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THE IMPACT OF UNIVERSITY PATENT OWNERSHIP ON COMMERCIALIZATION

Jun Wang
Yi Qian

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ABSTRACT

In recent years, China has sought to promote the commercialization of patents at universities, notably through the three rights (26 universities) and mixed ownership (3 universities) 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 in question, while the mixed ownership approach allocates the majority of patent ownership to the inventors. We empirically tested the effects of these two patent ownership allocation models on the commercialization of patents using Chinese patent data and university statistics. We found that the institutional environment (i.e., patent management system) caused unexpected effects in both reform models. The three rights reform has a significant impact on patent licensing, while the mixed ownership reform has significantly increased patent sales while tilting research and development (R&D) toward research with relatively low creativity. These findings yield broader implications for the organization and commercialization of innovations, and this paper contributes to the literature on innovation policies governing the conditions for effective institutional changes.

Jun Wang
Intellectual Property Research Institute
Xiamen University
Siming District, Xiamen City
Fujian Province
P.R.China
junwang@xmu.edu.cn

Yi Qian
Sauder School of Business
University of British Columbia
2053 Main Mall
Vancouver, BC V6T 1Z2
and NBER
yi.qian@sauder.ubc.ca

1 Introduction

Are institutional changes to be consistent with other aspects of the institutional environment to have the intended impact (Eesley, Li, & Yang, 2016; Scott, 2014)? This issue is still not well understood. The institutional environment encompasses more than just the background conditions (Meyer, Estrin, Bhaumik, & Peng, 2009); it directly influences the strategic actions available to an organization (Ingram & Silverman, 2002). Previous studies have emphasized that institutional voids or changes affect the mechanisms for market rewards and sanctions as well as organizations' strategic behaviors (Bothello, Nason, & Schnyder, 2019; Gao, Zuzul, Jones, & Khanna, 2017; Hirsch, 1975; Tolbert, David, & Sine, 2011), but have ignored other conditions of the institutional environment that could become important constraints for the expected effects of institutional changes. This is particularly likely in emerging markets, which tend to favor the transplantation of existing systems from developed countries in their institutional changes. However, theories and findings from developed market settings are not necessarily applicable in emerging market contexts (Khanna, 2014; Marquis & Raynard, 2015), perhaps because institutional change ignores differences in other environmental conditions, which makes it difficult to achieve the effect desired from the institutional change.[i] We therefore bridge this gap by examining a form of specific institutional change.

A clear understanding is especially necessary in the context of innovation (Prabhu, Chandy, & Ellis, 2005). Universities play an important role in national innovation systems (Cai & Liu, 2015; Leydesdorff & Etzkowitz, 1998; Liu & Huang, 2018), and many inventions that have had an important impact on human development also originated from universities.[ii] Existing research on university innovation has primarily focused on characteristics such as the quantity and quality of university patents (Fisch, Block, & Sandner, 2016; Zhang et al., 2023). There have also been studies highlighting the challenges of commercializing university patents. However, explanations for the low level of

commercialization have primarily focused on the immaturity of university patents and the high uncertainty of their value (Gambardella, Giuri, & Luzzi, 2007; Thursby, Jensen, & Thursby, 2001; Thursby & Thursby, 2002).

The ownership of university patents remains an important problem. University patents funded by government research programs, although filed in the name of the university, are essentially owned by the government, but governments often lack the incentive and ability to commercialize them. This results in a lack of implementers to promote the commercialization of these patents. To combat this, two models of inventor and university ownership of university patents have emerged: (a) Japan and most European countries assign ownership of university patents to the inventors (i.e., "professors' privilege"; Organization for Co-operation and Development [OECD], 2003); and (b) America passed the Bayh–Dole Act in the early 1980s, which allowed universities to retain the patent rights to the research findings arising from federal research grants (Hackett & Dilts, 2004). However, existing research on the impact of university patent ownership changes in the United States, Europe, and other countries has reported inconsistent results, even for the same university patent ownership (Henderson, Jaffe, & Trajtenberg, 1998; Mowery, Nelson, Sampta, & Ziedonis, 2001; Mowery & Sampat, 2004; Mowery, Sampat, & Ziedonis, 2002; Mowery & Ziedonis, 2002; Sampat, 2006).

Why do seemingly identical university patent ownership systems produce different commercialization outcomes? Are there other institutional conditions that influence the effectiveness of patent ownership systems? In this paper, we examine how changes in two different university patent ownership institutions affect patent commercialization in China and what institutional factors moderate the desired effects of patent commercialization. Emerging markets like China have long faced the problem of low efficiency in their attempts to commercialize university patents. Influenced by the remarkable results achieved by the transfer of university patent ownership from the state to

universities in the United States,[iii] China has essentially copied the content of the Bayh–Dole Act since 2002. The law stipulates that, except in special circumstances, the intellectual property rights (IPR) arising from the research results of funded national scientific projects are granted to the project-executing unit. However, the transplantation of the Bayh–Dole Act to China has not had the desired effect: most patents in universities remain inactive (Gong & Peng, 2018; Luan, Zhou, & Liu, 2010).

China has continued to promote the commercialization of university patents by reforming the patent ownership system. Upon reflection, policymakers concluded that the main reason for the failure was that Chinese universities, unlike US universities, do not acquire ownership rights in the sense of independent and autonomous disposal of patents. Since 2011, China started a patent ownership reform (hereinafter referred to as the Three Rights Reform [TRR]), which granted central-level public institutions (including universities directly under the Ministry of Education) three rights for university-owned patents—usus (the right to use), disposal (the right to handle), and fructus (the right to the fruits of the property)—in Beijing, Wuhan, Shanghai, and Hefei. This changed the status quo of universities with only nominal patent ownership.

China is also exploring a reform similar to some European countries that would give professors ownership of university patents (Martínez & Sterzi, 2021). In the context of the central government's support for pilot programs in Sichuan Province and the nationwide promotion of the TRR policy, in 2016, Southwest Jiaotong University (SWJTU), located in Sichuan Province, adopted a model in which patent rights are shared between the university and the inventor. SWJTU decided to transfer a substantial portion (70%) of patent ownership that originally belonged to universities to inventors, thus realizing a reform comprising mixed patent ownership. The ex-post reward for inventors is thus transformed into an ex-ante property rights incentive, which also changes the attribute of state assets of university patents and theoretically helps to increase the incentive of inventors to participate in

patent commercialization. This mixed ownership reform (MOR) was supported by the local government; the MOR pilot was then extended to other universities in the same province. It was then gradually recognized by the central government, which issued a document in 2020 to launch more MOR pilot projects in 40 Chinese universities and research institutes.

