NBER WORKING PAPER SERIES

THE IMPACT OF UNIVERSITY PATENT OWNERSHIP ON INNOVATION AND COMMERCIALIZATION

Jun Wang
Yi Qian

Working Paper 31021
http://www.nber.org/papers/w31021

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
March 2023

We acknowledge the support by the Social Sciences and Humanities Research Council of Canada [grant 435-2018-0519] and National Natural Science Foundation of China [grant 72003161]. All inferences, opinions, and conclusions drawn in this study are those of the authors, and do not reflect the opinions or policies of the funding agencies and data stewards. No personal identifying information was made available as part of this study. Procedures used were in compliance with British Columbia's Freedom in Information and Privacy Protection Act. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

The Impact of University Patent Ownership on Innovation and Commercialization
Jun Wang and Yi Qian
NBER Working Paper No. 31021
March 2023
JEL No. K11,O30,O32,O38

ABSTRACT

This paper contributes to the literature on innovation policies and institutional theory on conditions for effective institutional changes. The "three rights" reform of 26 universities and the mixed ownership reform of Southwest Jiaotong University are important explorations made by China in recent years to promote innovations and the commercialization of patents in universities. The two reforms have adopted different models in the allocation of university patent ownership. The former completely allocated the patent ownership to universities, while the latter allocated 70% of the patent ownership to the inventors. Based on Chinese patent data and university statistical data, we empirically test the effects of these two university-patent ownership allocation models on innovations and the commercialization of patents. We find that the institutional environment caused unexpected effects in both reform models. The "three rights" reform has a significant impact on patent-licensing in 26 universities. The mixed ownership reform has significantly increased the number of patent transfers and patent applications of Southwest Jiaotong University, yet has tilted R&D toward experimental research with relatively low creativity. The findings yield broader implications for organization and innovation.

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

Introduction

The two issues of whether institutional changes should be consistent with other aspects of the institutional environment to have the intended impact (Scott 2014; Eesley et al., 2016) and how institutional changes that are inconsistent with institutional environment affect organizations are not well-understood. A clear understanding is especially called for in the organization and innovation context (Prabhu et al. 2005). Previous studies emphasized that institutional changes will affect market reward and sanction mechanisms as well as the organizations' strategic behaviors (Hirsch 1975, Tolbert et al. 2011), yet ignored other institutional environmental conditions that would become important constraints for the expected effects of institutional changes. We address this gap by examining how changes in two opposite institutional changes affect organizations and what factors moderate the effects of institutional changes. We do so by studying the impacts of changes in Chinese university patent ownership on innovation and commercialization.

As well documented in the literature, radical innovation is an important driver of the growth and wealth of firms and nations (Tellis et al. 2009; Aghion and Howitt 2008). Universities play an important role in national innovation systems. Many inventions that have an important impact on human development also originated from universities.[1] However, universities' research findings suffer from two problems: First, innovative findings are mainly presented in the form of academic publications (Mowery et al., 2001). The lag between academic publishing and their industrial application is about 20 years (Adams, 1990). Second, even if the innovations are presented in the form of patents, their commercialization

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

is extremely low. For example, in 1980, less than 5% of the 28,000 patents in American universities were licensed (United States General Accounting Office [GAO], 1998). There are inherent difficulties in commercializing university patents, including the fact that university patents are far from mature (Thursby et al., 2001; Thursby & Thursby, 2002), and have greater uncertainty in value (Gambardella et al, 2007, Marx & Hsu, 2022). Perhaps more importantly, universities lack incentives to commercialize their patents. University patents are often funded by government research projects, so that patents filed in the name of the university are de facto owned by the government. The result is a lack of implementers to specifically promote the commercialization of patents. To combat this, the U.S. passed the Bayh–Dole Act in the early 1980s. This allowed universities to retain patent rights to the research findings arising from federal research grants (Hackett and Dilts, 2004). This transfer of university patent ownership from the state to universities has achieved remarkable results.[2] Understanding university patent productivity in a broader context would then contribute to the research on innovation when organizations and innovation “are increasingly important as product development becomes more complex and tools more effective but demanding” (Hauser et. al. 2006, p.687).

Emerging markets like China have long faced the problem of low efficiency in its attempt to commercialize university patents. This has become an important impediment to technological innovation. Influenced by the U.S., promoting the commercialization of patents in universities through shifting patent ownership has become a major focus for China in the

[2] 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).

past two decades. Chinese university patent ownership has also evolved from state-owned to university-owned, with some universities even explored allocating partial patent ownership to inventors in recent years. In 2002, the Ministry of Science and Technology and the Ministry of Finance issued a joint document allowing project undertakers to own patents arising from research projects funded by government funds. This provision was further confirmed in the revised Science and Technology Progress Law of 2007. Under the state-owned asset management system of public universities in China, although the law clearly states that universities have ownership of university patents, patents in Chinese universities are state-owned assets and the disposal of state-owned assets requires the consent of the finance and education administrations. Therefore, they do not have the right to autonomously use, dispose of, or obtain benefits from patents (He and Chen, 2013; Zhu, 2016). Until 2011, China began a patent ownership reform, 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) (hereinafter: “Three Rights Reform [TRR]”) in Beijing. This changes the status quo of universities with only nominal patent ownership. In 2013, the pilot was extended to central-level public institutions in Wuhan, Shanghai, and Hefei. Subsequently, the three-rights reform was extended to cover the entire country through the amendment of the Law on Promoting the Transformation of Scientific and Technological Achievements at the end of 2015.

Another completely different change in the form of university patent ownership allocation occurred at Southwest Jiaotong University (SWJTU) in 2016. In order to give inventors more incentives, SWJTU independently decided to transfer a substantial portion of patent ownership that was originally owned by universities to inventors in violation of the current law, thus realizing a reform comprising mixed ownership of university patents. The idea of allocating university patents to inventors is actually similar to the situation in some European countries where the ownership of patents was enjoyed by professors before 2000s (Martínez and Sterzi, 2021). While SWJTU is the only university to have done so, related literature reports on other organizations provide representative cases with fruitful insights (e.g., Scherer and *Weisburst* [1995] examine Italy's patent reform, Levitt and Venkatesh [2000] investigate one drug-selling street gang, etc.).

China's two pilot projects provide us with a unique quasi-natural experiment to analyze the impact of changes in university patent ownership. Existing research on the effects of adjusting the patent ownership model of universities in other countries usually do not use suitable control groups because the adjustment is carried out uniformly across the country (Henderson et al., 1998; Sampat et al., 2003; Mowery and Samptat, 2005; Geuna and Rossi, 2011). As for studies comparing the impact of university patent ownership in different countries through cross-country studies (Giuri et al., 2013), it is difficult to make accurate causal inferences because it is difficult to exclude the heterogeneity of different countries. However, China's pilot projects provide useful regional variations within a country that overcome the challenge of suitable control groups. Based on Chinese patent data as well as university science and technology statistical data for the years 2008 to 2020, this paper studies the impact of university patent ownerships on patent commercialization and production through effective identification strategies. In particular, we apply a combination of difference-in-difference panel analyses, propensity-score matching, and synthetic control methods to arrive at robust results.

We find that the TRR does affect the incentive level for universities to undertake commercialization, while the Mixed Ownership Reform (MOR) has had significant incentive for inventors to commercialize and increase their innovations. Specifically, with regard to patent commercialization, the TRR had significantly increased the number of licenses for pilot university patents, which is consistent with the commercialization model based on patent licensing in American universities (Thursby et al., 2001). While the effects of MOR were reflected in the significant increase in the number of patent transfers. Regarding the innovation outputs, the TRR has no significant impact on patent applications, while the MOR has significantly increased the number of patent applications of Southwest Jiaotong University. We consider impacts on the research orientation, namely the direction of research toward basic research with a high level of innovativeness that propose and solve fundamental problems or toward applied research with a focus on improvement of existing technologies and techniques. We find that the TRR has no impact on the research orientation, and the MOR has led to a significant increase in the proportion of projects with relatively weak creativity, possibly because the uncertainty of MOR makes inventors place more emphasis on short-term benefits, thus encouraging inventors to shift their research orientation to applied research that requires a lower level of innovation.

The findings of this article enrich the institutional theory with conditions for the effectiveness of institutional changes and provide a reference for China (as well as other countries) to implement effective reforms in the university patent ownership. It should be noted, however, that our sample includes Chinese universities directly under the jurisdiction of the Ministry of Education. Although the 61 universities directly under the Ministry of Education only account for 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.[3] Thus, these universities represent the highest level of Chinese universities, making the findings here salient to better understand the operation of patent commercialization and application of core innovations in the context of reform.

Conceptual Framework and Hypotheses

Literature and Institutional Context

Promoting the commercialization of university patents from the perspective of changes in ownership began in the United States. In December 1980, the U.S. passed the Bayh-Dole Act, granting the 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 expected results. In 1965, only 96 patents were granted to 28 U.S. universities, but by 1992, about 1,500 patents were granted to 150 universities, reflecting a 15-fold increase, while total U.S. patents increased by less than 50% during the same period (Henderson et al., 1998). Inspired by this,

---

[3] 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 the Web Appendix Table 1 for detailed comparative information.

in 2000, Denmark, Germany, Austria, Norway, Finland and other major European countries began to gradually move away from inventor ownership toward university ownership of patent rights. China also passed legislation in 2007 indicating that government-funded university inventions should be owned by universities.

