Research Policy 54 (2025) 105241

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Bridging the ivory tower and industry: How university science parks promote university-industry collaboration?☆

Yankun Kang [a,1], Ruiming Liu [b,1], Bingyan Yang [c,1,*]

[a] School of Economics and Finance of Xi'an Jiaotong University, 28 Xianning West Road, Xi'an 710049, China
[b] National Academy of Development and Strategy, Renmin University of China, 59 Zhongguancun Street, Beijing 100872, China
[c] School of Economics, Renmin University of China, 59 Zhongguancun Street, Beijing 100872, China

A R T I C L E I N F O

JEL classification:
O31
O32
O38

Keywords:
University science park
University-industry collaboration
Patents

A B S T R A C T

We investigate the impact of university science parks (USPs)—platforms designed to foster university-industry (UI) connections, specifically focusing on their role in UI patent collaboration. Utilizing the introduction of USPs in China between 2006 and 2016, we find that they are associated with a notable 50.8 % increase in UI collaborative patents, equivalent to approximately 1.8 additional patents per year. We further proposed that USPs can facilitate UI collaboration through three mechanisms—spatial proximity, intermediary services, and knowledge complementarity—and provided corresponding empirical evidence to support these claims. Furthermore, measured by the patent citations, we also find that these parks significantly enhance the quality of UI collaborations. These results underscore the pivotal role of USPs as facilitators of interaction between academic institutions and industries.

1. Introduction

In modern societies, as the economy shifts toward being science and knowledge-based, universities—serving as centers of knowledge—have become increasingly essential partners for industry. Collaboration between academia and industry has become more significant and widespread than ever before (Jensen and Thursby, 2001; Perkmann et al., 2013). For instance, as early as the 1990s, 90 % of biotech companies disclosed their collaborations with university scientists in their initial public offerings (Zucker et al., 2002). Consequently, many countries have sought to foster university-industry (UI) collaboration (Zucker et al., 2002; Cohen et al., 2002; Hausman, 2022), with university science parks (USPs) emerging as a particularly important strategy (Phan et al., 2005; Albahari et al., 2023).

Ideally, USPs are expected to facilitate innovation spillovers by fostering UI collaboration, thereby enhancing industrial competitiveness and driving economic growth (Link and Scott, 2003; Storey and Tether, 1998). However, empirical evidence on their impact remains inconclusive (Lecluyse et al., 2019; Albahari et al., 2023). While some studies report positive effects on UI linkages (Van Dierdonck et al., 1991; Westhead and Storey, 1995; Löfsten and Lindelöf, 2002, 2003; Lindelöf and Löfsten, 2004; Fukugawa, 2006; Squicciarini, 2009; Minguillo et al., 2015; Ramírez-Alesón and Fernández-Olmos, 2018; Anton-Tejon et al., 2024a), others find no impact or even negative effects (Quintas et al., 1992; Felsenstein, 1994; Malairaja and Zawdie, 2008; Radosevic and Myrzakhmet, 2009; Albahari et al., 2017). The contradictions in the literature stem primarily from a lack of comprehensive data on USPs (Phan et al., 2005). This data scarcity has made it difficult for most studies to conduct rigorous causal analyses. Consequently, identifying the causal effects of USPs on UI collaboration and developing precise measures for UI collaboration remain significant challenging.

Building on these considerations, we measure UI collaboration using collaborative patents, which reflect both the presence and intensity of UI interactions. Using panel data from 326 universities between 2006 and 2016, we apply the difference-in-differences (DID) estimators proposed by Borusyak et al. (2024) to estimate the causal effects of USPs on UI patent collaboration in China. Our findings indicate that the establishment of USPs leads to a 50.8 % increase in UI collaborative patents, along with increases of 40.0 % and 37.1 % in invention patents and utility model patents, respectively. To test the parallel trends

☆ This work was supported by Major Projects of National Social Science Foundation of China (No. 20&ZD118) and National Natural Science Foundation of China (No. 72403192).
* Corresponding author.
E-mail addresses: liuruiming@ruc.edu.cn (R. Liu), yangbingyan201@ruc.edu.cn (B. Yang).
[1] All authors contribute equally and are listed in alphabetical order.

https://doi.org/10.1016/j.respol.2025.105241
Received 15 May 2024; Received in revised form 25 March 2025; Accepted 31 March 2025
Available online 16 April 2025

assumption, we also conduct an event study approach. The results show a stable, flat, and statistically insignificant difference between the treated and control groups before the introduction of USPs, supporting the validity of our specification.

Next, we examine the mechanisms through which USPs promote UI collaborations, focusing on three key channels: spatial proximity, intermediary services, and knowledge complementarity. First, USPs leverage geographical proximity to enhance UI collaboration (Vedovello, 1997; Link and Scott, 2003; Ferguson and Olofsson, 2004; Vásquez-Urriago et al., 2016; Anton-Tejon et al., 2024a). Proximity is critical for innovation as shorter distances foster linkages and facilitate knowledge transfer (Knoben and Oerlemans, 2006; Hervas-Oliver and Albors-Garrigos, 2009), particularly tacit knowledge (Gilly and Torre, 2000; Howells, 2002), which often requires face-to-face interaction due to its localized nature (Jaffe et al., 1993; Gertler, 2003; Acosta et al., 2012). To test this mechanism, we calculated the distance between each USP and its affiliated university, using a 3 km threshold to classify universities as either close to or far from a USP. Comparing to universities without a USP, we found that universities within 3 km of a USP experienced a significant increase in collaborative patents after the park's establishment, while those farther away did not. This result highlights spatial proximity as a key driver of USP-induced UI collaborative research and development (R&D).

Second, USPs provide intermediary services to foster UI interaction. The lack of effective communication channels often hinders the alignment of university scientific resources with the specific needs of the industry (Guan et al., 2005; Hellmann, 2007; Fransman, 2008; Chai and Shih, 2016). USPs address this gap by organizing events such as exhibitions and salons, as well as offering technology brokerage services and shared laboratories. These initiatives enhance UI interactions and reduce information asymmetry between universities and enterprises. Our analysis shows that the establishment of USPs resulted in a 43 % increase in the number of firms engaging in collaborative patents with universities, with small enterprises driving most of this growth. Smaller firms, which typically have weaker R&D capabilities, rely more heavily on knowledge spillovers from universities (Huang et al., 2012). Additionally, we observe significant increases in both the number of patents transferred from universities to firms and the number of R&D contracts, further highlighting the role of USPs as a bridge for UI collaboration.

Third, USPs facilitate UI knowledge complementarity, where alignment in technological ability and expertise alongside geographical proximity (Woerter, 2012). Effective UI collaboration requires that universities possess resources that address technological challenges or complementing a firm's expertise. Without such complementarity, firms are unlikely to benefit from joint research and have little incentive to invest in it (Zucker et al., 1998, 2002). We provide evidence for this mechanism from two perspectives. First, the impact of USPs on UI collaborative patent applications is more pronounced in universities with stronger capabilities to address technological complexities. Second, USPs significantly enhance collaborative patenting in fields where universities hold a technological advantage. These findings underscore how USPs leverage academic intellectual assets to foster knowledge complementarity between universities and firms.

Additionally, we rule out two alternative hypotheses. The first hypothesis concerns university-owned firms (Wu, 2010; Li and Tan, 2020). It suggests that incentivized by government-provided land and tax benefits, universities may establish new firms in USPs or encourage existing university-owned firms to relocate there. This, in turn, could increase investment in collaborative research and strengthen UI collaboration. However, our analysis of all identified university-owned firms reveals no significant increase in collaborative patents between universities and their affiliated firms.