China's two pilot projects provide a unique quasi-natural experiment to analyze the impact of different university patent ownership regimes within a single country. We found that the two different patent ownership regimes have different impacts on commercialization and research direction; this result goes against the expectations of the implementers of the institutional change. A reasonable explanation for this needs to consider the effects of the institutional environment outside the patent ownership regime, particularly the management of patents as state assets in Chinese universities, as this is an important factor influencing the strategic behavior of patent-related subjects in universities.

This article makes a twofold contribution: first, it enriches the understanding of the relationship between university patent ownership models and the institutional environment by identifying that the impact of changes in the university patent ownership models is constrained by the state-owned asset management system for university patents, which significantly limits the effectiveness of the patent ownership system on patent commercialization. Second, the adjustments in university patent ownership in existing studies were made uniformly across countries, which has made it difficult to select an appropriate control group to exclude the influence of other institutional environment factors. It is difficult to make accurate causal inferences based on cross-country studies (Giuri et al., 2013). China's pilot projects thus provide useful within-country variations that overcome the challenge of suitable control groups. It may thus be helpful for identifying the impact of changes in patent ownership at different universities on patent commercialization and the orientation of university research with maximum precision. The results provide a reference for China (and other countries) to

implement effective reforms in university patent ownership.

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 gives the conclusions and insights.

2 Conceptual Framework and Hypotheses

2.1 Literature Review

Promoting the commercialization of university patents from the perspective of changes in ownership began in the United States. In December 1980, the United States passed the Bayh–Dole Act, which granted ownership of intellectual property rights generated by government-funded research projects to the universities, small businesses, and non-profit organizations that completed the projects. This change seemingly achieved the results expected. In 1965, only 96 patents were granted to 28 U.S. universities, yet about 1,500 patents were granted to 150 universities by 1992, reflecting a 15-fold increase, although total U.S. patents increased by less than 50% during the same period (Henderson et al., 1998). Inspired by this success, Denmark, Germany, Austria, Norway, Finland, and other major European countries began to gradually move away from inventor ownership toward university ownership of patent rights in 2000.

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 & Sampat, 2004; Mowery et al., 2002; Mowery & Ziedonis, 2002; Sampat, 2006). However, previous studies have reported inconsistent results for the same university patent ownership. For example,

Mowery and Sampat (2005) constructed a trend chart reflecting the number of university patent applications, the proportion of university patents to total patents, and the number of university patents per capita of R&D investment in the United States from the 1960s to the 1990s. They found that the implementation of the Bayh–Dole Act did not have a structural impact on these indicators. Between the late 1960s and the 1990s, the number of patents stayed on a relatively stable growth trajectory. 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 number 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, Geuna, Nomaler, and Verspagen (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 commercialization 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 & Sampat, 2005). 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 commercialization. To identify the real impact of the patent ownership system reform on patent commercialization 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.[iv] Chinese universities also differ from public universities in countries such as the United States. Chinese universities are classified as public institutions (*shiye danwei*) and possess a unique organizational nature that combines the roles of both public and private legal entities. The fact that they assume government functions means that, the university's operating funds mainly come from government allocations, so

the incentives to commercialize patents are limited. Universities also cannot obtain income from patent commercialization directly.[v] Such provisions also reduce universities' enthusiasm to commercialize patents. Using university patents also requires following the same procedures needed to use other state-owned assets;[vi] the complicated procedures and potential risk of the loss of state assets further hinder university patent commercialization (He & Chen, 2013; Zhu, 2016).

It is, however, true that China has formally copied the content of the Bayh–Dole Act (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) and that patent ownership derived from government-funded research findings was formally granted to universities. 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,[vii] 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 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. Although universities have acquired real ownership of patents, the risk of losing state assets associated with commercialization, such as patent transfers, makes universities less motivated to promote commercialization. In addition, relying only on rewards with great uncertainty without granting patent ownership to inventors is not an effective incentive for inventors to participate in patent commercialization.

Therefore, the central government's "Overall Program for Systematically Promoting Comprehensive Innovation and Reform Experiments in Selected Regions," which granted early implementation to Sichuan Province as a pilot innovation and reform zone, along with the nationwide implementation of the TRR, provided the foundation for SWJTU to explore the implementation of another reform of university patent ownership within the university. 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, and the inventor acquires the decision-making power to commercialize the patent. The change in the nature of the property rights of university patents provides an incentive for the inventor to participate in the commercialization of the university patent, while it also overcomes the concern that the commercialization of university patents may result in the loss of state assets.

MOR had a direct effect: Within just over a year of MOR implementation, more than 168 patents were divided and validated, and 16 high-tech start-ups were established. In contrast, from 2010 to 2015, SWJTU only had a total of 14 patent transfers and licenses.[viii] Therefore, motivated by the good results, the Sichuan provincial government selected another 10 universities to carry out MOR pilot projects in 2016 (Gu and Xiong, 2017). The positive results achieved led to the MOR gradually being recognized by the central government. In May 2020, the Ministry of Science and Technology and nine other departments issued the "Pilot Implementation Plan for Granting Researchers Ownership or Long-term Use of Scientific and Technological Achievements on Duty" and selected 40 universities and research institutions nationwide to conduct MOR pilot projects. The Patent Law revised in October 2020 also emphasized that units have the right to dispose of the patent rights of inventions on duty, so MOR has largely cleared the legal hurdle.

It is noteworthy in the first batch of MOR pilots that, compared with other pilot universities, SWJTU has taken a greater step toward reform than the other universities involved. In November 2016, SWJTU introduced 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. In addition to the MOR, SWJTU thus also implemented a reform of the patent management system.

MOR has important theoretical and practical significance. The model of sharing patent rights between inventors and universities is an original institutional arrangement with the theoretical advantages of both university and inventor ownership. Can both universities and inventors be incentivized to participate in patent commercialization? Are there likely to be unintended effects? These questions require further research to determine the effects of MOR and to inform improvements in the larger MOR pilot currently underway.

Implementing the TRR at 26 universities expanded university patent rights, which allowed universities to acquire real patent ownership. MOR extended patent ownership from universities to inventors, thus making the inventor the main implementer of commercialization for university patents. What effects, in practice, do these different ownership structures have? We hypothesized and analyzed the effects of different patent ownership models on university patent commercialization and research orientation based on the two pilot projects discussed above.