However, the university patent ownership changes in other countries have not actually achieved the expected results. 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 et al. (2010) compared patents owned by universities with patents for inventions not owned by universities in six European countries and found no significant differences in commercialization rates. Hvide and Jones (2018) found that the number of patent applications and the number of enterprises established by university inventors decreased after Norwegian universities' patent ownership 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, and found that, although the number of university patent applications significantly increased, there was no significant change in patent quality or commercialization.

Previous studies reported inconsistent results for the same university patent ownership. Regardless of whether the studies focused on U.S. or European changes in university patent ownership, they typically examined university patent quantity and quality before and after the policy changes. Causal inference cannot be based on observational before and after data, because universities may continuously improve the patent production and commercialization. Mowery and Sampat (2005) constructed a trends chart reflecting the number of university patent applications, proportion of university patents to total patents, and the number of university patents per capita of research and development (R&D) investment in the U.S. from the 1960s to the 1990s and found that implementing the Bayh-Dole Act did not have a structural impact on the above indicators. Between the late 1960s and the 1990s, the number of patents stayed on a relatively stable growth trajectory. In addition, several factors may have affected university patenting and licensing before and after the policy changes. For example, in the U.S., university patent production and commercialization may have changed as a result of Bayh-Dole Act enforcement, 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 patents that universities can obtain (Henderson et al., 1998). As early as the late 1960s, U.S. universities were beginning 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, and encouraged universities to attach importance to patent commercialization (Geiger, 1993).

Existing research on the impact of university patent ownership changes in the U.S., Europe, and other countries examined the quantity and quality, research orientation, and commercialization of university patents (Henderson et al., 1998; Mowery et al., 2001; Mowery and Sampat, 2005; Sampat, 2006; Mowery et al., 2002; Thursby and Thursby, 2011; Sampat et al., 2003; Mowery and Ziedonis, 2002). However, there is generally lack of clear identification of whether these differences were driven by the institutional environment of corresponding development trends, legislation and policies related to patent creation and protection, or by changes in university patent ownership.

Two pilot projects in China's universities provide an effective way to compare the impact of university-owned and inventor-owned patent ownership on patent commercialization and patent production in a country context. Public universities in China are generally under the jurisdiction of national ministries or local governments.[4] For a long time, Patents produced by researchers in Chinese universities originally belonged to the State. There is no specific subject to realize the commercialization of the patent. In order to promote the patent commercialization in Chinese universities, in the Chinese version of the Bayh-Dole Act (Science and Technology Progress Law, amended in 2007), patent ownership derived from government-funded research findings was formally granted to universities. Yet Chinese universities have only obtained nominal patent ownership, since they have no right to dispose of the patent. Using university patents requires the same procedures needed to use other state-owned assets.[5] The complicated procedures and prolonged approval process hinder

[4] 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.

[5] 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

university patent commercialization (He and Chen, 2013; Zhu, 2016). In addition, income from patent commercialization is subject to "two lines of revenue and expenditure" management; universities cannot directly obtain the income from patent commercialization. Such provisions also reduce universities' enthusiasm to commercialize patents.

To solve the difficulties surrounding university patent commercialization, In May 2011, with the approval of the State Council, the Ministry of Finance launched a pilot reform of the management of the disposal and revenue rights of scientific and technological achievements of central-level institutions in Zhongguancun Innovation Pilot Zone in Beijing. This reform covers 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,[6] where pilot units may independently decide to carry out patent commercialization by means of transfer, licensing, and share investments under certain criteria. Therefore, pilot units' patent commercialization did not require filing with or approval from the competent authority when the value of the patent is less than 8 million yuan, and the pilot units could determine the patents' transaction price through agreement pricing, technology market listing transactions, and auctions, etc. The income from patent commercialization was partially retained by the pilot unit and did not need to be turned over

---

Ministry of Finance in 2009, university intellectual property, a kind of intangible property, is correspondingly included in the scope of state-owned assets management.

[6] Referring to the Zhongguancun National Innovation Pilot Zone Yearbook 2013, most of the universities in the cities where each pilot zone is 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 reveals that the pilot zone covers all universities directly under the Ministry of Education in Beijing, Shanghai, Wuhan and Hefei.

to the treasury. This pilot reform program was initiated at 26 qualifying universities, granting them real patent ownership comprising three elements of property rights: usus (the right to use), disposal, and fructus (the right to the fruits of the property). In October 2015, the TRR was able to be 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 granted patent ownership, including the aforementioned rights.

However, Southwest Jiaotong University (SWJTU) still believes that granting patent ownership to the university alone, while ignoring inventors closely related to the university patents, cannot effectively promote the commercialization of patents. There is also a theoretical basis for such concerns. On the one hand, since the inventors have no ownership of the invention, they also lack legitimate rights and reasons to participate in the commercialization of their patents, rendering inventors as mere bystanders most times in the patent commercialization process (Grossman and Hart, 1986). On the other hand, although the TRR requires universities to reward inventors with a certain percentage of their income after the commercialization of patents, some universities have not adopted formal royalty-sharing arrangements with academic inventors. Due to contractual incompleteness, that can prevent inventor from getting the *ex post* return required to compensate for his *ex ante* investment (Grossman and Hart, 1986). Even if institutional arrangements for *ex post* rewards exist, the extremely low rate of commercialization of university patents leaves inventors with no incentive to participate in the commercialization process.

Therefore, SWJTU explored the implementation of another reform on university patent ownership within the university. In January 2016, SWJTU issued the "Regulations on

Patent Management of Southwest Jiaotong University," where the *ex post* inventor cash and equity awards were changed to *ex ante* patent rights incentives, thereby changing university patent from purely owned by the university to mixed ownership by the university and inventor. The university and the inventor have 30% and 70% ownership of the patent, respectively, the inventor acquires the decision-making power to commercialize the patent, thus providing an incentive for the inventor to participate in the commercialization of the university patent with property rights.

It is worth noting that since the MOR involves the issue of ownership of scientific and technological achievements on duty, it violates the provisions of the relevant articles of Chinese Patent Law and the Law on Promoting the Transformation of Scientific and Technological Achievements at that time. Therefore, the MOR adopted by SWJTU is an important challenge to the existing patent ownership system, and the MOR has even been called the "Xiaogang Village experiment" of China's science and technology system reform, and its experimental effect has important theoretical and practical significance.[7] This experimentation also conveniently enables our identification strategy, providing a standard application of the synthetic control method.

Implementing the TRR at the 26 universities expanded university patent rights, allowing universities to acquire real patent ownership. SWJTU's patent MOR extended patent ownership from universities to inventors, making the inventor the main implementer of the commercialization of university patents. What effects do these different ownership structure

---

[7] Xiaogang Village is the birthplace of China's rural reform. In order to stimulate farmers' enthusiasm for production, farmers in Xiaogang Village, Anhui Province, risked great political risks in 1978 when they began to contract out land to households and resume family agricultural production in the era of planned economy.

have in practice? We hypothesize and analyze the effects of different patent ownership models on university patent commercialization and production based on two pilot projects.

Theoretical Mechanism and Research Hypotheses

The essence of the TRR and MOR involves the redistribution of intellectual property rights that emerge from university research. Reconfiguring ownership affects all parties' costs and benefits regarding the innovation process, thereby changing the incentives of all parties involved in innovation (Aghion and Tirole, 1994). Those affected by the effects of TRR and MOR are mainly universities and inventors. The difference is that TRR is an *ex post* incentive for patent commercialization, while MOR is an *ex ante* incentive for patent commercialization; therefore, TRR directly incentivizes universities, while MOR directly incentivizes inventors. We assess the potential impact of TRR and MOR in the following three areas: the commercialization of university patents, the innovation output, and the research orientation, accounting for the differences in incentive recipients of the pilot reform and the institutional environment in which the pilot was implemented.

First, we focused on patent commercialization. Both the TRR and MOR provide incentives for patent commercialization, the difference lies in the target of the incentives. Implementing the TRR has given universities an incentive to reap the benefits of patent commercialization. The right to independently dispose of and gain benefits from patent commercialization allows universities to promote patent commercialization, and they have the resources and potential capacity to do so. In contrast, the MOR encourages inventors to actively participate in the patent commercialization process, since they gain ownership of 70% of the patent prior to commercialization, and thus gains the decision-making power to commercialize the patent. Because inventors are most familiar with the patent technology, they have tacit knowledge that would facilitate commercialization, their participation in commercialization facilitated connecting with an enterprise’s technical staff, thereby shortening the patented technology cycle from theory to practical application and increasing the probability of successful patent commercialization.

However, a number of limiting factors, particularly the institutional environment associated with the pilot reforms, can affect the achievement of TRR and MOR in incentivizing patent commercialization goals and the corresponding strategies of implementing entities. On the one hand, the bureaucratization of universities and the complexity of commercialization may constrain the realization of the TRR effect (Kenney and Patton, 2011). On the other hand, inventors often lack the human and financial resources needed for patent commercialization, which may also limit the realization of the MOR effects. Overall, the stimulating effects of TRR and MOR on universities and inventors to commercialize their patents are likely to remain greater than the effects of negative restrictive factors, and thus both policies should have a positive impact on patent commercialization.

