to China that manage university patents as state assets. Treating patents as state assets leads to a situation where, despite the desire of all parties to maximize the value of patents through commercialization, concerns about the risk of losing state assets reduce the motivation of both universities and inventors to promote commercialization. The result is a tragedy of the commons. This study therefore serves as a reminder to scholars that, when studying policy impacts, they should fully consider the influence of the institutional context in which the policy is implemented on its effectiveness.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data Availability

Data will be made available on request.

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Appendix

Table A1 Comparison of R&D levels of Chinese Universities by Affiliation (2014)

	Central ministry-affiliated institutions	**Universities directly under the Ministry of Education**	**Local government-owned universities**	**Total**
Quantity	27	64	1058	1146
Number of R&D personnel	19072	116138	234300	369510
Average number of R&D personnel	706.37	1903.9	221.46	
R&D funds allocated	11495754	42315738	28693908	82505400
Average R&D funds allocated	425768.67	693700.62	27120.9	
R&D expenditure	8719224	35043779	23231515	66994518
Average R&D expenditure	322934.22	574488.18	21957.95	
Number of patents granted	5233	28614	48522	82369
Average number of patents granted	193.81	469.08	45.86	

Note: The summary statistics were based on the 2015 compilation of science and technology statistics of Chinese higher education institutions (Department of Science and Technology, Ministry of Education, P. R. China, 2015). The units of the R&D funds and expenditure variables are in thousands of RMB, and the numbers for universities and patents are in numbers as listed. The units of R&D personnel are in persons.

Table A2 Prerequisites for TRR Pilot University Selection

	(1) Universities in the TRR (2011)	(2) Universities in the TRR (2013)
Ln (R&D personnel)	-1.943** (0.770)	-0.892** (0.408)
Ln (graduate students)	0.593 (0.609)	-0.375 (0.316)
Ln (sci-tech funds)	1.446* (0.772)	1.376*** (0.457)

Ln(patent applications)	-1.502*** (0.549)	-0.902*** (0.334)
Ln(Marketization)	8.639*** (3.183)	4.541*** (1.282)
N	120	192
Pseudo R^2	0.342	0.111

Note: The model controls for year-fixed effects. All explanatory variables are first-order lagged terms.

Table A3 Covariates-Balance Test

		2009		2011		2013		2015	
Covariate		%bias	t	%bias	t	%bias	t	%bias	t
Ln (R&D personnel)	Un-matched	-44.6	-1.67	-25.0	-0.91	-24.7	-0.91	-33.4	-1.25
	Matched	-5.8	-0.21	20.0	0.71	5.6	0.20	1.6	0.06
Ln (graduate students)	Un-matched	9.9	0.36	5.0	0.18	-13.5	-0.50	-8.6	-0.32
	Matched	2.5	0.08	25.3	0.84	1.0	0.03	20.7	0.67
Ln (sci-tech funds)	Un-matched	-5.8	-0.21	-4.9	-0.18	-14.1	-0.52	-20.9	-0.79
	Matched	-5.8	-0.21	3.4	0.13	-1.2	-0.04	-7.9	-0.29
Ln (patent applications)	Un-matched	-34.7	-1.31	-29.9	-1.08	-37.5	-1.4	-46.7	-1.74
	Matched	2.4	0.10	-7.6	-0.28	-4.2	-0.15	2.3	0.08