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 & 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 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. Chinese public universities are a special category of institutions (*shiye danwei*), and their scientific and technological achievements are recognized as state assets. The desire to avoid the risk of losing state assets during patent commercialization reduces the incentive for Chinese universities to commercialize their patents. As a result, when only ex-post rewards are available, inventors expect great difficulty in obtaining rewards; even if a return is achieved, it is often limited to the income generated by patent licensing, which does not involve a change in the patent rights.

Although the TRR requires universities to reward inventors with a certain percentage of their income after patent commercialization,[ix] 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 turn, the impact on universities may be limited to incentivizing commercialization through patent licensing, where there is no change in patent ownership and thus no risk of the loss of state assets.

In MOR, however, a majority of the patent rights are assigned to the inventor *ex-ante*, thus giving the inventor an incentive 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 allow inventors to choose more short-sighted forms of commercialization and research in the absence of stable expectations, while the system of managing university patents as a state asset may also limit their choices in terms of the form 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 universities and inventors choose their patent commercialization strategies? 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, Lee, & Kim, 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.

We also believe that SWJTU's patent management system reform could affect the form of patent sales. The nature of university patents as state-owned assets limits their commercialization. SWJTU's reform of managing university patents without treating them as state-owned assets has a primary impact: the university need no longer be concerned about the loss of state-owned assets during patent commercialization. As a result, SWJTU's approach to assigning patent rights to inventors may be more regulated compared with the approaches adopted by other universities. After comparing the relevant patent management documents of universities implementing the MOR reforms, it was found that only SWJTU clearly stipulates in its regulations that for established and

newly applied patents, the rights will be confirmed by applying to the State Intellectual Property Office (SIPO) for a change of right holders, while other pilot universities have not made explicit provisions regarding the formalities for changes in patent rights.

Indeed, other universities have generally adopted an ambiguous treatment. 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,[x] 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. The legal formalization of patent sales is of great significance for patent commercialization. By enhancing the stability of rights through standardized legal empowerment, the incentives for inventors in the commercialization process are increased, but potential buyers may be more inclined to acquire patents with formalized and well-regulated transfers of rights. We thus develop the following hypothesis:

Hypothesis 2: Whether or not university patents are managed as state assets has an impact on the formalization of patent rights confirmation, which in turn affects the form of patent sales. Universities that do not manage their patents as state assets are more likely to increase the number of legally formalized patent commercialization sales.

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 could 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, Kannankutty, & Strickland, 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, Thursby, & Gupta-Mukherjee, 2007).

However, although the TRR has enabled universities to obtain real patent rights, university researchers still understand that Chinese universities do not have a strong incentive to commercialize patents and 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. Both in theory and in reality, 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 research 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 patent data were published by 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),"[xi] which includes relevant statistical data on research projects, R&D expenditures, number of R&D personnel, and the research orientation of various universities. Our sample only included Chinese universities directly under the jurisdiction of the Ministry of Education. Although these 64 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 expenditure, and 34.74% of the number of patents granted in Chinese universities.[xii] Thus, these universities represent the highest level of research Chinese universities, which makes the findings here salient to better understand the operation of patent commercialization for core innovations in the context of reform.

The TRR was first implemented in 2011 at 12 universities under the jurisdiction of the

Ministry of Education in Beijing and then extended to 14 universities under the same jurisdiction in Wuhan, Shanghai, and Hefei in 2013. 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. The MOR was first adopted by SWJTU in 2016, a further 10 universities in Sichuan province—including Sichuan University and the University of Electronic Science and Technology, which are directly under the Ministry of Education—then joined the pilot in 2017. Three universities under the jurisdiction of the Ministry of Education were used as the treatment group for this study. In October 2020, the Ministry of Science and Technology issued a notice that significantly expanded the scope of the pilot to implement MOR.[xiii] Correspondingly, other universities under the jurisdiction of the Ministry of Education served as the control group; 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.

In summary, we defined two observational periods: 2008–2015 for the TRR and 2008–2020 for the MOR. Table 1 shows the key timing and policies for the two reform pilots. For TRR and MOR, if the pilot program began in the first half of the year, we considered the same year as the pilot implementation year. However, if it began in the second half of the year, we considered the following year as the pilot implementation year.

Table 1. Timetable and specific policies for implementing TRR and MOR

TRR			MOR		
Year. month	Target	Specific policies	Year. month	Target	Specific policies
2011. 2	Central-level institutions in Beijing	Notice on the Pilot Reform of the Right to Dispose of Scientific and Technological Achievements of Central-level Institutions in Zhongguancun National Independent Innovation Demonstration Zone; Opinions on the Reform Pilot for the Management of Income Rights from Scientific and Technological Achievements by Central-Level Institutions in the Zhongguancun National Innovation Demonstration Zone	2016. 1	Southwest Jiaotong University	Patent Management Regulations of Southwest Jiaotong University
2013. 11	Central-level institutions in Wuhan, Shanghai and Hefei	Notice on expanding the scope of the pilot reform of the management of disposal rights of scientific and technological achievements of central-level institutions and extending the pilot period	2017.3	10 universities including Sichuan University and University of Electronic Science and Technology	Implementation Program for the Pilot Reform of Mixed Ownership of Ownership of Functional Scientific and Technological Achievements in Sichuan Province
2015. 8	Nationwide	Promote the transformation of scientific and technological achievements law	2020.1 0	40 universities and research institutions	Pilot Implementation Plan for Granting Researchers Ownership or Long-term Use of Scientific and Technological Achievements on Duty

3.2 Empirical Strategy

Early domestic and foreign policy changes in university patent ownership were one-size-fits-all. However, it is hard to identify the causal effects of this policy, because it is difficult to determine whether the changes before and after the policy were driven by corresponding time trends or other factors not included in the model. 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. The DID method uses forward and backward changes in the control group to estimate the impact of the trend change, while eliminating this type of effect in the

estimation results. 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,[xiv] thus representing the highest caliber of Chinese universities; this ensured that the treatment and control samples were as similar as possible. To ensure the robustness of the research results, we also used the staggered DID method for robustness checks; specific results can be found in Appendix 1.