For the impact of patent commercialization strategies. Commercializing patents involves patent selling and licensing, 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? Selling or licensing? Essentially, these are two alternative ways of allocating the risk of uncertainty between the parties in 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 loss of state assets. Despite the fact that Chinese public universities have acquired real patent ownership, university patents are still state-owned assets in terms of their legal nature, and university administrators are liable for the loss of state-owned assets if the value of the patents depreciates during commercialization. Since 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. As for the MOR, although the vast majority of the patent rights were granted to the inventor prior to commercialization, the stability of rights can affect inventor's decision to commercialize patent. Since the MOR was implemented at the discretion of SWJTU and conflicts with the current law regarding university patent rights, there is a high degree of uncertainty regarding the patent rights obtained by the inventor. The risk of uncertainty, coupled with the inventor's lack of ability to manage the commercialization of the patent, could add to the inventor’s 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 can incentivize universities and inventors to implement patent commercialization, respectively, thus may increase the probability of 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 transfer.

However, a premise of commercialization is that there be as many patents as possibly available for commercialization. Therefore, we further discuss the impact of the changes in university patent ownership on patent applications. The increase in the number of patents depends on whether the incentive to patent can be assured.

TRR directly incentivizes university patent applications. However, the incentive effect on researchers is indirect. University researchers can only obtain *ex post* rewards after the commercialization of patents. Patentable scientific and technological achievements originate from researchers. To increase the number of patents, universities could improve the external environment that allows researchers to create inventions or they could promote patent applications for existing or near-completed technical inventions. Improving the external environment is a gradual process that may take years to yield significant results, while results produced by promoting patent applications for exiting or nearly complete inventions depend on whether the university can resolve information asymmetry between the university and inventor, where the inventor has information about the research progress but the university does not. Therefore, motivating inventors to apply for patents relies on altering the incentive levels to apply. In fact, inventors at Chinese universities are extremely low in expectation of obtaining rewards from patents. 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). Therefore, if the reward mechanism (post-reward) for inventors remains unchanged, the TRR may not increase patent filings when it only incentivizes universities to file patents.

The MOR could incentivize both universities and researchers to file patents. SWJTU has shared the reform dividend, giving the university an incentive to promote patent production. However, by granting 70% ownership to the inventor after the patent is granted, rather than as a reward after the patent is commercialized, the indeterminate debt of the inventor is converted into a definitive property right. This gives the inventor an incentive to disclose patent information to universities and to convert existing and near-completed technical inventions into patents, thereby promoting the inventor's patent applications. In light of this, we propose

> **Hypothesis 2**: Increasing the number of patent applications requires incentives from both universities and inventors. The TRR only motivates universities to promote patent applications; it does not affect the incentive level for inventors to apply for patents. However, the MOR can simultaneously motivate the university and inventors to apply for patents and may have a better stimulating effect on patent filing as compared to TRR.

Next, we asked, do changes in university patent ownership affect the orientation of university research? Previous studies examined the impact on universities' research orientation of implementing the Bayh-Dole Act, and found that applied research significantly increased after the Act was implemented (Morgan et al., 1997). The logic behind it is that implementing the Bayh-Dole Act shifted ownership of State-funded research projects from the State to universities, which have an incentive to promote patent commercialization and increase universities’ revenue. Inventors can then share the commercialization benefits. University researchers are more inclined to invest their energy in applied research that is likely to yield benefits. Thursby et al. (2007) established a career development model for university researchers and proposed that the utility function of university researchers includes an alternative relationship between basic research and applied research efforts. Patent commercialization income has allowed researchers to increase their efforts in applied research after gaining academic reputation and professional titles through basic research.

China's TRR and the Bayh-Dole Act both transfer university patent ownership from the State to universities. Do they produce similar effects? From the university's perspective, unlike universities in the U.S., Chinese universities are established and funded almost entirely by the government, they are evaluated primarily on the basis of papers that emphasize basic research, there is little incentive for universities to gain short-term benefits from scientific and technological achievements. In contrast, universities are influenced by TRR to conduct high-level research that both can yield gains from the disposal of scientific and technological results and is compatible with the university’s evaluation system. Therefore, it is also difficult for TRR to change the setting of research orientations in Chinese universities without changing the institutional and evaluation systems of Chinese universities. From the perspective of university researchers, Chinese universities have a very low rate of patent commercialization. Based on previous experiences, university researchers do not expect to gain benefits from patent commercialization, so the TRR may not change their inherent preferences for basic or applied research.

The MOR changes the incentives of inventors who make decisions about the research orientation. When inventors choose research orientation, applied research has a shorter period and lower risk than basic research. Given the uncertainty of the pilot reform itself,[8] inventors may have an incentive to devote more energy to applied research that will facilitate patentable results, thereby obtaining patent commercialization benefits 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, and the MOR stimulates inventors' enthusiasm to promote patent commercialization. However, policy uncertainty encourages inventors to shift their research orientation to research that requires a lower level of innovation and is more likely to yield research findings.

Data Sources

We empirically test these research hypotheses with a unique dataset we assembled from various sources. The research data included patent and university data. The patent data were published by the State Intellectual Property Office from 2008 to 2020, and contained information about the applicant, application date, grant date, and the legal status changes,

[8] There has been widespread controversy since the MOR, the practice of granting university patent ownership to inventors. First, it is contrary to current laws and regulations, such as the Patent Law and the Regulations on Service Inventions; and second, it involves the possibility of loss of state-owned assets.

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 independently applied. The university data came from the "Compilation of Scientific and Technological Statistics of Colleges and Universities (2009-2017),"[9] which included relevant statistical data on research projects, R&D expenditures, number of R&D personnel, and various universities' research orientation.

For the two pilot reforms of university patent ownership, the TRR selected 26 universities under the jurisdiction of the Ministry of Education located in Beijing, Shanghai, Wuhan and Hefei. The MOR was only adopted by SWJTU. These universities were used as the treatment group for this study. Correspondingly, other universities under jurisdiction of the Ministry of Education served as the control group. There are 75 such universities, including arts, languages, finance, and others. Some of such universities indicated almost no scientific achievements. To ensure that the universities in the control group were as comparable as possible to the treatment group, we excluded the 15 art, 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.

Regarding the implementation time of the two reform pilots, 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

---

[9] From 2018, the compilation no longer provides university-level data.

reform began to be implemented nationwide, thereby ending the pilot program. The MOR started in January 2016. In October 2020, the Ministry of Science and Technology issued a notice that significantly expanded the scope of the pilot to implement MOR.[10] In summary, we define two observational periods: 2008-2015 for the TRR, and 2008-2020 for the MOR.

Empirical Strategy

Difference-in-Difference

Early domestic and foreign policy changes in university patent ownership were one-size-fits-all. Therefore, we could only use the "single difference method" to compare before and after policy changes. However, the “single difference method” cannot identify the policy’s causal effects, because it cannot determine whether the before and after 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, allowing us to apply the “difference-in-difference” (DID) method to estimate the impact of university patent ownership changes 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, eliminating this type of effect in the estimation results. Therefore, if the treatment and control group samples are sufficiently

[10] 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 ".

similar and meet the parallel-trend assumption, the DID method can detect net effects of the policy change. Both the treatment and control universities were under the jurisdiction of the Ministry of Education,[11] representing 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 for the variables related to human and physical capitals. In addition, to prevent (as much as possible) missing variable bias caused by unobservable variables, we added fixed effects at the university and time levels to control for the influence of factors that do not change by university or over time.[12] The two-way fixed-effect panel model based on the DID was:

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

where $Policy_{i,t}$ represents 26 universities' TRR, and 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 pilot reform had been launched, the $Policy_{i,t}$ was 1, otherwise 0. β gives 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 term.

$Y_{i,t}$ was measurement of patent commercialization, production and research orientation, where patent commercialization was proxied by patent selling and patent licensing frequency,

---

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

[12] We have 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 implemented together with the reform of the ownership of scientific and technological achievements in the intervention period.

patent production was measured by the number of patent applications and research orientation was proxied by the share of low-level applied projects in university R&D. Specifically, it was measured by the number of experimental development (ED) projects in the total number of projects. The internationally accepted criteria for classifying R&D activities include: basic research, applied research, and experimental development (OECD, 2015). The Chinese Bureau of Statistics applied the same criteria as OECD, but differs slightly in the definitions of different categories of R&D activities.[13] According to the criteria for classifying R&D activities, both basic and applied research involve a high level of creativity, while experimental development involves improvement, without strong creativity. In a question-and-answer session with the head of the Chinese Statistics Bureau, it was also pointed out that basic and applied research are theoretically forward-looking and usually take place in universities and research institutes with strong capabilities, while experimental development is more likely to take place in enterprises.[14] This shows that experimental development is categorized as a less creative type of R&D activity. Therefore, we chose the proportion of experimental development projects as the dependent variables, to test the

---

[13] According to the definition of the Chinese Bureau of Statistics, basic research refers to experimental or theoretical research to obtain new knowledge about the basic principles of phenomena and observable facts. It does not aim at any specific application or use. Applied research refers to creative research carried out to identify possible uses of basic research results, or to explore new methods or approaches to achieving predetermined goals. Experimental development (ED) is the use of existing knowledge obtained from basic research, applied research, and practical experiences to create new products, materials, and devices; establish new processes, systems, and services; and produce and establish substantial improvement and systematic work. See the National Statistical Bureau's National Statistical Bulletin on Scientific and Technological Funds.