The second hypothesis, referred to as the "investment expansion" hypothesis, proposes that USPs may attract increased industry funding (Gulbrandsen and Smeby, 2005; Welsh et al., 2008; D'este and Perkmann, 2011; Ankrah et al., 2013; Bikard et al., 2019), thereby expanding R&D personnel in universities and facilitating the recruitment of more innovative researchers. This enhanced input could increase the likelihood of translating scientific achievements into industrial applications. However, our examination of university-level personnel data finds no significant impact of USPs on either the size or composition of university R&D staff, challenging the validity of the "investment expansion" hypothesis.

In the final section, we examine the impact of USPs on patent quality. Simply obtaining a patent does not ensure its practical application in the industry; such patents are often labeled as "sleeping patents" (Torrisi et al., 2016). As directly measuring patent applications is challenging, we use patent citations as a proxy for quality. Our analysis reveals that USPs significantly improve the quality of UI collaborative patents, particularly invention patents. These findings suggest that the impact of USPs extends beyond merely increasing the number of patents, highlighting their role in fostering higher-quality innovation.

This paper makes three key contributions. First, it provides robust causal evidence on the impact of USPs on UI collaboration. While numerous studies have examined collaborative behaviors involving firms within and outside USPs, their conclusions remain mixed.[2] This ambiguity largely arises from the lack of large-sample panel data, which has hindered causal inference in previous research. By utilizing panel data from 2006 to 2016 and employing a DID approach, this paper fills this gap and offers clear causal evidence on how USPs foster UI collaboration.

Second, this paper advances the measurement of UI collaboration by employing collaborative patents as a key indicator. Previous studies often rely on survey or interview data that merely indicate the presence of UI links, providing limited insight into their depth or tangible outcomes.[3] In contrast, this paper utilizes the number of UI collaborative patents as a metric, capturing both measurable achievements and the intensity of these collaborations (Kato and Odagiri, 2012). This shift toward an objective, outcome-oriented measure significantly improves the precision and reliability of evaluating the impact of USPs on UI collaboration. Additionally, collaborative patents are widely regarded as a robust indicator in the USP literature due to their comparability across regions and countries, further enhancing the generalizability of the findings (Huang et al., 2012; Albahari et al., 2017; Lamperti et al., 2017; Ünlü et al., 2023; Anton-Tejon et al., 2024a, 2024b).

Thirdly, this paper identifies and empirically validates the mechanisms through which USPs influence UI collaboration. Our findings highlight three key channels: spatial proximity, intermediary services, and knowledge complementarity. While these mechanisms have been broadly mentioned in prior literature (Vedovello, 1997; Löfsten and Lindelöf, 2003; Phan et al., 2005; Abramovsky and Simpson, 2011; Vásquez-Urriago et al., 2016; Phongthiya et al., 2022; Anton-Tejon et al., 2024a), empirical evidence supporting them remains scarce. Specifically, USPs enhance geographic proximity, provide intermediary services, and align technological capabilities and expertise to maximize UI complementarity. These findings underscore the multifaceted role of USPs in fostering effective UI collaboration.

The rest of this paper proceeds as follows. Section 2 introduces the

[2] For this strand of literature, see Quintas et al. (1992), Felsenstein (1994), Westhead and Storey (1995), Vedovello (1997), Phillimore (1999), Bakouros et al. (2002), Colombo and Delmastro (2002), Löfsten and Lindelöf (2002), Lindelöf and Löfsten (2004), Fukugawa (2006), Squicciarini (2009), Díez-Vial and Fernández-Olmos (2015), Malairaja and Zawdie (2008), Vásquez-Urriago et al. (2016), Albahari et al. (2017), Ramírez-Alesón and Fernández-Olmos (2018), Anton-Tejon et al. (2024a), etc.

[3] Previous research has distinguished between formal and informal links. The former includes informal personal contacts and sharing of university equipment (Vedovello, 1997; Phillimore, 1999; Malairaja and Zawdie, 2008), while informal links involve personal contacts, equipment sharing, and other less structured interactions (Colombo and Delmastro, 2002; Löfsten and Lindelöf, 2002; Lindelöf and Löfsten, 2004; Fukugawa, 2006).

institutional background and the conceptual framework. Section 3 provides details of the sample, data, and identification strategy. Section 4 shows the baseline results and test the potential mechanisms. Section 5 presents several robustness checks. Section 6 shows the effect of USPs on the quality of collaborative patents. Finally, Section 7 concludes.

2. Institutional background and conceptual framework

2.1. USPs in China

Science Parks have become widespread worldwide, becoming central hubs in the innovation ecosystem. As defined by the International Association of Science Parks, these parks aim to facilitate and manage the flow of knowledge and technology among universities, R&D institutions, companies, and markets.[4] This paper focuses specifically on university-established parks, which are usually located on or near university campuses. These parks are expected to promote knowledge spillovers and offer entrepreneurs access to academic resources, expert guidance, and support for launching new enterprises (Wright et al., 2008; Alshumaimri et al., 2010).

In 1951, Stanford University established the world's first science park, laying the foundation for the renowned high-tech cluster, "Silicon Valley." This remarkable success became a global model, inspiring the development of university science parks in numerous European countries, including the United Kingdom and Russia, particularly after the 1970s (Theeranattapong et al., 2021).

In the early 1990s, as China's reform policies progressed, the government increasingly emphasized the role of technological innovation in driving economic growth. Universities, as critical innovation centers, began to play a pivotal role in translating research outputs into economic value. Inspired by Stanford University's Science Park model, Northeastern University in China established China's first USP in 1990. In 1999, the Ministry of Education and the Ministry of Science and Technology jointly issued *The Guidelines on Developing National University Science Parks*, advocating for USPs. By 2001, the official launch of the National University Science Park Program provided enhanced support for university-led science parks, leading to the rapid development.

After 2001, numerous universities in China have established science parks within or near their campuses.[5] These parks are largely financed and managed by the universities themselves, connecting academic research and industrial application. They generate revenue through several channels, such as leasing office space to technology-oriented small and medium-sized enterprises or R&D branches of larger firms. Additionally, they offer services like business incubation and technology transfer facilitation (Hu and Mathews, 2008). Moreover, these parks often benefit from substantial government policy support, including exemptions from land-use fees, income tax reductions, and financial subsidies, which further strengthen their operational sustainability and attractiveness to firms.

The Chinese government's strategic support for USPs reflects its ambition to harness university-based intellectual assets in driving the transfer and commercialization of scientific innovations. This approach aims to enhance national innovation capacity and stimulate economic growth, tackling critical challenges faced duringChina's rapid development in the early 21st century. At that time, the country faced a significant gap in innovation capacity, particularly within firms, which struggled with limited R&D capabilities due to constraints in talent, knowledge, and equipment (Kafouros et al., 2015; Li and Tan, 2020).

In stark contrast, Chinese universities were well-endowed with abundant innovation resources. Over 60 % of the national key laboratories and over 40 % of academicians were hosted within universities.[6] As reported by the Ministry of Science and Technology, universities accounted for over 80 % of SCI-indexed publications nationwide and over 20 % of invention patents in 2013, highlighting their pivotal role in national innovation. This significant contribution underscored the potential of universities to serve as engines of innovation.

Given these disparities between academia and industry, USPs emerged as crucial UI bridges, streamlining the transfer of knowledge and resources from universities to enterprises. By fostering collaboration, promoting knowledge spillovers, and providing resources such as talent and advanced infrastructure, USPs play a pivotal role in bridging academic research and industrial application. These efforts address China's innovation bottleneck while advancing its broader economic aspirations.