In the DID model, we controlled the variables related to human and physical capitals. In addition, to ameliorate omitted variable bias from unobservables, 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.[xv] The two-way fixed-effect panel model based on the DID was developed as follows:

$$Y_{i,t} = \beta policy_{i,t} + \gamma' X_{i,t-1} + \eta_i + \mu_t + \varepsilon_{i,t} \quad (1)$$

where $Policy_{i,t}$ represents the 26 universities in the TRR and 3 universities in the MOR; 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, $Policy_{i,t}$ was 1, otherwise it was 0. 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 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, the number of contracts for the sale of patents, and the revenue from the sale of patents as proxy variables, where the number of patent transfers is the number of patent transfers registered in the SIPO, and research orientation was proxied by the share of basic research in the university's R&D investment and expenditure.

The selection of universities participating in the TRR and MOR pilot may be non-random. The selection was probably influenced by university characteristics, thus making the model estimation results biased by whether the university enters the pilot variable $Policy_{i,t}$ 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 $X_{i,t-1}$ was included to mitigate the possible bias in estimates due to the endogeneity of the TRR and MOR 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, and investment in sci-tech funds 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 3 reveal that the selection of TRR pilot universities was influenced by the R&D personnel, the number of graduate students, and investment in sci-tech funds. Therefore, a first-order lagged term of these variables are included in the regression model to control for possible endogeneity in the selection of universities participating in the TRR.

Given that only SWJTU implemented MOR in the treatment group, we were unable to identify a university in the control group with characteristics similar to SWJTU in all aspects to examine the impact of SWJTU's decision to manage patents without treating them as state-owned assets. The DID method may not be applicable for assessing the effects of MOR effects. Following Arkhangelsky, Athey, Hirshberg, Imbens, and Wager (2021),[xvi] we used the synthetic difference-in-difference (SDID) approach to construct a synthetic SWJTU with similar characteristics to all aspects of SWJTU by

linearly combining other universities in the control group and comparing the two to obtain the true effect of SWJTU's MOR.

4 Empirical Findings

4.1 Impact on University Patent Commercialization

The direct purpose of the TRR and MOR was to promote universities' patent commercialization. Tables 2 and 3 show the effects of the two types of pilot reforms on patent sales and licensing. We found that both TRR and MOR had a significant and positive impact on patent commercialization, but there were differences in how this manifested.

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

	(1)	(2)	(3)	(4)
	Ln (Patent transfers)	Ln (Patent sell contracts)	Ln (Patent transfer income)	Ln (Patent licenses)
Policy	-0.167	-0.044	0.444	0.328**
	(0.214)	(0.221)	(0.473)	(0.129)
Ln (R&D personnel)	-0.215	0.337	0.037	-0.272
	(0.247)	(0.382)	(0.701)	(0.248)
Ln (graduate students)	0.026	0.040	0.098	0.267
	(0.215)	(0.169)	(0.399)	(0.239)
Ln (sci-tech funds)	0.172	0.155	0.870	0.185
	(0.375)	(0.243)	(0.686)	(0.215)
Year FE	Yes	Yes	Yes	Yes
University FE	Yes	Yes	Yes	Yes
Obs.	420	419	419	420
Adjusted R^2	0.601	0.749	0.606	0.658

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%.

Table 3. *The Effects of MOR on Patent Commercialization in Universities*

	(1)	(2)	(3)	(4)	(5)
	Ln (Patent sell contracts)	Ln (Patent transfer income)	Ln (Patent licenses)	Ln (Patent transfers)	SWJTU Ln (Patent transfers)
Policy	0.688**	1.558**	-0.414	0.386	1.421**
	(0.320)	(0.772)	(0.309)	(0.397)	(0.659)
Ln (R&D personnel)	0.250	0.001	-0.181	0.158	
	(0.323)	(0.634)	(0.150)	(0.187)	
Ln (graduate students)	-0.078	-0.289	0.096	0.036	
	(0.223)	(0.432)	(0.099)	(0.107)	
Ln (sci-tech funds)	0.210	0.653	0.051	0.078	
	(0.313)	(0.637)	(0.141)	(0.229)	

Year FE	Yes	Yes	Yes	Yes	Yes
University FE	Yes	Yes	Yes	Yes	Yes
Obs.	539	539	720	720	720
Adjusted R^2	0.713	0.595	0.540	0.688	

Note. Column 5 presents the estimates obtained using the synthetic DID method, with university characteristic variables controlled.

The TRR had a significant positive impact on the number of patent licenses at the 5% level, but no significant impact on sales; the MOR had a significant positive impact on patent sales, but no significant impact on licenses. After implementing MOR, the number of patent sales contracts increased by an average of 95.03% and the revenue from patent sales increased by an average of 374.93% compared with universities that did not implement MOR.

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 only 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 United States 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.

Regarding the impact of SWJTU's decision to manage patents without treating them as state-

owned assets, it is worth noting from Columns (1)–(4) of Table 3 that the MOR had a significant effect only on the number of patent sales contracts and the sales amount, but was not significant in terms of the number of patent transfers registered with SIPO. However, from the results in Column (5), it can be seen that SWJTU, which no longer manages its patents as state assets, registered significantly more transfers in the SIPO system than did other universities. This confirms Hypothesis 2—namely, that whether or not university patents are managed as state assets has a significant impact on the form in which university patents are commercialized. Managing university patents without treating them as state-owned assets has increased the formalization of SWJTU's legal process for patent transfers, thus enabling SWJTU to register a higher number of patent transfers through the SIPO system.

4.2 Impact on Universities' Research Orientation

We further explored the empirical implications of the two pilot programs on research orientations, which we measured using the proportion of funding allocated and expenditure on basic research, respectively. Considering that university–industry collaboration in research and development may influence the research direction of universities, we have added the proportion of university R&D funding sourced from enterprises as a control variable. The results are shown in Table 4.