[14] See the official website of the National Bureau of Statistics of China, Wan Donghua, the main person in charge of the Department of Social Science and Culture of the National Bureau of Statistics, answers reporters' questions on the release of the Specification for Research and Experimental Development (R&D) Input Statistics (for Trial Implementation), http://www.stats.gov.cn/tjsj/sjjd/201905/t20190507_1663329.html

impact of pilot reform on universities' research orientation.

The selection of universities participating in the TRR pilot may be non-random. The selection is likely to be influenced by the 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 $\varepsilon_{i,t}$. In order to obtain unbiased estimates of the coefficients β in model (1), a vector of university characteristics variables $X_{i,t-1}$ should also be included to mitigate the possible bias of the model estimates due to the endogeneity of the TRR pilot selection.

Since there is no relevant document specifying the selection criteria for universities to enter the TRR pilot. We conjecture that the R&D personnel, the number of graduate students, and investment in sci-tech funds may be the determinants of whether a university is included in the TRR pilot. In order to verify whether the above university characteristics are the main influencing factors (Lu et al. 2013), logit models were constructed to estimate the probability of universities being included in the 2011 and 2013 TRR pilots, respectively. The results from the Web Appendix Table 2 reveal that the selection of TRR pilot universities is influenced by the R&D personnel, the number of graduate students, and investment in sci-tech funds. Therefore, lagged university characteristics were included in the regression model to control for possible endogeneity in the selection of universities participating in the TRR.

Synthetic Difference-in-Difference

Although the SWJTU's MOR was a spontaneous experiment, it may have its own particularities. Since only SWJTU implemented MOR, we could not identify a university in the control group that had characteristics similar to all aspects of SWJTU. Therefore, the DID may not be applicable to the assessment of MOR effects, while the synthetic control method (SCM) is exactly suitable for assessing the impact of individual cases.

SCM was first applied to the study of terrorist activities in the Basque region of Spain. A combination of two Spanish regions was used to synthesize a Basque region similar to that before the Basque region was affected by terrorist activities, allowing investigators to study the impact of terrorist activities on economic growth (Abadie and Gardeazabal, 2003). Since then, the SCM has been widely used in case studies, with representative applications, such as the impact of the California Tobacco Control Act on tobacco consumption, the impact of German unification on the per capita GDP of West Germany, etc. (Abadie et al., 2010; Abadie et al., 2015).

The synthetic control method can produce 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 real effect of the SWJTU MOR. The SCM has transparency and the choice of weights is determined by data, which reduces subjective judgment. Therefore, we can apply SCM to assess the impact of MOR on SWJTU's patent commercialization and production. However, since the SCM does not have analytical solution, it is not possible to estimate standard errors and thus it is difficult to assess the policy effects of MOR.

The Synthetic Difference-in-Difference (SDID) (Arkhangelsky et. al. 2021) is not only able to estimate the policy impact of MOR, but also has the advantages of both DID and SCM. SDID can apply the placebo method to estimate standard errors, thus allowing the policy effects of MOR to be assessed and compared with the policy effects of TRR.

SDID combines the advantages of both DID and SCM. On the one hand, the 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 posttreatment periods, thus taking advantage of the SCM and weakening the reliance on the parallel trend assumption. On the other hand, the SDID also incorporates the advantages of the DID method by introducing individual- and time-fixed effects, and allows for valid large panel inference. Therefore, compared with DID and SCM, using the SDID method may arrive at more robust estimates.

Therefore, we use the SDID to evaluate the effects of MOR on patent commercialization and production in SWJTU. We also use the SCM to test the robustness of the MOR's effects.

Empirical Findings

Impact on University Patent Commercialization

The direct purpose of the TRR and MOR was to promote universities' patent commercialization. Table 1 shows the effects of the two types of pilot reforms on patent selling and patent licensing.

[Insert Table 1 about here]

We found that both TRR and MOR had a significant and positive impact on patent commercialization, but there are differences in the manifestations of patent commercialization. The TRR had a significant positive impact on the number of patent licenses at the 5% level, but no significant impact on the number of patent transfers; while the MOR had a significant positive impact on the number of patent transfers at the 1% level, but no significant impact on the number of patent licenses. These findings supported Hypothesis 1. The significant positive impact of TRR and MOR on patent commercialization demonstrates 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 have produced different strategies for commercializing their patents. The impact of TRR on patent commercialization is only on patent licensing, while the impact of MOR is only on patent transfer. The above differences can only be reasonably explained in terms of the institutional environment. For TRR, the possible reason is that under the state asset management system, the university administrators are concerned about the risk of losing state assets due to the transfer of patents. For MOR, since the content of the MOR is inconsistent with the provisions of the Patent Law, the risk of policy uncertainty also makes inventors more willing to obtain immediate benefits in the form of patent transfer. thereby increasing the probability of successful patent commercialization.

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

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

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 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 and is in the jth year before being listed. We use 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 number of patent licenses between the treated and control groups in the year j after (or the year before) the university's participation in TRR. The meaning of other variables was 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. The results are shown in Figure 1, which illustrates that the estimate of θ_j is not significantly different from 0 When $j<0$, with the exception of the patent licenses of 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 reform implementation, we found that, the number of patent licenses was significantly higher for TRR universities than for the control group universities, and the policy effects of TRR on patent licensing gradually increased over time.

[Insert Figure 1 about here]

Impact on Universities' Patent Production and Research Orientation

An increase in the number of university patents was also the desired effect of reform implementation. We further explored the empirical implications of the two pilot programs by examining patent production changes after the policy's introduction, including the two dimensions of patent applications and research orientations. which we measured using the logarithm of the number of patent applications and the proportion of experimental development (ED) projects, respectively. The results are shown in Table 2.

[Insert Table 2 about here]

Comparing the TRR and MOR effects on the number of patent applications, we found that the TRR did not have a significant impact on universities' patent application. However, the MOR had a significantly positive impact at the 1% level, with patent applications increasing by about 55%. This corroborated Hypothesis 2. Because the TRR did not change the status of inventors who can only passively wait for patents to be commercialized for rewards, in the absence of an expectation that the inventor will receive an *ex post* reward for commercialization of the patent, it did not stimulate inventors to speed up patent application for existing inventions when the likelihood of receiving a reward is extremely low. The MOR provided inventors 70% ownership of their own patents, thereby enhancing their motivation to patent existing results. This in turn stimulated patent filing.

As for the impact of the pilot reform on universities' research orientation, we found that the TRR had no significant impact on the proportion of ED projects, while the MOR significantly increased the proportion of ED projects. This suggests that the proportion of basic and applied research requiring higher creativity decreased, corroborating Hypothesis 3. Just as the TRR has failed to motivate Chinese university researchers to boost patent applications in the absence of reward expectations, the TRR has also failed to change the research orientation preferences of university researchers. However, under the MOR, universities sharing patent ownership with inventors facilitated inventors taking the initiative to promote commercialization. The uncertainty of MOR encouraged inventors to shift their research orientation to lower levels of innovation with short-term cycles and faster payoffs.

Robustness Test

The Effects of TRR on Patent Licensing in Universities

To verify the impact of TRR on university patent licensing, we perform robustness tests through three aspects as follows: First, although the treatment and control groups were universities under the Ministry of Education's jurisdiction, the 26 pilot universities involved in TRR may differ tremendously from other universities, we use propensity score matching with difference-in-difference to further verify the TRR's impact on university patent licensing. Since we had a panel of universities observed over time, matching universities was implemented year-by-year using lagged covariates. After estimating the propensity score with the Kernel method, 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.[15] Then we applied the DID model to further verify the real TRR effect. The DID model is shown in Equation (1). The results are shown in Column 1 of Table 3. We found that the TRR have a significant impact on universities' patent licensing and the magnitude of the effect was similar to the results for DID.

Second, we restrict our sample to Chinese universities selected for the project 985, which are the top comprehensive or science and technology universities and are the main

---

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

force engaged in high-level R&D in China, thus making the samples of the treatment and control groups more comparable. Among the universities studied in this paper, 32 of them belong to the 985 Project universities. The results from Column 2 of Table 3 found that the results based on DID still support the conclusion that TRR has a significant and positive impact on the number of patent licenses.

Third, 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 relevant patent policies implemented by universities on inventors. We divide 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 that 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 construct the above five policy variables at the “university-annual” level. When the above variables are 0, it means that the university does not adopt such policies. When Equity share and Royalty share are greater than 0 and less than 1, it means the share that the inventor can obtain. When the other three policy variables are 1, it means that the university has adopted the policy. From Column 3 of Table 3, it can be found that the TRR still has a significant and positive impact on patent licensing after controlling the policy variables at the university level.

[Insert Table 3 about here]

The Effects of MOR on SWJTU

We use the synthetic control method (SCM) to test the robustness of the MOR effects. The predictive control variables include the number of R&D personnel in universities, the number of graduate students, and the total investment in science and technology. The advantage of SCM is that it provides an intuitive way to show the effects of MOR.