2.2. Conceptual framework

2.2.1. The effect of USPs on UI collaboration

Effective UI collaboration hinges on three key prerequisites. First, geographic proximity plays a foundational role in facilitating collaborative R&D by enabling direct and frequent interactions (Knoben and Oerlemans, 2006; Hervas-Oliver and Albors-Garrigos, 2009). Proximity supports frequent face-to-face interactions, critical for the transfer of tacit knowledge—intangible insights that are inherently difficult to convey across long distances (Gilly and Torre, 2000). However, as geographic distance grows, the efficiency of tacit knowledge transfer diminishes significantly. Second, the establishment of robust communication channels is essential to overcome barriers inherent in UI collaboration. Differences in organizational structures, incentive mechanisms, and operational constraints between universities and firms often hinder collaboration (Partha and David, 1994; Bercovitz and Feldman, 2006; Ryan et al., 2008). Implementing systematic communication strategies can effectively bridge these gaps. Third, effective collaboration is contingent upon the alignment of university expertise and capabilities with firm needs. Achieving this alignment is critical not only for realizing synergies but also for maximizing the value and impact of collaborative efforts. The widespread adoption of USPs worldwide can be attributed to their effectiveness in addressing the three key prerequisites for successful UI collaboration.

First, USPs are strategically located near universities, providing logistical and spatial advantages that facilitate collaboration (Vedovello, 1997; Link and Scott, 2003; Ferguson and Olofsson, 2004; Vásquez-Urriago et al., 2016; Anton-Tejon et al., 2024a). This proximity encourages frequent interactions between university researchers and park-based firms, while also allowing firms to actively participate in academic initiatives. By reducing communication and coordination costs, such locations foster an optimal setting for collaborative R&D. Moreover, park-based firms can strengthen partnerships with university research teams through shared laboratories or joint research centers, amplifying the benefits of geographic proximity.

Second, USPs serve as "bridges" that facilitate information sharing and communication platforms (Phongthiya et al., 2022). USPs often establish technology transfer centers or innovation service institutions, linking university researchers with firms and reducing information search costs. Additionally, they organize activities like innovation matchmaking events and technology expos to foster trust, overcome communication barriers, and enhance the prospects of successful

[4] There are primarily two modes of USPs. One is government-established and operated, as seen in Europe and Japan. The other is university-established and operated, as seen in the UK and China. Some countries have both modes coexisting, like the United States.

[5] There are also a few USPs that have been organized and invested by the government.

[6] National key laboratories refer to research entities established by the China's government since 1984, selecting strong universities and research institutes to support innovative research in cutting-edge disciplines, important areas and directions for national economic, social development, and national security through funding assistance and other means.

collaboration (Morgan, 2004; Laursen et al., 2011; Hemmert et al., 2014; Tan, 2006).

Third, USPs enhance UI alignment by attracting firms that align with the academic expertise of their affiliated universities. For instance, semiconductor or software firms prefer universities specializing in electronic information technology, while less technologically advanced firms seek partnerships with universities possessing superior technological expertise. Such alignment of knowledge and expertise establishes a robust foundation for collaborative R&D.

Based on the above, we propose the following hypothesis:

H1. : USPs significantly enhance UI collaboration.

2.2.2. The mechanism of USPs on UI collaboration: Spatial proximity

The extent to which firms benefit from university research largely depends on geographic proximity. Tacit knowledge, embedded in the practices and experiences of scientists and engineers (Von Hippel, 1994), is inherently difficult to articulate or codify (Polanyi, 1966). Its transfer requires rich communication channels, particularly face-to-face interactions (Amin and Wilkinson, 1999). In China, most USPs strategically embed their infrastructure within or adjacent to campuses. Through shared office spaces and co-located research facilities, these USPs systematically minimize physical barriers between universities and industries, enabling daily researcher-industry interactions (Vedovello, 1997; Link and Scott, 2003; Ferguson and Olofsson, 2004; Vásquez-Urriago et al., 2016; Anton-Tejon et al., 2024a). This spatial configuration not only reduces friction in exchanging complex, experience-based insights but also an environment conducive to spontaneous collaboration.

Additionally, as technological innovation becomes more complex, firms increasingly require expertise from multiple fields, making interdisciplinary collaboration essential. As Carbonell and Rodriguez (2006) observe, "*When dealing with technological complex projects [...], they [...] depend more heavily on other functional specialists for the expertise*." Science parks, by reducing the physical distance between firms and university researchers, provide an ideal environment for such collaboration. Proximity enables easier access to university facilities, facilitates interactions between firms and university researchers from diverse academic disciplines, and promotes the exchange of interdisciplinary knowledge, helping firms tap into the broad range of academic expertise necessary for innovation (Westhead and Batstone, 1998; Mae Phillips and Wai-chung Yeung, 2003).

Based on the above, we propose the following hypothesis:

H2. : USPs facilitate UI collaboration by bridging geographic gaps, enabling closer interactions between firms and universities.

2.2.3. The mechanism of USPs on UI collaboration: Intermediary services

Numerous studies highlight the challenges in establishing effective UI interactions (Guan et al., 2005; Chai and Shih, 2016; Hsu et al., 2024). Differences in goals, language, and organizational cultures create significant communication barriers (Bercovitz and Feldman, 2006; Ryan et al., 2008). Universities primarily focus on academic research, emphasizing knowledge creation and scholarly impact, whereas firms are market-driven, prioritizing economic returns and practical applications (Bruneel et al., 2010). Moreover, information asymmetry exacerbates these challenges. Firms often lack awareness of the technological resources and expertise available at universities, while universities face difficulties in identifying and understanding the specific technological needs of firms (Westhead and Storey, 1995; Hellmann, 2007; Fransman, 2008).[7] Even when connections are made, assessing the professional capabilities of potential partners remains a persistent challenge (Ryan et al., 2008).

USPs offer intermediary services to foster collaboration between universities and enterprises (Phongthiya et al., 2022). First, they employ professional technology brokers to connect firm needs with university knowledge and talent. Second, they offer technical exchange services to strengthen UI collaboration for technology and product development through activities like industry salons and exhibitions of scientific and technological achievements.[8]

Third, USPs establish dedicated spaces and platforms for collaborative innovation, such as joint research platforms and shared laboratories. These facilities facilitate collaboration between university researchers and corporate technical teams to co-develop innovations. By participating in foundational research, firms gain access to cutting-edge academic insights as providing universities with immediate market feedback. Such initiatives not only promote trust and information sharing (Morgan, 2004; Laursen et al., 2011; Hemmert et al., 2014) but also reduce matching costs (Nooteboom, 2002) and enhance the successful collaborations (Jaffe et al., 1993; Tan, 2006).

Based on the above, we propose the following hypothesis:

H3. : USPs enhance UI collaboration through intermediary services, significantly strengthening connections between universities and firms.

2.2.4. The mechanism of USPs on UI collaboration: Knowledge complementarity

As technologies become increasingly complex and diverse, firms need to access external complementary resources to overcome technological challenges (Nooteboom, 1999). USPs play a crucial role by facilitating complementary knowledge sharing between universities and firms, helping them access the resources needed for technological advancement.

USPs achieve this primarily by attracting firms whose technological needs align with the university's expertise. For instance, a USP affiliated with a university specializing in materials science and engineering may focus on attracting firms engaged in advanced materials or smart manufacturing. Some parks even restrict tenant industries to those aligned with the university's technological expertise, ensuring a strong match between firms' needs and university capabilities. This targeted strategy maximizes the value of collaborative R&D and fosters effective partnerships.

The effectiveness of USPs becomes particularly pronounced when they are linked to universities with high technological capacity. Science parks associated with such universities achieve superior performance, as research-based knowledge generated within universities spills over to tenant firms (Villasalero, 2014). These firms, in turn, absorb and apply the advanced knowledge, driving innovation and amplifying the impact of the collaboration (Bishop et al., 2011). Thus, USPs serve as a vital mechanism for translating academic expertise into industrial innovation, especially when supported by robust university technological capacities.