Table 4. *The Effects of Pilot Reform on Research Orientation*

Variables	TRR		MOR	
	Proportion of funding allocated to basic research	Proportion of expenditure on basic research	Proportion of funding allocated to basic research	Proportion of expenditure on basic research
Policy	0.013	-0.003	-0.069**	-0.061**
	(0.026)	(0.027)	(0.026)	(0.024)
% of corporate R&D investment	0.033	0.085	-0.020	0.010
	(0.117)	(0.114)	(0.111)	(0.118)
Ln (R&D personnel)	0.021	0.014	0.001	-0.002
	(0.041)	(0.043)	(0.036)	(0.038)
Ln (graduate students)	0.012	0.021	0.016	0.027
	(0.025)	(0.027)	(0.024)	(0.025)
Ln (sci-tech funds)	-0.020	-0.027	-0.037	-0.047
	(0.062)	(0.061)	(0.054)	(0.057)
Year FE	Yes	Yes	Yes	Yes

University FE	Yes	Yes	Yes	Yes
Obs.	420	420	540	540
Adjusted R^2	0.690	0.678	0.692	0.674

We found that the TRR had no significant impact on the research orientation, while the MOR significantly reduced the share of inputs and expenditures for basic research. This 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 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 or MOR 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:

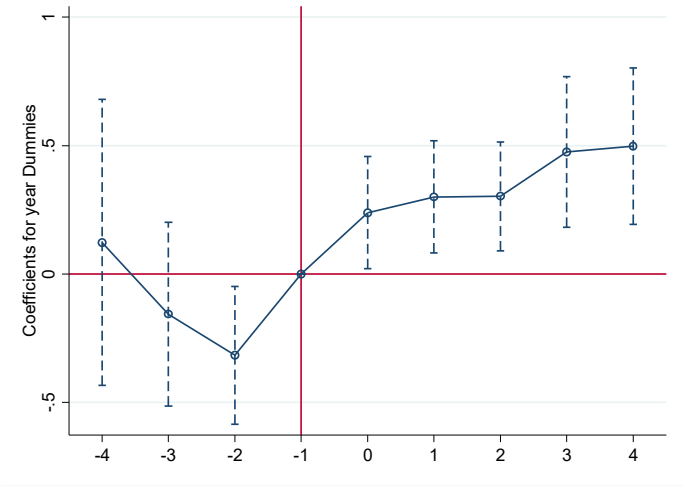
$$Y_{it} = \sum_{j=-4, j\neq -1}^{n} \theta_j T_{it}^{j} + \lambda X_{i,t-1} + \eta_i + \mu_t + \varepsilon_{it} \quad (2)$$

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 or MOR and is in the jth year after being listed, and T_{it}^{j}=1 when j<0 if university i is a university that will participate in the TRR or MOR and is in the jth year before being listed. We used the year prior to the university's participation in the TRR/MOR 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

commercialization and research orientation between the treated and control groups in the year *j* after (or the year before) the university's participation in TRR or MOR. 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, patent sales income, and proportion of expenditure on basic research, where the control group was the period before policy implementation. The results are shown in Figures 1–3. Figure 1 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. Figure 2 shows that there was no significant difference in patent sales income between MOR universities and other universities in the control group. After the implementation of the reform, we found that the income from patent sales was significantly higher for MOR universities than for the control group universities, and the policy effects of MOR on this income gradually increased over time. Figure 3 shows that there was no significant difference in the proportion of expenditure on basic research between MOR universities and other universities in the control group even 2 years after MOR implementation, but from the third year onwards the proportion of expenditure on basic research was significantly lower for MOR universities than for the control group.

Figure 1. *Parallel-Trends Test of Patent Licenses: TRR versus Universities in the Control Group*



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

Figure 2. *Parallel-Trends Test of Patent Selling Income: MOR versus Universities in the Control Group*

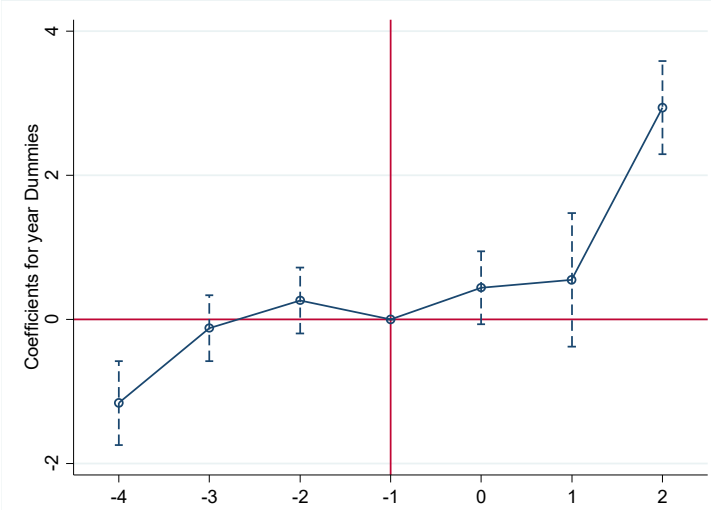
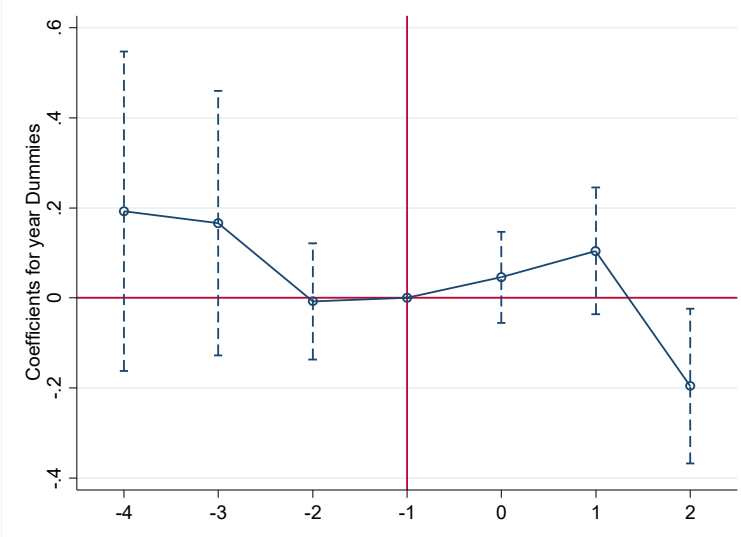


Figure 3. *Parallel-Trends Test of Proportion of expenditure on basic research: MOR versus Universities in the Control Group*



5.2 PSM-DID

Although the treatment and control groups were universities under the Ministry of Education's jurisdiction, the 26 pilot universities involved in TRR and 3 pilot universities involved in MOR may differ tremendously from other universities; we therefore used propensity score matching with DID to further verify the impact of TRR and MOR. 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 based on the propensity scores. 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.[xvii] After retaining the samples that satisfied the common support assumption, we applied the DID model to further verify the true effects of the TRR and MOR reforms. The DID model is shown in Equation (1). The results are shown in Table 5. We found that the magnitude of the effect was similar to the results using the DID method.