First, we examined the impact of MOR on the number of patent transfers. Applying the SCM method, we found that 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 2. We found that before the MOR implementation, 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 to the synthetic SWJTU, beginning with the year 2015.

[Insert Figure 2 about here]

Then we constructed a comparison chart of the logarithm of the number of patent applications between SWJTU and synthetic SWJTU, we found that the synthetic SWJTU was composed of six universities, Sichuan University, Chang’an University, China University of Geosciences (Beijing), China University of Geosciences (Wuhan), Southwest University and China University of Petroleum (East China) (with weights 0.427, 0.225, 0.161, 0.093, 0.071 and 0.021, respectively). Trends in the number of patent applications between SWJTU and synthetic SWJTU are shown in Figure 3. We found that in 2015, before the MOR implementation, patent application trends were almost the same between the synthetic SWJTU and the real SWJTU, indicating that the SCM was a good fit for the SWJTU patent applications change path before MOR implementation. After MOR implementation, the real SWJTU patent applications were significantly higher than those for the synthetic SWJTU. These results are consistent with our previous findings, indicating that the finding that MOR had a significant positive effect on the number of patent applications was robust.

[Insert Figure 3 about here]

Finally, we examined MOR’s impact on the proportion of ED projects. Applying the SCM method, we found that the synthetic SWJTU comprised East China University of Science and Technology, Southwest University and Fudan University (with weights 0.488, 0.309 and 0.203, respectively). Figure 4 shows that before the MOR, SWJTU had mostly similar proportions of ED projects to synthetic SWJTU. However, after the MOR, SWJTU's proportion of ED projects sharply increased and the gap between SWJTU and synthetic SWJTU significantly increased in 2016. However, in 2017, the proportion began to decline and no longer significantly different from synthetic SWJTU. The possible reason is that the uncertainty of MOR is waning as it is not repealed by the government after one year of implementation. Therefore, university inventors no longer deliberately adjust the research orientation to applied research with short cycles but low returns.

[Insert Figure 4 about here]

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 use placebo tests. Based on methods used by Abadie and Gardeazabal (2003) and Abadie et al. (2010), we ran placebo studies by applying the SCM to a university that did not implement 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.

In addition, the placebo test has an applicable premise; the 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 could not reflect the true effects. Therefore, we conducted the placebo tests suggested by Abadie et al. (2010), excluding universities that had a pre-MOR of more than two times SWJTU's MSPE, allowing 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 estimated treatment effects and placebo effects were compared graphically. If the treatment effects for SWJTU were larger than most placebo effects, the treatment effects may be considered plausible. Figures 5a-c display the placebo test results. The dashed lines represent the MOR effect on patent commercialization, patent application and research orientation for each university in the control group, while the solid line denotes the effect for SWJTU. As shown in Figures 5, in general, the effect line for SWJTU is unusually large relative to the distribution of the control universities' lines after MOR implementation, which demonstrated the significant positive impact of MOR on patent transfers, the patent applications, and the shift of R&D direction to applied research. The placebo test results were consistent with the previous findings.

[Insert Figure 5 about here]

Discussion and Conclusion

As reviewed and proposed in the research agenda for innovations, the impacts of macro-environmental factors such as government policies on innovations have been listed as one of the key challenges in organizations and innovations (Hauser, et al. 2009). The 26 universities' TRR and SWJTU's MOR are important explorations made by a typical emerging market, China, in recent years to promote patent commercialization in universities. Which patent ownership allocation model better promotes innovation and commercialization of university patents? How do different policies shape the research orientations and innovation directions? These questions are of general interests to policy makers, academic researchers, and industry practitioners.

Based on Chinese patent data and university science and technology statistical data, our study tests the effects of two university patent ownership allocation models on university patent commercialization and production. Our results revealed that the two opposite models for the allocation of university patent ownership produce different patent commercialization outcomes, with TRR favoring an increase in the number of patent licenses and MOR favoring an increase in the number of patent transfers. As the two main types of patent commercialization models, the choice between patent licensing or patent transfer 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 and policy uncertainty risk in China. Under the management system of university patents as state-owned assets, in order to avoid the risk of losing state-owned assets, Chinese universities can only commercialize their patents through patent licensing, which may be the reason why TRR can only significantly increase the number of patent licenses. Since MOR is a policy implemented by SWJTU on its own initiative that contradicts with higher norms, the uncertainty makes inventors more willing to obtain short-term income through patent transfer, thus the impact of MOR is only reflected in increasing the number of patent transfers.

Furthermore, in terms of the impact of TRR and MOR on university patent output, the "anti-commons tragedy" of patents caused by the state-owned asset management system has led to the extremely low commercialization level of Chinese universities for a long time. In this situation, the TRR, which does not directly affect the incentive level of researchers, cannot change researchers' patent applications and research orientations. The MOR, on the other hand, has changed the status of university patents as state-owned assets by giving inventors the majority of ownership of patent commercialization, thus effectively motivating researchers to accelerate patent applications, yet the uncertainty of MOR also makes researchers more focused on short-term gains, and thus tend to shift their R&D projects to low-level applied research.

Therefore, in terms of the impact of the two different patent rights allocation models in China, it is difficult to make a judgment on which model is more conducive to promoting patent commercialization. For the TRR, it can promote the increase of patent licenses with sustainable benefits, so it is conducive to the formation of a virtuous circle of patent commercialization. However, it cannot effectively stimulate the increase of patent output as the basis of patent commercialization; while for the MOR, from the perspective of increasing the number of patent transfers and applications, the MOR achieved remarkable results. Nonetheless, we need to be aware of two potential problems: first, in terms of impact on research orientation, the MOR may guide universities’ R&D investment to research with a lower level of innovativeness. This deviates from the original intention of promoting patent commercialization in China's universities and does not facilitate the realization of China's innovative national strategic goals in the long run. Second, the type of university patent commercialization driven by the MOR was patent transfer, not patent licensing. Patent transfer cannot bring sustainable and stable benefits to universities.

Problem solving needs to start with the root of the problem. For the TRR, the state asset management system is a key constraint on patent transfer, and although it objectively leads universities to adopt a patent licensing model that is more conducive to generating sustainable income, it does not mean that all patents can only be licensed, but should respect the laws of the market and give implementing entities the option to adopt appropriate commercialization models depending on the circumstances of different patents. This can also increase the income from the commercialization of university patents, thus stimulating the production of a larger number of patents by raising the expectation that researchers will receive *ex post* rewards.

For the MOR, the main problem lies in the instability of the MOR. The MOR breaks through existing laws and regulations on the distribution of university patent ownership. Therefore, researchers are not sure whether the ownership allocated to inventors by MOR still exists when more resources have been invested in more innovative research, so they invest more energy into short-term research. Therefore, we must clarify the legal issues related to MOR, and new innovation policies in general, as soon as possible to ensure the stability of ownership, so that university patent inventors can form long-term stable expectations. Article 6 of the Patent Law, revised in October 2020, provides that entities can dispose of their service invention patent application rights and patent rights in accordance with the law, providing an opportunity to legalize MOR.

In addition, University researchers are often poor at patent commercial operation and management, and often sell patents to save time and effort. Therefore, while giving the vast majority of ownership rights to inventors, universities should also take an active role. If universities can establish professional technology transfer teams, allowing inventors to devote themselves to patent production while the technology transfer team manages patents after application and connects patent commercialization channels to continuously improve patent maturity, 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.[16]

---

[16] In April 2018, the Department of Science and Technology of the Ministry of Education and the Zhongguancun Management Committee issued the Implementation Plan on

In summary, institution does not operate in isolation. In order to achieve the desired effect of institutional changes, it is necessary to analyze whether the institutional changes are consistent with the relevant regulative, normative, and cognitive-cultural institutional environment. In cases of inconsistency, our research suggests ways to adjust and adapt in order to achieve the expected effect of the institutional changes. As long as the relevant institutional obstacles and uncertain expectations are effectively addressed, it is believed that both the TRR and MOR can achieve effective incentives for patent commercialization and promote a virtuous cycle of university innovation and patent commercialization.

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 technology transfer office models in Chinese universities.

References

Abadie, A., Gardeazabal, J. 2003. The economic costs of conflict: A case study of the Basque Country. *American economic review*, 93(1), 113-132.

Abadie, A., Diamond, A., Hainmueller, J. 2010. Synthetic control methods for comparative case studies: Estimating the effect of California's tobacco control program. *Journal of the American statistical Association*, 105(490), 493-505.

Abadie, A., Diamond, A., Hainmueller, J. 2015. Comparative politics and the synthetic control method. *American Journal of Political Science*, 59(2), 495-510.

Adams, J. D. 1990. Fundamental stocks of knowledge and productivity growth. *Journal of Political Economy*, 98(4), 673-702.

Aghion, P., Howitt, P. W. (2008). *The Economics of Growth*. MIT press.

Aghion, P., Tirole, J. 1994. The management of innovation. *The Quarterly Journal of Economics*, 109(4), 1185-1209.

Association of University Technology Managers, 1996. *AUTM Licensing Survey: Survey Summary*. Association of University Technology Managers, Norwalk, CT.

Association of University Technology Managers, 1998. *AUTM Licensing Survey: Survey Summary*. Association of University Technology Managers Norwalk, CT.