Based on the above, we propose the following hypothesis:

H4. : USPs foster UI collaboration by facilitating knowledge complementarity, particularly when universities possess advanced technological capabilities or expertise in specific fields.

3. Data, variables, and identification strategy

3.1. Data and variables

We assess the impact of USPs on UI collaboration using balanced panel data from 2006 to 2016, focusing on 326 China's Tier 1

[7] A 1996 survey of 950 companies in Beijing revealed that the "lack of effective communication channels" was cited as the primary barrier to obtaining research outcomes from R&D institutions and universities (Guan et al., 2005; Hsu et al., 2024).

[8] For example, the Huazhong University of Science and Technology Science Park provides such technology exchange services.

universities. Tier 1 universities, denoted as "*yiben*," are regarded as flagship institutions in China (Shi et al., 2020). These universities are categorized based on admission scores, with Tier 1 having the highest scores and a primary emphasis on scientific research, while Tier 2 and Tier 3 prioritize teaching with comparatively weaker research capabilities.[9] Notably, Tier 1 universities accounted for over 90 % of UI collaborative patents during the study period. Consequently, our empirical analysis is restricted to Tier 1 universities. To prevent estimation bias related to the always-treated group (Goodman-Bacon, 2021), universities that established science parks before 2007 were excluded. Ultimately, our sample comprises 326 China's universities. Fig. 1 illustrates the geographic distribution of universities in our sample.

3.1.1. USP dataset

We manually collected the data on USP opening dates from official websites and news sources. In our sample, 84 universities established parks from 2007 to 2016. Fig. 2 illustrates the annual distribution of newly established parks during this period. The number of newly established USPs shows a consistent trend each year, with no significant variations observed between different years.

3.1.2. UI collaborative patents dataset

Following Kong et al. (2022) and Tan et al. (2022), we measure UI collaboration using the number of successfully granted UI collaborative patent applications. UI collaborative patents are defined as those jointly applied for by universities and firms. Our dataset includes information from 326 universities that filed applications for UI collaborative patents with the State Intellectual Property Office of China (SIPO) between 2006 and 2016. The data encompass details such as application date, authorization date, applicants, International Patent Classification (IPC), patent type, and transfer status. Consistent with Kong et al. (2022), we categorize patents based on their application year rather than their authorization year, as this better reflects the actual time of invention (Griliches et al., 1987).[10]

In China, there are three types of patents: invention, utility model, and design. Invention patents are granted for new technical solutions related to products, processes, or improvements, similar to utility patents in the United States. Utility model patents are granted for new and practical technical solutions related to the shape or structure of a product, resembling utility patents in Europe and Japan. Design patents specifically cover the appearance of a product and involve limited technological improvement. Notably, invention and utility model patents generally exhibit higher technical content and originality compared to design patents, as highlighted in studies by Zheng et al. (2018) and Tan et al. (2022).

We separately calculated the number of UI collaborative patent applications for each of the three patent types at the university-year level: invention patents (*invention*), utility model patents (*utility*), and design patents *(design*). Additionally, we constructed the total number of patent applications (*total*) by aggregating these three categories. To facilitate analysis, all variables are expressed as the natural logarithm of one plus the number of patents.

To explore the impact of science parks on UI patent transfer, we obtained transfer records for the 326 universities from the SIPO. To assess the quality of these UI collaborative patents, we collected citation data from the IncoPat database. The IncoPat database is a comprehensive platform for retrieving and analyzing global patent data, widely used in research on innovation and intellectual property. It contains >180 million patents from 170 countries/organizations/regions around the world. Its data are procured from official and commercial intellectual property organizations in various countries, updated four times a week, and support batch searches based on the full text of patent documents. In recent years, IncoPat has been extensively utilized in innovation research, as evidenced by studies such as Wu et al. (2022) and Shen et al. (2023).

3.1.3. University characteristics dataset

We collected data on R&D staff, full-time R&D staff, and R&D contracts from 2006 to 2016. All these data are from *The Compilation of Scientific and Technical Statistics of China's Higher Education (Compilation),* compiled by the Science and Technology Department of the Ministry of Education of the People's Republic of China.[11]

Additionally, we collected Chinese journal papers and Web of Science (WOS) journal papers published by China's universities. The data on Chinese journal papers were obtained from the *Evaluation and Analysis Database of Scientific Research Achievements of Chinese Universities*. For WOS journal papers, the data was scraped from the Web of Science database and aggregated at the university level. To facilitate regression analysis, the counts were transformed using the natural logarithm of one plus the number of papers.

3.1.4. Firm-level dataset

We obtained our firm-level data from *Tianyancha*, a platform offering paid access to firm registration records. These records are officially authorized by the National Enterprise Credit Information Publicity System, which is managed by the State Administration for Industry and Commerce (SAIC). The data encompasses all firms registered in China over the past four decades, with over 75 million entries as of the end of 2021, including firm branches. It provides detailed information for each registered firm, including legal representatives, shareholders and their holdings, executives, registered capital value, year of establishment, and any historical changes or updates related to these details. This data is widely utilized in studies focusing on firm dynamics (Allen et al., 2019; Shi et al., 2021).

Table 1 presents the descriptive statistics.

3.2. Identification strategy

To test the impact of USPs on UI collaboration, we leverage the variation in the timing of science park establishments across universities to construct a difference-in-differences (DID) model. However, recent literature has raised concerns about potential biases in traditional estimates with staggered treatment timing, particularly when already-treated units are used as part of the control group for later-treated units (Goodman-Bacon, 2021). To address these issues, we adopt the staggered estimator proposed by Borusyak et al. (2024).[12] This estimator is selected for its ability to: (1) address the estimation bias inherent in traditional two-way fixed effect (TWFE) estimators, (2) flexible add joint

[9] China's universities initiate enrollment by province. A university is categorized as a Tier 1 university if it was listed as such for any year between 2006 and 2015. We exclude data from after 2016 due to changes in enrollment practices, where several provinces began merging the enrollment of Tier 1 and Tier 2 universities, rendering it impossible to differentiate between the two tiers.

[10] There is a time delay in the patent application approval process. On average, it takes approximately 3 years for invention patents, around 1 year for utility model patents, and about half a year for design patents to be granted. As our data from the State Intellectual Property Office of China (SIPO) was obtained in March 2021, some invention patent applications submitted after 2016 are still under review. Recognizing the potential bias introduced by this lag, our sample period is confined to the years 2006 to 2016 to ensure a more accurate and consistent analysis.

[11] For the details of *Compilation*, see Kang & Liu (2021).

[12] We also re-estimate the baseline model and event study using the estimators of traditional two-way fixed effects, De Chaisemartin and d'Haultfoeuille (2020), Callaway and Sant'Anna (2021) and Sun and Abraham (2021). USPs' UI cooperation facilitation effect remains significantly positive (see Appendix Figure A1).