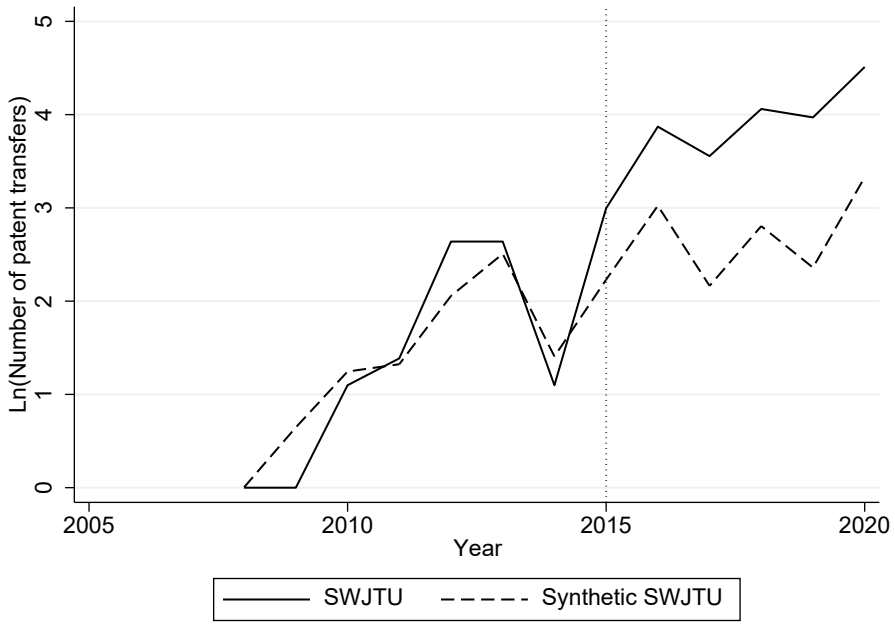
Table 5. *The Effects of TRR and MOR (PSM-DID)*

	(1)	(2)	(3)	(4)	(5)
	TRR			MOR	
Variables	Ln (Patent licenses)	Ln (Patent sell contracts)	Ln (Patent transfer income)	Proportion of funding allocated to basic research	Proportion of expenditure on basic research
Policy	0.300**	0.917**	1.960***	-0.066*	-0.062*
	(0.133)	(0.366)	(0.631)	(0.037)	(0.035)
Ln (R&D personnel)	-0.242	0.777	0.617	0.107*	0.106*
	(0.287)	(0.487)	(0.759)	(0.056)	(0.056)
Ln (graduate students)	0.278	-0.514	-0.819	0.029	0.034
	(0.262)	(0.365)	(0.530)	(0.033)	(0.034)
Ln (sci-tech funds)	0.220	-0.018	-0.120	-0.027	-0.053
	(0.202)	(0.782)	(0.977)	(0.072)	(0.065)
Year FE	Yes	Yes	Yes	Yes	Yes
University FE	Yes	Yes	Yes	Yes	Yes
Obs.	376	268	268	269	269
Adjusted R^2	0.654	0.720	0.674	0.154	0.166

5.3 The Effects of SWJTU's Patent Management System Changes

We use the synthetic control method (SCM) to test the robustness of the effects of SWJTU's changes to the patent management system. The predictive control variables included the number of R&D personnel in universities, the number of graduate students, and the total investment in science and technology. Applying the SCM method, the synthetic SWJTU was composed of four universities: Huazhong Agricultural University, Xidian University, Wuhan University of Technology, and Sichuan University (with weights 0.584, 0.215, 0.198, and 0.003, respectively). Trends in the number of patent transfers between SWJTU and synthetic SWJTU are shown in Figure 4. We found that before the implementation of the patent management system reform at SWJTU, the number of patents transferred by SWJTU and synthetic SWJTU almost converged. However, after the MOR implementation, the number of patent transfers at SWJTU increased significantly compared with synthetic SWJTU, beginning with the year 2015.

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



However, could the above results have occurred by chance? How often would we obtain these

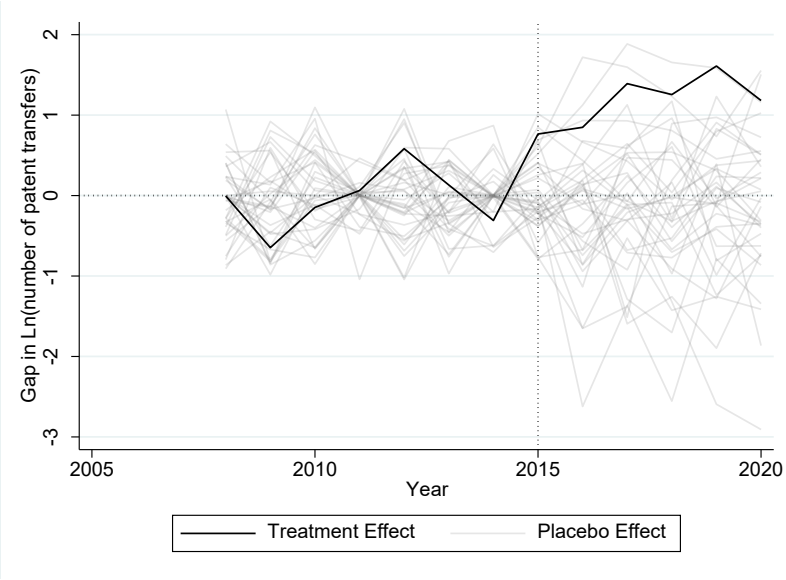
results if we had chosen a university at random instead of using SWJTU? To verify the robustness of the results, we used placebo tests. Based on methods used by Abadie and Gardeazabal (2003) and Abadie, Diamond, and Hainmueller (2010), we ran placebo studies by applying SCM to a university that did not implement the patent management system reform 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. Figure 5 displays the results; the dashed lines represent the MOR effect on patent transfers for each university in the control group, while the solid line denotes the effect for SWJTU. As shown in Figure 5, 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 transfers. The placebo test results were thus consistent with the previous findings.

Figure 5. *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)*



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 6 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 commercialization 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 6, 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 6. *The Effects of TRR on Patent Licensing in Universities*

Variables	985 Universities	985 Universities (including university-level patent policies)
Policy	0.545***	0.517***
	(0.195)	(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).