Arkhangelsky, D., Athey, S., Hirshberg, D. A., Imbens, G. W., & Wager, S. 2021. Synthetic difference-in-differences. *American Economic Review*, 111(12), 4088-4118.

Cohen, W. M., Nelson, R. R., & Walsh, J. P. 2002. Links and impacts: the influence of public research on industrial R&D. *Management science*, 48(1), 1-23.

Cowan, R., Zinovyeva, N. 2013. University effects on regional innovation. *Research Policy*, 42(3), 788-800.

Crespi, G. A., Geuna, A., Nomaler, Ö., Verspagen, B. 2010. University IPRs and knowledge transfer: is university ownership more efficient? *Economics of Innovation and New Technology*, 19(7), 627-648.

Department of Science and Technology, Ministry of Education. 2015. *Compilation of Science and Technology Statistics of Higher Education Institutions in 2015*， Higher Education Press.

Eesley, C., Li, J. B., Yang, D. 2016. Does institutional change in universities influence high-tech entrepreneurship? *Organization Science*, 27(2):446-461.

Gambardella A, Giuri P, Luzzi A. 2007. The market for patents in Europe. *Research policy*, 36(8), 1163-1183.

Geiger, R.L., 1993, *Research and Relevant Knowledge: American Research Universities Since World War II*, New York: Oxford University Press.

Geuna, A., Rossi, F. 2011. Changes to university IPR regulations in Europe and the impact on academic patenting. *Research Policy*, 40(8), 1068-1076.

Giuri P, Munari F, Pasquini M. 2013. What determines university patent commercialization? Empirical evidence on the role of IPR ownership. *Industry and Innovation*, 20(5), 488-502.

Grossman, S. J., Hart, O. D. 1986. The costs and benefits of ownership: A theory of vertical and lateral integration. *Journal of Political Economy*, *94*(4), 691-719.

Hackett, S. M., Dilts, D. M. 2004. A systematic review of business incubation research. *The Journal of Technology Transfer*, 29(1), 55-82.

Hauser, J., Tellis, G. J., & Griffin, A. (2006). Research on innovation: A review and agenda for marketing science. *Marketing science*, *25*(6), 687-717.
He, L., Chen J. 2013. Failure of China's "Bayh-Dole Act" and the way out for the transformation of University Intellectual Property, *Intellectual Property*, (3), 84-88.
Henderson, R., Jaffe, A. B., & Trajtenberg, M. 1998. Universities as a source of commercial technology: a detailed analysis of university patenting, 1965–1988. *Review of Economics and statistics*, 80(1), 119-127.
Hirsch, P. M. 1975. Organizational effectiveness and the institutional environment. *Administrative Science Quarterly*, 327-344.
Hvide, H. K., Jones, B. F. 2018. University Innovation and the Professor's Privilege. *American Economic Review*, 108(7), 1860-98.
Jeong S, Lee S, Kim Y. 2013. Licensing versus selling in transactions for exploiting patented technological knowledge assets in the markets for technology. *The Journal of Technology Transfer*, 38(3), 251-272.
Kenney M, Patton D. 2011. Does inventor ownership encourage university research-derived entrepreneurship? A six university comparison. *Research Policy*, 40(8), 1100-1112.
Lee, K., Jung, H. J. 2021. Does TTO capability matter in commercializing university technology? Evidence from longitudinal data in South Korea. *Research Policy*, 50(1), 104133.
Levitt, S. D., Venkatesh, S. A. 2000. An economic analysis of a drug-selling gang's finances. *The Quarterly Journal of Economics*, 115(3), 755-789.
Luan, C., Zhou, C., & Liu, A. 2010. Patent strategy in Chinese universities: a comparative perspective. *Scientometrics*, 84(1), 53-63.
Martínez, C., & Sterzi, V. 2021. The impact of the abolishment of the professor's privilege on European university-owned patents. *Industry and Innovation*, 28(3), 247-282.
Marx, M. and Hsu, D. (2022), Revisiting the Entrepreneurial Commercialization of Science: Evidence from 'Twin' Discoveries, *Management Science*, 68, pp. 1330-1352.
Morgan, R. P., Kannankutty, N., Strickland, D. E. 1997. Future directions for university-based research. *ASEE Prism*, 6(7), 30-36.
Mowery, D. C., Nelson, R. R., Sampat, B. N., Ziedonis, A. A. 2001. The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh–Dole act of 1980. *Research policy*, 30(1), 99-119.
Mowery, D. C., Sampat, B. N. 2005. The Bayh-Dole Act of 1980 and university–industry technology transfer: A model for other OECD governments? *The Journal of Technology Transfer*, 30(1-2), 115-127.
Mowery, D. C., Sampat, B. N., Ziedonis, A. A. 2002. Learning to patent: Institutional experience, learning, and the characteristics of U.S. university patents after the Bayh-Dole Act, 1981-1992. *Management Science*, 48(1), 73-89.
Mowery, D. C., Ziedonis, A. A. 2002. Academic patent quality and quantity before and after the Bayh–Dole act in the United States. *Research Policy*, 31(3), 399-418.
OECD, 2015, *Frascati Manual* 2015.
Prabhu, J. C., Chandy, R. K., & Ellis, M. E. (2005). The impact of acquisitions on innovation: poison pill, placebo, or tonic? *Journal of Marketing*, *69*(1), 114-130.
Sampat, B. N. 2006. Patenting and U.S. academic research in the 20th century: The world before and after Bayh-Dole. *Research Policy*, 35(6), 772-789.

Sampat, B. N., Mowery, D. C., Ziedonis, A. A. 2003. Changes in university patent quality after the Bayh–Dole act. *International Journal of Industrial Organization*, 21(9), 1371-1390.

Scherer, F. M., Weisburst, S. 1995. Economic effects of strengthening pharmaceutical patent protection in Italy. *International Review of Industrial Property and Copyright Law*, 26(6), 1009-1024.

Scott WWR, 2014. *Institutions and Organizations: Ideas, Interests, and Identities*, Sage Publications, Thousand Oaks, CA.

Tellis, G. J., Prabhu, J. C., & Chandy, R. K. (2009). Radical innovation across nations: The preeminence of corporate culture. *Journal of marketing*, *73*(1), 3-23.

Thursby, J. G., Thursby, M. C. 2011. Has the Bayh-Dole act compromised basic research? *Research Policy*, 40(8), 1077-1083.

Thursby, J. G., Jensen, R., Thursby, M. C. 2001. Objectives, characteristics and outcomes of university licensing: A survey of major U.S. universities. *The Journal of Technology Transfer*, 26(1-2), 59-72.

Thursby, J. G., Thursby, M. C. 2002. Who is selling the ivory tower? Sources of growth in university licensing. *Management science*, 48(1), 90-104.

Thursby, M., Thursby, J., Gupta-Mukherjee, S. 2007. Are there real effects of licensing on academic research? *Journal of Economic Behavior & Organization*, 63(4), 577-598.

Tolbert, P. S., David, R. J., Sine, W. D. 2011. Studying choice and change: The intersection of institutional theory and entrepreneurship research. *Organization Science*, 22(5), 1332-1344.

United States General Accounting Office. 1998. *Technology Transfer: Administration of the Bay-Dole Act by Research Universities*.

Yi, W., & Long, C. X. 2021. Does the Chinese version of Bayh-Dole Act promote university innovation? *China Economic Quarterly International*, 1(3), 244-257.

Zhu, Y., 2016. Review and reconstruction of the legal system for the transformation of scientific and technological achievements in universities, *Law Science*, (4), 81-92.

Table 1. *The Effects of Pilot Reform on Patent Commercialization in Universities*

Variables	TRR(DID)		MOR(SDID)	
	Ln(Patent transfers)	Ln(Patent licenses)	Ln(Patent transfers)	Ln(Patent licenses)
Policy	-0.167	0.328**	1.421**	0.610
	(0.214)	(0.129)	(0.659)	(0.538)
University Characters	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
University FE	Yes	Yes	Yes	Yes
Obs.	420	420	720	540
Adjusted R^2	0.601	0.658		

Note. Standard errors are clustered by university in parentheses. In applying the SDID, we use the "placebo method" standard error estimator.
***Significant at 1%, **at 5%, *at 10%.