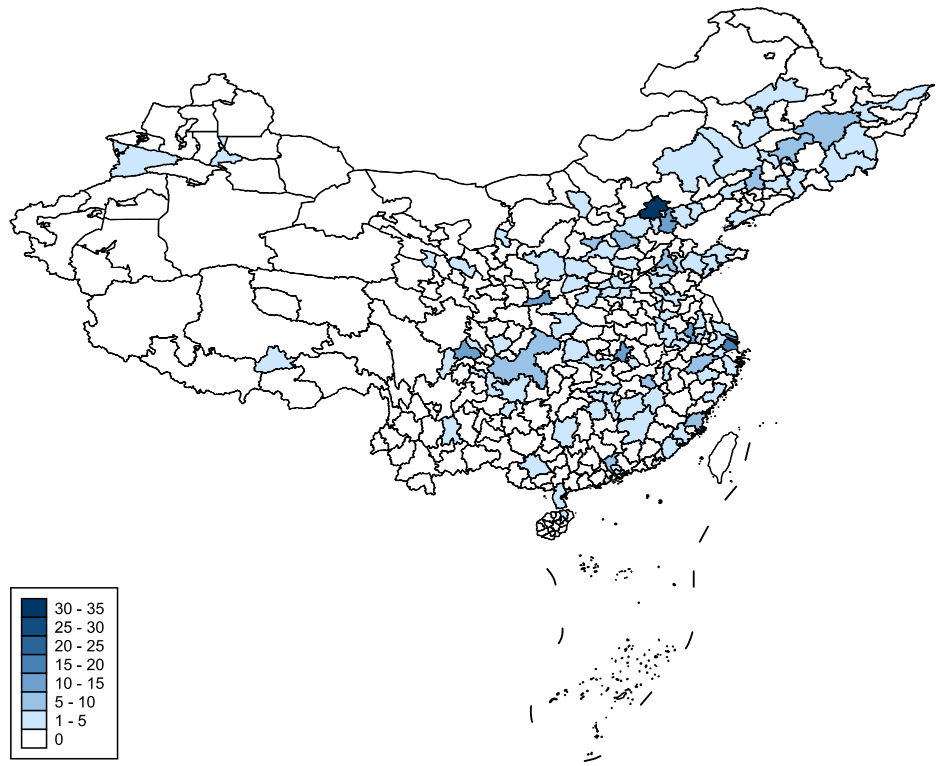


Fig. 1. Geographic distribution of 326 universities. *Notes:* This figure shows the distribution of 326 universities in our sample. We include only Tier 1 universities and exclude universities that established science parks before 2007.

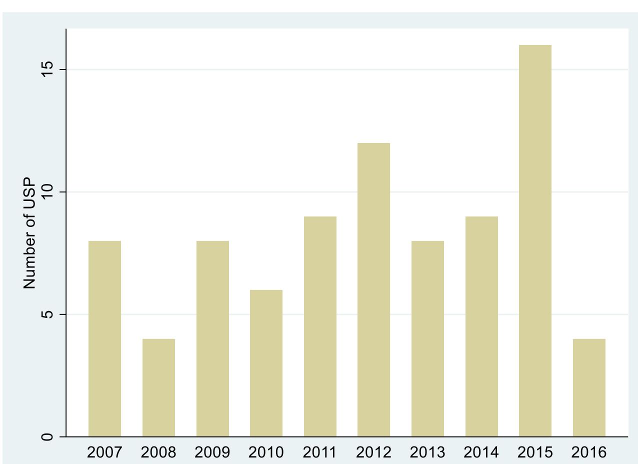


Fig. 2. Number of newly established USPs (2007–2016). *Notes:* This figure shows the annual count of newly established science parks from 2007 to 2016. To avoid estimation bias caused by always always-treated group, we exclude universities that established science parks before 2007.

fixed effects and enjoy high computational efficiency, and (3) incorporate interaction terms.[13]

Specifically, our model compares the change in UI collaboration patents before and after the establishment of USPs using the estimator from Borusyak et al. (2024). For university *i* and year *t*, we estimate the

[13] The inclusion of city-year joint fixed effects leads to the omission of 90 observations in the estimation. As a result, the effective sample size for the regression is 3496. Similarly, all subsequent estimations that incorporate city-year fixed effects also result in a reduction in sample size.

Table 1
Descriptive statistics of main variables.

Variable	Obs	Mean	Std.Dev.	Sources
Science Park	3586	0.120	0.325	1
Patent	3586	3.494	9.080	2
Invention	3586	2.142	5.921	2
Utility	3586	1.289	3.556	2
Design	3586	0.063	1.813	2
Technological fields	3586	2.896	5.857	2
Firms	3586	1.993	4.243	2
New firms	3586	0.016	0.135	3
Big_firms	3586	0.116	0.340	2 & 3
Small_firms	3586	0.507	0.750	2 & 3
Total_unifirm	3586	0.054	0.891	2 & 3
Invention_unifirm	3586	0.040	0.676	2 & 3
Utility_unifirm	3586	0.014	0.252	2 & 3
Total	3586	0.362	0.709	2 & 4
Invention	3586	0.436	0.849	2 & 4
Utility	3586	0.084	0.208	2 & 4
Total_std	3586	0.059	0.117	2 & 4
Invention_std	3586	0.070	0.144	2 & 4
Utility_std	3586	0.019	0.044	2 & 4
R&D contracts	2761	22.47	361.9	5
Patent transfer	3586	1.296	5.545	2
R&D staff	2761	507.6	614.1	5
Full-time R&D staff	2761	406.9	492.4	5
Ratio of professors in R&D staff	2761	0.740	0.164	5
Ratio of full-time R&D staff	2761	0.801	0.014	5
Chinese journal paper	3586	1101	805.9	6
WOS journal papers	3586	258.1	362.9	7

Notes: The specific sources of the data are as follows: 1. Hand-collected from news and university websites; 2. State Intellectual Property Office of the People's Republic of China (SIPO); 3. *Tianyancha* Websites: https://www.qcc.com/; 4.Incopat Websites: https://www.incopat.com/; 5. *The compilation of scientific and technical statistics of Chinese higher education*; *6. Evaluation and Analysis Database of Scientific Research Achievements of Chinese Universities*; 7. Web of Science (WOS) Websites: https://www.webofscience.com/wos.

following regression:

$$lninova\_co_{it} = \beta_0 + \beta_1\ USPs_{it} + \gamma_t + \mu_i + \theta_{ct} + \varepsilon_{it} \quad (1)$$

$lninova\_co_{it}$ is the natural logarithm of one plus the number of successfully granted patent applications in year t and university i. This includes total collaborative patent applications, collaborative invention patent applications, collaborative utility model patent applications, and collaborative design patent applications. *Science park*$_{it}$ is a dummy variable for whether the university i establishes the USPs in year t. University fixed effects μ_i control for unobserved university-specific factors that may have influenced the timing of the USP, and year fixed effects γ_t control those specific factors that both influenced the patent collaborations and the USP, such as national-level innovation policies. City-year fixed effects θ_{ct} control for time-variant city-specific shocks and policies. ε_{it} is a random, idiosyncratic error term. The standard errors are clustered at the university level to account for serial correlation in the dependent variable. β_1 is the coefficient of interest, which identifies the impact of USPs on UI collaborative patents.

The identification assumption of the DID estimation is that in the absence of the USPs, university-level outcomes would have followed the same path over time in universities treated by the USP in different years after partialling out the university and year fixed effects. We test this assumption using the event study model and estimate the following equation using the estimator from Borusyak et al. (2024):

$$lninova\_co_{it} = \beta_0 + \sum_{k=-7+}^{7+} \beta_k {}^{*} D_{itk}^{park} + \gamma_t + \mu_i + \theta_{ct} + \varepsilon_{it} \quad (2)$$

where k is the event time that captures the difference between year t and the USPs implementation year. D_{itk}^{park} is a dummy variable indicating the event time. We use the year before the USPs is proclaimed, or $k = -1$, as the reference group. All coefficients can be interpreted as changes relative to the year before the USP is proclaimed. The rest of the parameters are the same as eq. (1).