6. Discussion and Conclusions

As reviewed and proposed in the research agenda for innovations, the impacts of macro-environmental factors such as government policies on innovations are one of the key challenges in organizations and innovations (Hauser, et al. 2006). The 26 TRR universities and 3 MOR universities are important explorations made in a typical emerging market, China, to promote patent commercialization in universities. Which patent ownership allocation model better promotes such commercialization?

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 could be 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, which may be why TRR only significantly increased the number of patent licenses. 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. Whether university patents are managed as state-owned assets affects how they are commercialized. At SWJTU, where patents are not managed as state-

owned assets, the number of patent transfer registrations through the SIPO was significantly higher than at other universities.

The TRR and MOR also have different effects on the research orientation of universities, the anti-commons tragedy of patents caused by the state-owned asset management system has led to the extremely low commercialization level. In this situation, for the TRR, which does not directly affect researcher incentivization, researchers are aware that university patents managed as state-owned assets are less likely to be commercialized through high-reward patent transfers. The instability and relatively lower returns from patent licensing make it difficult to motivate inventors to change their research orientation. The MOR, on the other hand, grants inventors a larger share of patent rights. 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 and the pursuit of personal gain 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. In particular, the management of university patents as state-owned assets restricts the formalization of patent sales under the MOR, hindering the ability to adopt more flexible or suitable commercialization strategies. On the other hand, in terms of its impact on research orientation, the MOR may guide universities' R&D investment to research with a lower level of innovation.

These findings remind us that when formulating policies, it pays for policy-makers to 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 and the state asset management system for university patents represent significant institutional constraints. The management of university patents as state assets restricts certain forms of commercialization as well as affects the legality of patent sales; therefore, with the exception of SWJTU, which explicitly excludes patents from being managed as state assets, so they can be transferred through the SIPO system, the remaining universities sell them in the form of contracts, which undermines the stability of rights and the incentives of the parties to the transaction.
It is thus necessary to promote the commercialization of university patents in China and allow implementing entities the flexibility to adopt appropriate commercialization models based on the characteristics of different patents.

First, whether we choose TRR or MOR, the management system for university patents needs to stop treating them as state assets. 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 commercial operation and management; they often sell patents to save time and effort. While giving the vast majority of ownership rights to inventors, universities also take an active role. University technology managers could fully leverage their role. If universities can establish professional technology transfer teams to manage patents after application and connect patent commercialization channels to continuously improve patent maturity (Choudhury, Khanna, & 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.[xviii]

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 would fully consider the influence of the institutional context in which the policy is implemented on its effectiveness.

Data Availability Statement:

The data that support the findings of this study are available from SIPO. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from China National Intellectual Property Administration (http://english.cnipa.gov.cn) with the permission of SIPO.

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Appendices

Appendix 1 Staggered Difference-in-Differences Robustness Estimation

In the traditional two-way fixed effects difference-in-differences (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 Table A1. 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 A1–A3; the estimated coefficients for different samples are not significant before the implementation of the TRR and MOR pilot programs, which meets the parallel trends assumption. The treatment effect becomes gradually significant after the pilot is implemented, which indicates that the main results are robust.

Appendix 2 Additional Tables and Figures

Table A1. Robust estimator of heterogeneity-Callaway and Sant'Anna (2021)

	(1)	(2)	(3)	(4)	(5)
	TRR			MOR	
ATT	Ln (Patent licenses)	Ln (Patent sell contracts)	Ln (Patent transfer income)	Proportion of funding allocated to basic research	Proportion of expenditure on basic research
Policy	0.701**	0.431***	1.635***	-0.129***	-0.136***
	(0.259)	(0.131)	(0.402)	(0.044)	(0.044)
University Characteristics	Yes	Yes	Yes	Yes	Yes
Obs.	420	418	418	420	420

Figure A1. *Dynamic Effects Trend Graph of Patent Licenses: TRR vs Universities in the Control Group*

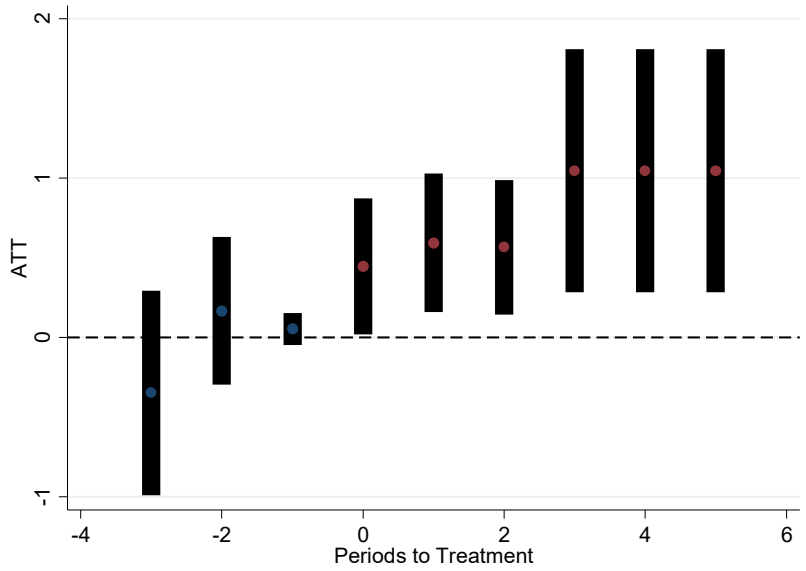

Figure A2. *Dynamic Effects Trend Graph of Patent Sales: MOR vs Universities in the Control Group*

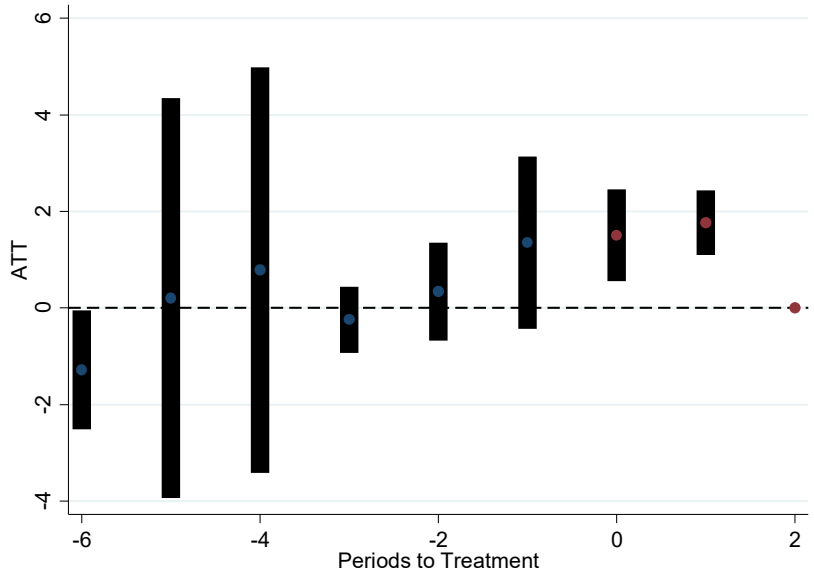

Figure A3. *Dynamic Effects Trend Graph of Proportion of expenditure on basic research: MOR versus Universities in the Control Group*