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

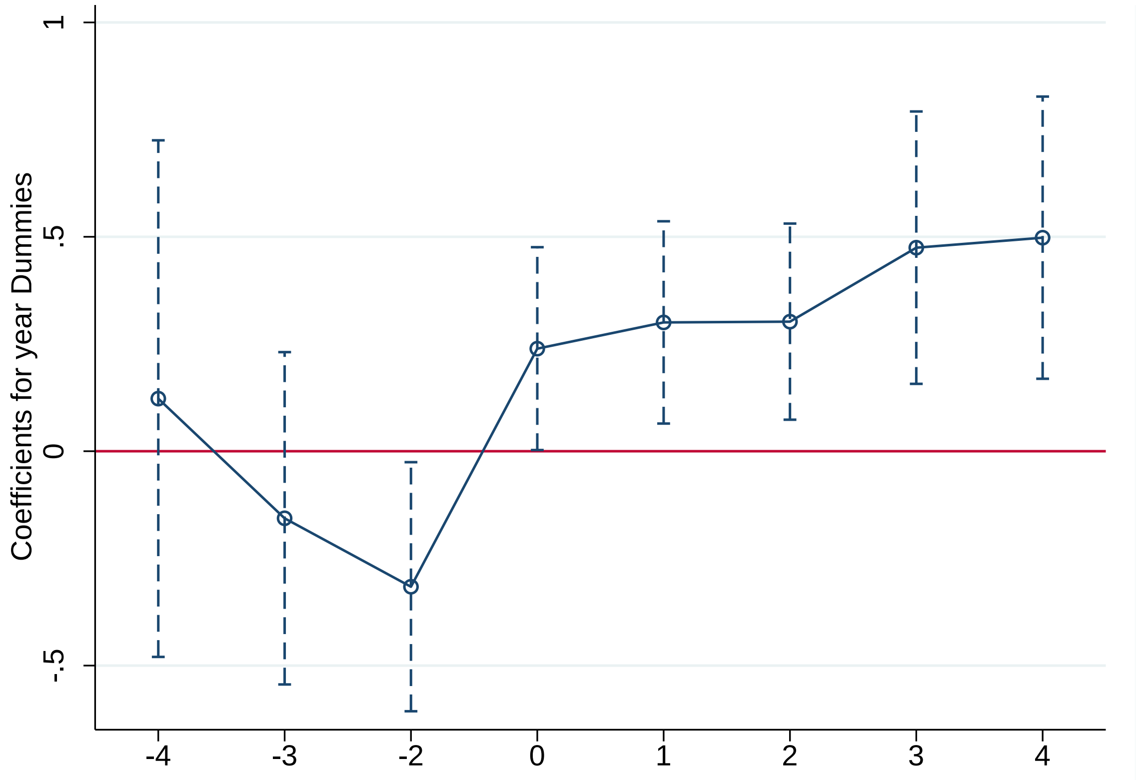


Table 2. *The Effects of Pilot Reform on the Number of Patent Applications and Research Orientation*

Variables	TRR(DID)		MOR(SDID)	
	Ln(number of patent applications)	Proportion of ED projects	Ln(number of patent applications)	Proportion of ED projects
Policy	-0.096 (0.082)	-0.001 (0.020)	0.549*** (0.203)	0.268*** (0.056)
University Characters	controlled	controlled	controlled	controlled
Year FE	Yes	Yes	Yes	Yes
University FE	Yes	Yes	Yes	Yes
Obs.	420	420	660	540
Adjusted R^2	0.936	0.743		

Table 3. *The Effects of TRR on Patent Licensing in Universities*

Variables	PSM-DID	985 Universities	985 Universities (including university-level patent policies)
Policy	0.300** (0.133)	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 Characters	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
University FE	Yes	Yes	Yes
Obs.	376	210	210
Adjusted R^2	0.654	0.759	0.756

Note: The five categories of university patent-related policy information in column 3 were obtained from (Yi and Long, 2021).