4. The effect of USPs on UI collaborative patents

4.1. Baseline results

Table 2 presents the baseline results. Columns (1)–(4) show that, after controlling for university and year fixed effects, USPs have a significantly positive impact on the number of UI collaborative patents, as well as on invention and utility model patents. To further account for time-variant shocks or policies specific to different cities, such as innovation policies, we also control for city-year fixed effects in columns (5)–(8).[14] Column (5) indicates that establishing USPs has led to a noteworthy 51 % increase in UI collaborative patents, equivalent to approximately 1.8 patents per university per year. Columns (6)–(8) reveal that this increase is primarily driven by invention and utility model patents, with invention patent applications rising by almost 40 % and utility model patents increasing by 37 % following the establishment of USPs. These findings are consistent with those of Van Dierdonck et al. (1991), Westhead and Storey (1995), Löfsten and Lindelöf (2002, 2003, 2004), Díez-Vial and Fernández-Olmos (2015), Albahari et al. (2017), Anton-Tejon et al. (2024a), etc., who also find the positive role of science parks in fostering UI linkages.

Although USPs significantly facilitate cooperation in UI invention and utility model patent applications, no notable effect was observed on design patent applications. The observed heterogeneity in the impact on different types of patents can be explained to two main reasons. Firstly, invention and utility model patents typically demand higher research capabilities compared to design patents, with the latter relying more on the technical advantages of universities. Consequently, USPs have a more pronounced impact on the applications for invention and utility model patents. Secondly, within our sample, design patents constitute only 0.4 % of UI collaborative patents, which may affect the variability and accuracy of coefficient estimates. Therefore, we exclude design patent applications from further discussion. These findings underscore the significant role of USPs in fostering collaborative innovation between universities and firms, particularly in areas requiring higher research capabilities.

The validity of our main results in Table 2 depends on the assumption that no differential trends exist for the treated and control groups in the pre-treatment period. For instance, if UI collaborative patents are already growing for the treatment group before the USPs implementation, our estimates in Table 2 could be overestimated. To address this concern, we further test for parallel pre-trends in the outcome variables using an event study method, as depicted in eq. (2). We report the results in Fig. 3. The coefficients before the USPs implementation are insignificant, indicating that UI collaborative patents show no significant change before the USP implementation. The coefficient estimates after that are positive and statistically significant, aligning with our baseline findings. This consistency reinforces the robustness of our main results and supports Hypothesis 1.

4.2. The mechanisms of USPs on UI collaboration

After establishing the link between USP and UI patent collaboration, we now focus on understanding the mechanism. It is important to emphasize that any factor accounting for our main findings must meet two criteria: (1) its effect should be correlated with USP, and (2) its effect should have changed discontinuously before and after the construction of USP.

4.2.1. Spatial proximity

Geographic proximity is crucial for enabling firms to benefit from academic research, as tacit knowledge—embedded in the expertise and practices of researchers—requires face-to-face interaction for effective transfer (Polanyi, 1966; Von Hippel, 1994; Amin and Wilkinson, 1999). USPs, when located near universities, can effectively reduce the geographic distance, promoting UI knowledge spillovers and collaboration (Vedovello, 1997; Link and Scott, 2003; Ferguson and Olofsson, 2004; Vásquez-Urriago et al., 2016; Anton-Tejon et al., 2024a). Notably, not all USPs in China are established near universities, providing a valuable opportunity to identify this mechanism. If geographic closeness is indeed a key channel, we would expect to observe a more pronounced increase in the number of UI cooperative patents in USPs located closer to universities.

To test this, we used Google Maps to calculate the distances between each university and its associated USP. Since the median distance of science parks from university campuses was 4.68 km, so we approximated 5 km as a distinguishing threshold. With a 5 km threshold, universities were classified into two groups: those with science parks within 5 km and those located farther away. These groups were then compared against universities without science parks. The results, presented in Table 3, reveal a clear pattern. Columns (1)–(3) show that universities with science parks located within 5 km experienced a significant increase in UI cooperative patents following the establishment of the park. In contrast, Column (5) shows that universities >5 km away from a science park saw only a 19.1 % increase in invention patents, considerably smaller than the 29 % increase reported in Column (2). While the results for utility model patents for science parks located farther from the campus were positive, they were not statistically significant.

These findings suggest that the closer a USP is to its affiliated university, the greater the increase in UI cooperative patents. Since we controlled for university, year, and city-by-year fixed effects, this difference cannot be attributed to factors that remain constant over time or

[14] At the request of the reviewers, we have used this estimator throughout the paper, except for Fig. A1.

Table 2
The effect of USPs on UI collaborative patents.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Ln (1 + Collaborative patents)							
	Total	Invention	Utility	Design	Total	Invention	Utility	Design
USPs	0.384***	0.314***	0.304***	0.018	0.508***	0.400***	0.371***	0.016
	(0.094)	(0.080)	(0.085)	(0.013)	(0.109)	(0.092)	(0.090)	(0.012)
University FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
City # Year FE	N	N	N	N	Y	Y	Y	Y
Observations	3586	3586	3586	3586	3496	3496	3496	3496

Notes: This table presents the results of eq. (1) using estimators proposed by Borusyak et al. (2024). The dependent variables, Ln (1 + Collaborative Patents), are the natural logarithm of one plus the number of collaborative patents. Columns (1)–(4) present estimates for the number of total collaborative patents, collaborative invention patents, collaborative utility model patents, and collaborative design patents with university and year fixed effects. Columns (5)–(8) include additional controls for city-year fixed effects. Standard errors are clustered at the university level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