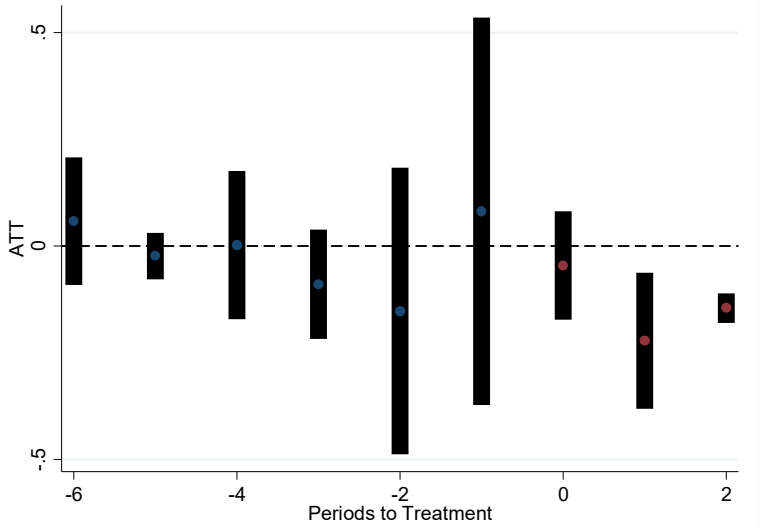

Table A2. Comparison of R&D levels of Chinese Universities by Affiliation (2014)

	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 A3. Prerequisites for TRR Pilot University Selection

	(1) Universities in the TRR (2011)	(2) Universities in the TRR (2013)
Ln (R&D personnel)	-2.438*** (0.693)	-0.860** (0.384)
Ln (graduate students)	1.578*** (0.565)	-0.169 (0.293)
Ln (sci-tech funds)	0.192 (0.539)	0.748** (0.324)
N	120	192
Pseudo R^2	0.193	0.035

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

Table A4. Balance Test

		2009		2011		2013		2015	
Covariate		%bias	t	%bias	t	%bias	t	%bias	t
Ln (R&D personnel)	Un-matched	-58.1	-2.21	-45.4	-1.72	-31.4	-1.17	-44.6	-1.68
	Matched	-0.8	-0.03	-12.3	-0.41	2.6	0.11	0.2	0.01
Ln (graduate students)	Un-matched	12.2	0.45	-1.8	-0.07	-13.7	-0.52	-15.0	-0.57
	Matched	4.0	0.12	-0.4	-0.01	-7.0	-0.25	10.5	0.36
Ln (sci-tech funds)	Un-matched	-3.3	-0.12	-2.3	-0.09	-9.5	-0.36	-25.3	-0.96
	Matched	-1.0	-0.04	-18.4	-0.65	5.1	0.18	-9.6	-0.36

[i] This article discusses institutional change and the institutional environment at the formal level of laws and policies, thus providing greater practical guidance.

[ii] For example, during the COVID-19 pandemic, the Pfizer and Moderna vaccines were all based on university mRNA research.

[iii] The report of the Association of University Technology Managers shows that the number of universities with technology transfer offices increased from 25 in 1980 to 200 in 1990, and the patent licensing income of the association's universities increased from $222 million in 1991 to $6.98 billion in 1997 (Association of University Technology Managers, 1996, 1998).

[iv] 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.

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

[vi] 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.

[vii] 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.

[viii] Chengdu Municipal Commission of Development and Reform: Reforming the ownership of scientific and technological achievements with incentives for prior property rights as the core opens up a new way for the rapid transformation of scientific and technological achievements, July 17, 2019.
https://cddrc.chengdu.gov.cn/cdfgw/c114131/2019-07/17/content_a0527a36b5f7457e953998fce42da4f4.shtml.

[ix] Although the patent-in-stock method can motivate inventors to participate in patent commercialization, the complicated approval procedures and many restrictions for university patents as state assets make it difficult to implement this method for university patent commercialization in practice (Kang Liu, & Yan, 2018).

[x] 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.

[xi] The compilation provides college-level data from 2008 to 2017. From 2018, the compilation no longer provides university-level data.

[xii] 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 2 for detailed comparative information.

[xiii] See the notice issued by China's Ministry of Science and Technology: "To give researchers the right to ownership of scientific and technological achievements or long-term use of the pilot unit list."

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

[xv] We searched for all patent-related information including the "Patent Management Regulations of Southwest Jiaotong University," which marked the beginning of the implementation of MOR. We have not found any other institutional support or other smaller initiatives/actions that could have been implemented together with the reform of the ownership of scientific and technological achievements in the intervention period.

[xvi] SDID combines the advantages of both DID and SCM. SDID matches the pre-treatment trends of individuals in the control group with those in the treatment group by introducing individual weights and time weights, and balances the pretreatment and post-treatment periods, which takes advantage of SCM and weakens the reliance on the parallel trend assumption. SDID also incorporates, however, the advantages of the DID method by introducing individual- and time-fixed effects, while allowing for valid large panel inference. Therefore, compared with both DID and SCM, using the SDID method may arrive at more robust estimates. However, the SDID method also has potential drawbacks, including sensitivity to weight selection and an inability to fully capture the unobserved heterogeneity that may exist between the treatment and control groups.

[xvii] The results of the balance test are shown in Appendix Table 4.

[xviii] In April 2018, the Department of Science and Technology of the Ministry of Education and the Zhongguancun Management Committee issued the "Implementation Plan on Promoting the Transformation of Scientific and Technological Achievements in Universities in Beijing." Establishing the first batch of 12 university technology transfer offices provides a useful exploration of models for managing technology transfer in Chinese universities.