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

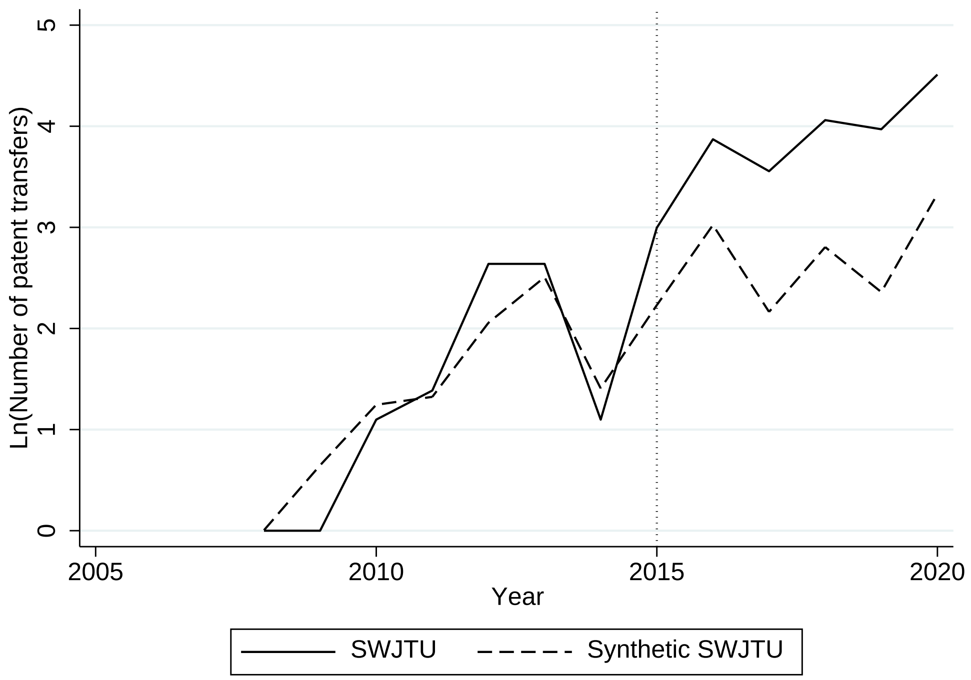


Figure 3. *Patent Application Trends: SWJTU and Synthetic SWJTU*

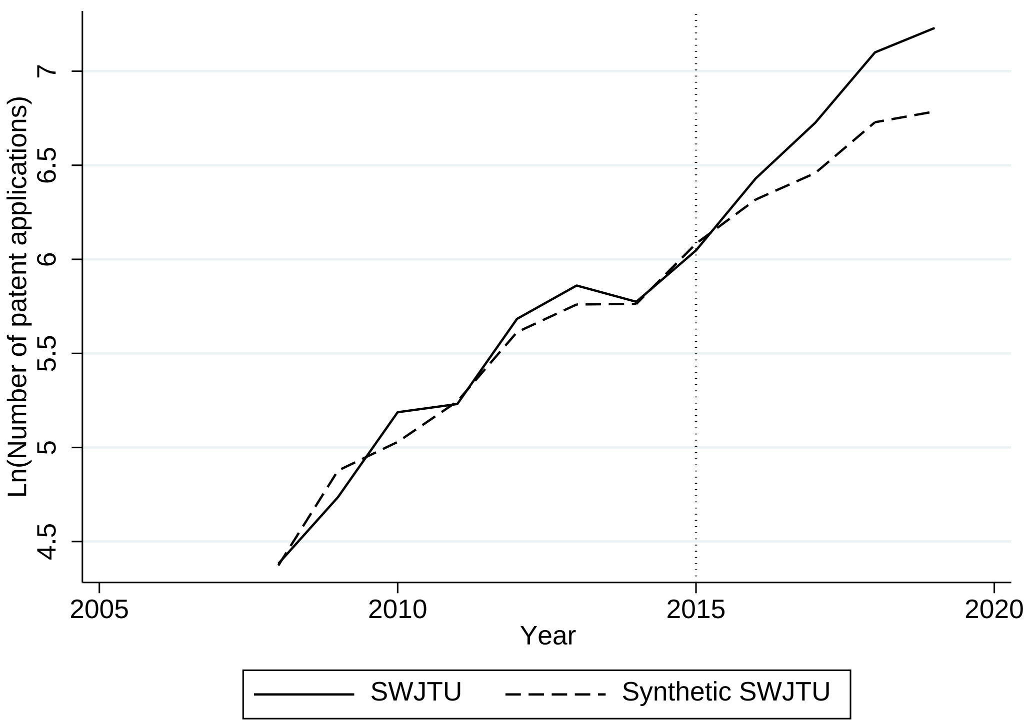


Figure 4. *Trends of Proportion of ED Projects: SWJTU and Synthetic SWJTU*

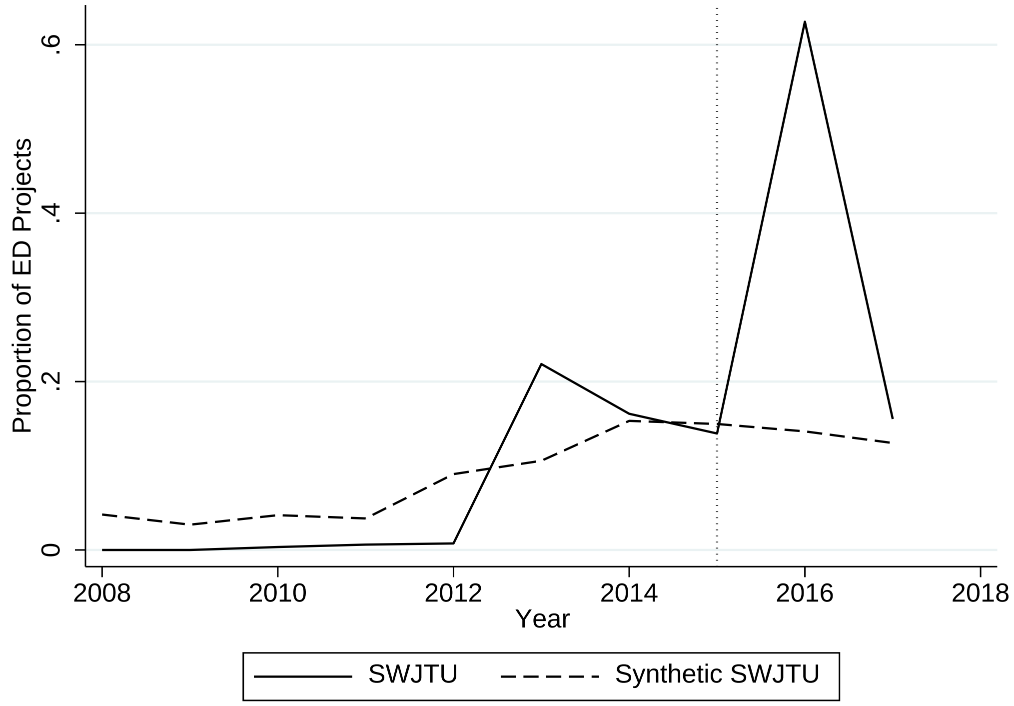
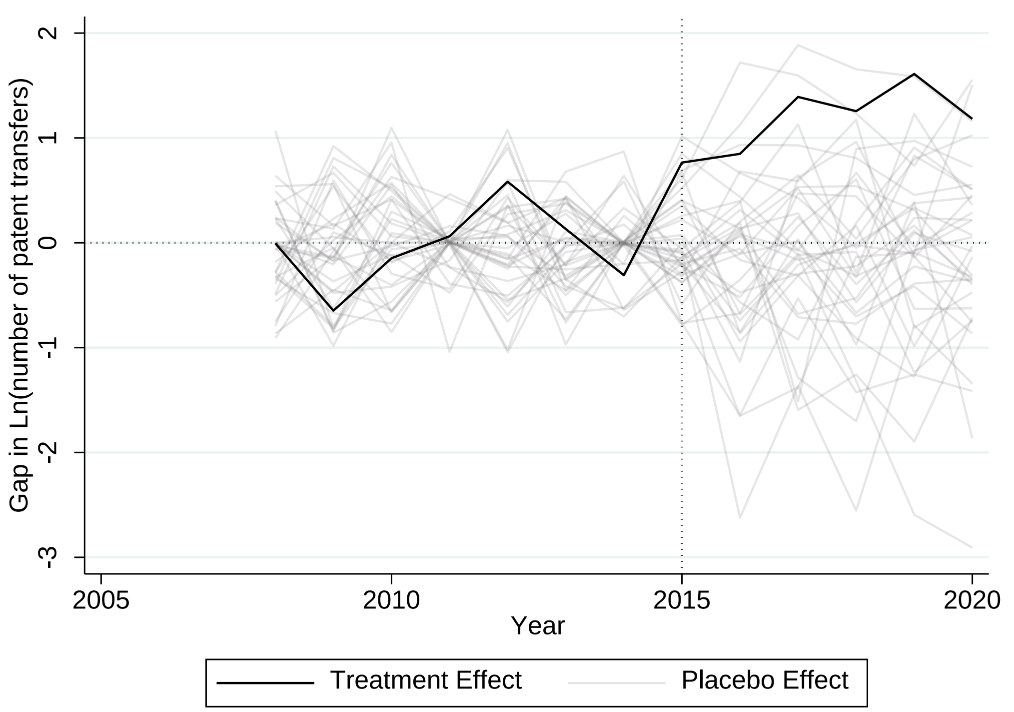
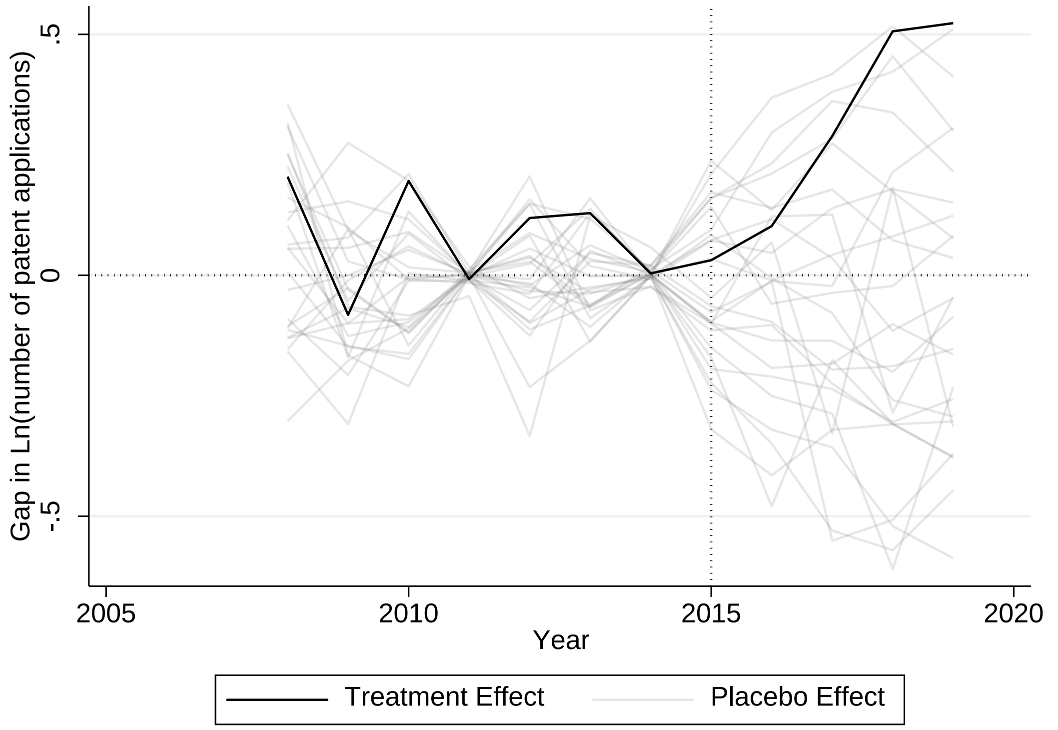


Figure 5

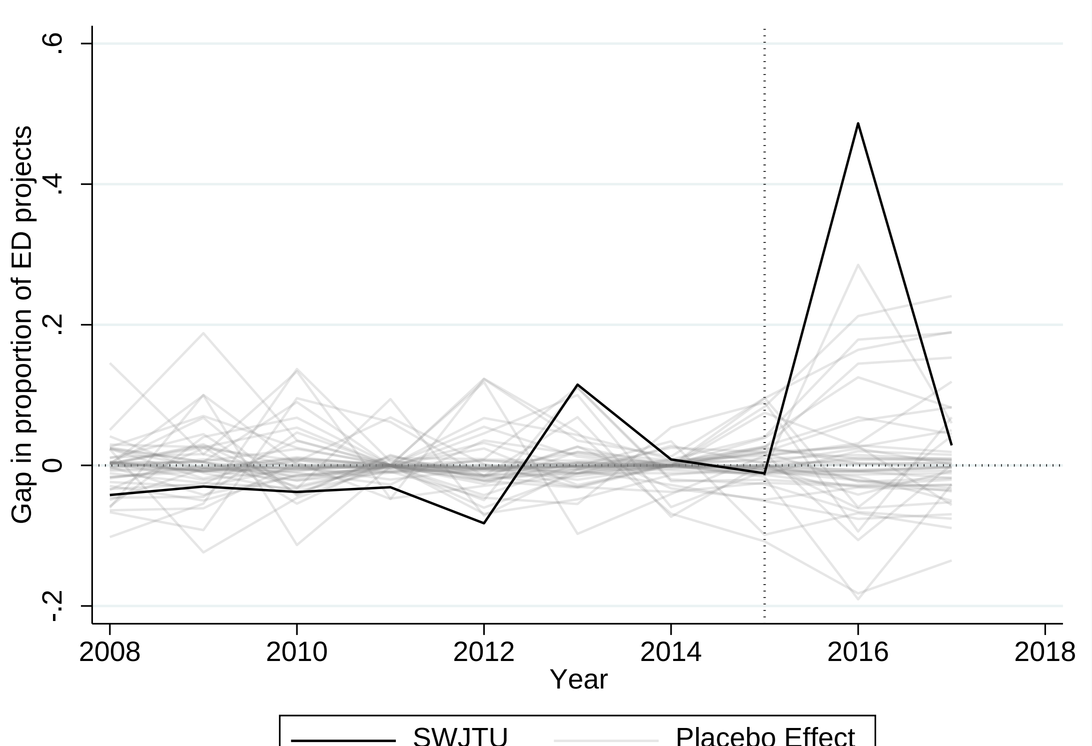
a. *The Logarithm of Patent Transfers Gaps in SWJTU and Placebo Gaps in Control Universities (Excludes Universities with Pre-MOR MSPE Two Times Higher Than SWJTU's)*



b. The Logarithm of Patent Applications Gaps in SWJTU and Placebo Gaps in Control Universities (Excludes Universities with Pre-MOR MSPE Two Times Higher Than SWJTU's)



c. Proportion of ED Projects Gaps in SWJTU and Placebo Gaps in Control Universities (Excludes Universities with Pre-MOR MSPE Two Times Higher Than SWJTU's)



Appendix Table 1

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	61	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 of universities and patents are in numbers as listed. The units of R&D Personnel are in persons.

Appendix Table 2

Pre-requisites 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.

Appendix Table 3

Test of Covariate Balances

		2009		**2011**		**2013**		**2015**	
Covariate		% bias	t-stat	% bias	t-stat	% bias	t-stat	% bias	t-stat
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