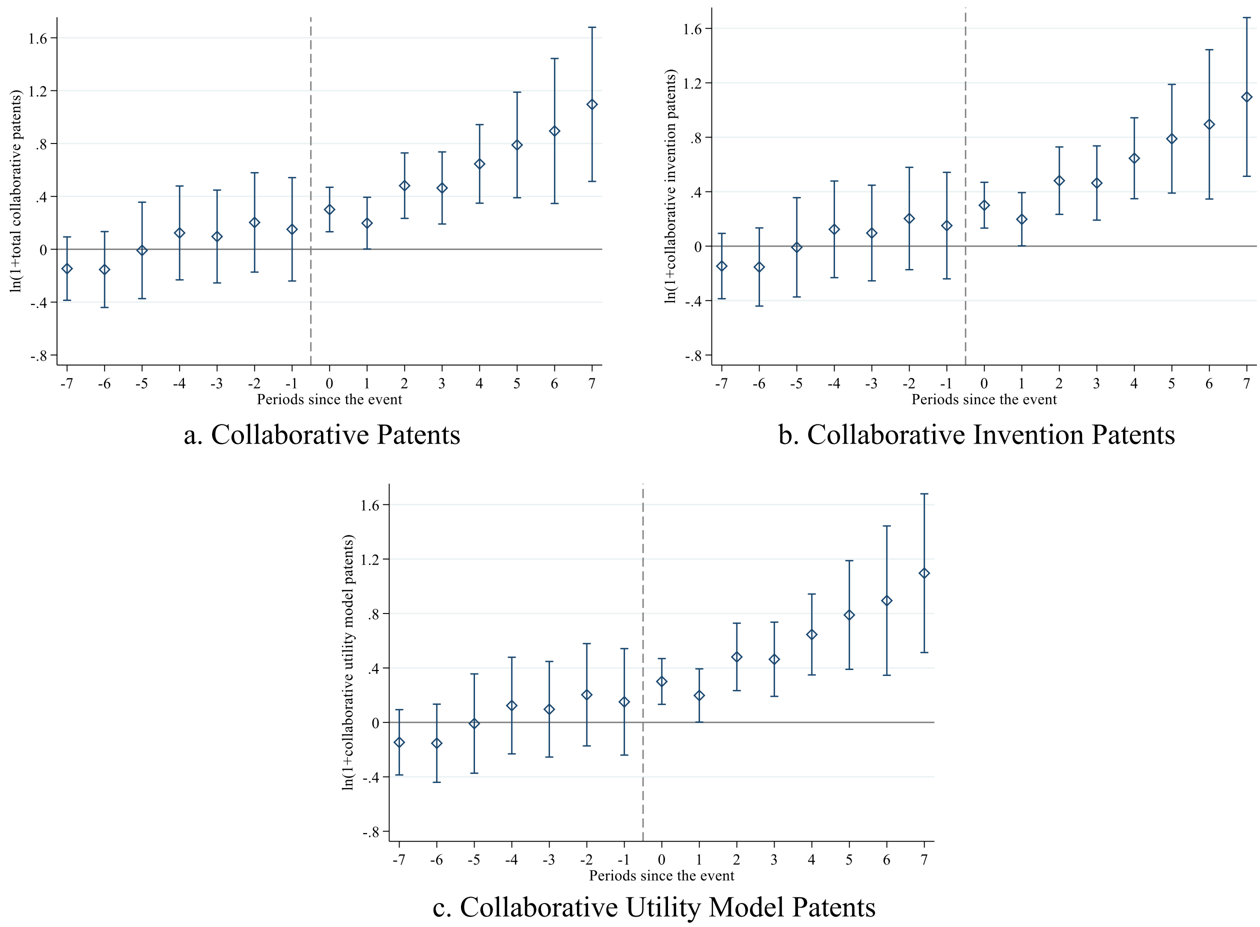


Fig. 3. Event study. *Notes:* The figure depicts the results of the event study using the estimator proposed by Borusyak et al. (2024). Fig. 3a to c represents the event study for the number of total collaborative patents, collaborative invention patents, and collaborative utility model patents, respectively. All the dependent variables are the natural logarithm of one plus the number of patents. The X-axis represents the relative time. The Y-axis represents the coefficients. The points in each figure represent the estimated effects at each event time, and the dotted blue lines represent the 95 % confidence intervals. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

across universities. The only plausible explanation for this variation is the distance between the USP and the university itself. These results strongly support Hypothesis 2.

4.2.2. Intermediary services

Establishing effective UI interactions is challenging due to differences in goals, language, and culture (Bercovitz and Feldman, 2006; Ryan et al., 2008), as well as information asymmetry (Guan et al., 2005). USPs help bridge this gap by providing intermediary services (Phongthiya et al., 2022), which reduce matching costs and enhance cooperation (Morgan, 2004; Laursen et al., 2011).

In this section, we present three pieces of evidence highlighting the intermediary services provided by USPs. First, USPs attract firms that seek to establish connections with universities and leverage university resources (Westhead and Storey, 1995; Phillimore, 1999; Löfsten and Lindelöf, 2002, Löfsten and Lindelöf, 2003; Abramovsky and Simpson, 2011; Ramírez-Alesón and Fernández-Olmos, 2018). The clustering of related firms within USPs facilitates face-to-face interactions and

Table 3
Mechanism: geographic proximity.

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln (1 + Collaborative patents)					
	Around the Campus			*Away from Campus*		
	Total	Invention	Utility	Total	Invention	Utility
USPs	0.376***	0.290***	0.307***	0.225*	0.191*	0.130
	(0.118)	(0.100)	(0.105)	(0.129)	(0.105)	(0.084)
University FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
City # Year FE	Y	Y	Y	Y	Y	Y
Observations	3365	3365	3365	3161	3161	3161

Notes: The table tests whether USPs promote UI collaboration by facilitating the geographical proximity of firms and universities. The dependent variables, Ln (1 + Collaborative Patents), are the natural logarithm of one plus the number of collaborative patents. Columns (1)–(3) and Columns (4)–(6) represent treatment groups of universities located relatively close to the science park (≤5 km) and those located far from the science park (>5 km), respectively. The control group in both cases consists of universities without an established science park. Standard errors are clustered at the university level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

enhances knowledge spillovers across organizations (Jaffe, 1989; Mansfield and Lee, 1996; Arundel and Geuna, 2004; Morgan, 2004; Laursen et al., 2011). USPs further enhance these connections by providing brokerage services, organizing technology salons and exhibitions, offering shared laboratories, and increasing opportunities for universities to engage with firms (Phongthiya et al., 2022).

Empirical results support this function: after controlling for university, year, and city-year fixed effects, USPs increased the number of collaborative firms associated with universities by approximately 43.1 %, or about 0.86 firms. This significant increase provides direct evidence supporting Hypothesis 3, highlighting the role of USPs in fostering UI connections.

Second, the size of a firm plays a critical role in determining UI collaboration. Larger firms typically face lower transaction costs (Fontana et al., 2006) and benefit from informal collaboration channels, such as alumni networks and donations (Yoshihara and Tamai, 1999; Fukugawa, 2006; Fransman, 2008). If the intermediary services provided by USPs are indeed impactful, we would expect their effects to be more pronounced for smaller firms, which often face higher barriers to establishing UI partnerships.

To test this, firms were categorized based on their registered capital: those above the mean were classified as large, and those below the mean as small. Columns (2) and (3) of Table 4 reveal that the establishment of USPs led to a 38.9 % increase in collaborations between universities and small firms, while the impact on large firms was relatively modest. This

Table 4
Mechanism: intermediary services.

	(1)	(2)	(3)	(4)	(5)
	Ln (1 + Firms)			Ln(1 + Patent transfers or contracts)	
	Firms	Big_firms	Small_firms	Patent transfer	R&D contracts
USPs	0.431***	0.069***	0.389***	0.370***	0.459**
	(0.090)	(0.026)	(0.084)	(0.077)	(0.199)
University FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
City # Year FE	Y	Y	Y	Y	Y
Observations	3496	3496	3496	3496	2652

Notes: This table evaluates how USPs promote cooperation by offering intermediary services that facilitate UI interactions. We defined the big and small firms based on their registered capital. Columns (1)–(3) present estimates for the number of collaborative firms, collaborative big firms, and collaborative small firms with university, year, and city-year fixed effects. Columns (4) and (5) present estimates of the number of patent transfers and R&D contracts with university, year, and city-year fixed effects. Because of the missing in *Compilation*, we only successfully matched 233 universities for R&D contracts. Standard errors are clustered at the university level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

evidence suggests that USPs effectively bridge the gap for smaller firms, enabling them to overcome resource constraints and access university innovation.

Third, the platform effect of USPs is further supported by their role in facilitating the commercialization of university innovations. Evidence for this is presented in Columns (4) and (5), which analyze the impact of USPs on the transfer of university patents and the signing of R&D contracts. The results indicate that USPs have increased patent transfers by 37 % and technology transfer contracts by 46 %. These findings align with Caldera and Debande (2010), who observed that universities with USPs are more likely to engage in technology transfer agreements.

Together, these three pieces of evidence: (1) the increase in the number of firms collaborating with universities, (2) stronger effect on collaborations with small firms, and (3) the enhanced commercialization of university achievements-strongly support Hypothesis 3, demonstrating the significant intermediary and platform role of USPs in fostering UI collaboration.

4.2.3. Knowledge complementarity

In addition to fostering geographical proximity and providing intermediary services, USPs also enhance knowledge complementarity by attracting firms that align with the university tecnological abilities and expertise, thereby boosting R&D collaborations and innovation.

To test this, we examine evidence from two perspectives: First, we assess the role of universities' ability to manage complex technologies. Using all patents solely applied by universities in 2006, we identified their primary IPC-4 classifications and matched them with technology complexity measures from Broekel (2019). Based on these metrics, we calculated each university's average technological complexity for 2006. Universities with complexity levels above the mean were categorized as "high ability universities," while those below the mean were labeled as "low ability universities."

The results in Table 5 reveal a significant increase in UI cooperative patents for high ability universities following the establishment of USPs. In contrast, low ability universities exhibited no significant changes. This finding indicates that USPs primarily facilitate collaborative patenting for universities with greater R&D capabilities, as these institutions generate more advanced knowledge spillovers, fostering better knowledge complementarity with firms.

Second, we analyze the effect of USPs on universities' advantageous technological fields. Using all patents applied by universities in 2006, we classified each university's IPC-4 fields based on the mean number of patents per field. Fields exceeding the mean were designated as advantageous fields, while those below the mean were considered non-advantageous fields. For each field, we calculated the annual number of UI collaborative patents.

The results in Table 6 highlight that USPs significantly boosted collaborative patents in universities' advantageous fields, with total

Table 5
Mechanism: knowledge complementarity (technological capabilities of universities).

	(1)	(2)	(3)
	Ln (1 + Collaborative patents)		
	Total	Invention	Utility
USPs × Universities with high ability	0.658***	0.525***	0.481***
	(0.111)	(0.097)	(0.095)
USPs × Universities with low ability	−0.131	−0.132	−0.097
	(0.128)	(0.081)	(0.095)
University FE	Y	Y	Y
Year FE	Y	Y	Y
City # Year FE	Y	Y	Y
Observations	3496	3496	3496

Notes: This table, from the perspective of the technological capabilities of universities, examines USPs' promotion of UI collaboration by facilitating UI knowledge complementarity. The dependent variables, Ln (1 + Collaborative Patents), are the natural logarithm of one plus the number of collaborative patents. Using data on patents independently applied for (and ultimately granted) by universities in 2006, we matched these patents to the technology complexity categories provided by Broekel (2019) and calculated the average technological complexity of patents for each university in 2006. Universities with complexity levels above the mean were categorized as "High-ability universities," while those below the mean were labeled as "Low-ability universities." Standard errors are clustered at the university level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

patents, invention patents, and utility model patents increasing by 21.6 %, 17.1 %, and 13.7 %, respectively. In contrast, non-advantageous fields showed a more modest increase of 11.9 % in total cooperative patents, primarily driven by utility model patents.

These findings underscore that the mechanism of knowledge complementarity in UI collaboration relies heavily on universities' advantages in technological capability and specialized knowledge. The establishment of USPs amplifies this effect, particularly for universities with strong R&D capabilities and advantageous technological domains, resulting in a higher volume of collaborative patents. Together, the evidence from Tables 5 and 6 strongly supports Hypothesis 4, demonstrating the critical role of USPs in fostering knowledge-driven UI collaboration.

4.2.4. *Other competing mechanisms*

In addition to the three main mechanisms discussed above, we also examined two alternative competing mechanisms. The first is "university-owned firms," which suggests that policy incentives and subsidies for USPs may encourage newly established university-owned firms to leverage academic achievements for profit or motivate existing university-owned firms to increase investment in collaboration with universities. To investigate this, we obtained data on firms controlled by universities from *Tianyancha*, classifying them as university-owned firms. The analysis involved calculating the number of newly established university-owned firms for each university in a given year. Subsequently, we matched the names of university-owned firms with collaborative patent applicants and determined the number of university-owned firms collaborating with universities in a specific year. Finally, the study identified the number of collaborative patents involving university-owned firms for each university in that year.

Table 7 examines whether the effects of USPs on collaborative patents are influenced by university-owned firms. Columns (1) and (2) reveal that USPs do not lead to the establishment of new university-owned firms and the number of university-owned firms collaborating with their affiliated universities does not show any significant increase. Columns (3)–(5) investigate the impact of USPs on the number of patents involving university-owned firms. The coefficients across these columns are close to zero, aligning with the results in Column (2) and indicating no discernible effect. Taken together, the findings in Table 7 demonstrate that the observed increases in collaborative patents following the establishment of USPs are not driven by university-owned firms.

The second is "investment expansion," which posits that establishing USPs could attract industry funds, increasing university income and incentivizing universities to invest more in applied research, thus expanding their R&D staff. A substantial body of literature has demonstrated that the income generated from research achievements significantly enhances scientists' motivation for innovation (Jensen and Thursby, 2001; Lach and Schankerman, 2008; Baldini, 2010; Hvide and Jones, 2018). Strengthening UI connection is advantageous for converting technological resources into income, thereby increasing returns from industry (Gulbrandsen and Smeby, 2005; Welsh et al., 2008; D'este and Perkmann, 2011; Ankrah et al., 2013; Bikard et al., 2019). This may lead universities to prioritize applied research (Henderson et al., 1998; Link and Scott, 2003; Chai and Shih, 2016), increasing the employment of highly productive researchers.

Utilizing data from *Compilation*, we measure the size of R&D staff and full-time R&D staff. Additionally, we gauge the structure of R&D staff by examining the proportion of R&D staff with professor titles and full-time positions. Table 8 reveals that USPs have no significant impact on the quantity or structure of R&D staff. These findings indicate that USPs do not contribute to an expansion in the university's R&D workforce or a change in its composition. Therefore, the effect of USPs on UI collaboration cannot be attributed to increased investment.

Table 6
Mechanism: knowledge complementarity (advantageous technologies of universities).

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln (1 + Collaborative patents)					
	Advantageous fields			Non-advantageous fields		
	Total	Invention	Utility	Total	Invention	Utility
USPs	0.216***	0.171***	0.137**	0.119**	0.079	0.091***
	(0.077)	(0.062)	(0.061)	(0.059)	(0.054)	(0.033)
University FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
City # Year FE	Y	Y	Y	Y	Y	Y
Observations	3496	3496	3496	3496	3496	3496

Notes: This table, from the perspective of the university's advantageous technological fields, examines USPs' promotion of UI collaboration by facilitating UI knowledge complementarity. The dependent variables, Ln (1 + Collaborative Patents), are the natural logarithm of one plus the number of collaborative patents. Using data on patents independently applied for (and ultimately granted) by universities in 2006, we calculated the number of patents for each university in each technology field (main IPC-4). Technology fields with patent counts above the mean were classified as "advantageous technology fields," while those below the mean were classified as "non-advantageous technology fields." Standard errors are clustered at the university level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7
Competitive mechanisms: university-owned firms.

	(1)	(2)	(3)	(4)	(5)
	Ln (1 + Firms)		Ln (1 + Collaborative patents with university-owned firms)		
	New firms	Univ_Firms_co	Total	Invention	Utility
USPs	−0.054	0.008	0.010	0.010	−0.002
	(0.068)	(0.008)	(0.014)	(0.012)	(0.005)
University FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
City # Year FE	Y	Y	Y	Y	Y
Observations	3496	3496	3496	3496	3496

Notes: The table excludes competitive mechanisms—USPs promote the increase in collaborative patents by facilitating the creation of university-owned firms. The dependent variable in Column (1) is the number of newly established university-owned firms. The dependent variable in Column (2) is the number of university-owned firms that collaborated with the university. The dependent variable in Columns (3) to (5) is the number of patents that collaborate with university-owned firms. All the regressions control the university, year, and city-year fixed effects. Standard errors are clustered at the university level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 8
Competitive mechanisms: investment expansion.

	(1)	(2)	(3)	(4)
	Size: Ln (1 + People)		Structure: Ratio	
	R&D staff	Full-time R&D staff	Ratio of professors in R&D staff	Ratio of full-time R&D staff
USPs	−0.010	−0.003	−0.024	0.011
	(0.088)	(0.095)	(0.019)	(0.011)
University FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
City # Year FE	Y	Y	Y	Y
Observations	2652	2652	2652	2652

Notes: The table excludes competitive mechanisms—USPs promote the expansion of R&D staff, thereby promoting an increase in collaborative patents. The dependent variables in Columns (1) and (2) are the number of R&D staff and full-time R&D staff. The dependent variable in Columns (3) and (4) is the proportion of R&D staff with professor titles and full-time positions. Because of the missing in *Compilation*, we only successfully matched 233 universities in this table. All the regressions control the university, year, and city-year fixed effects. Standard errors are clustered at the university level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5. Robustness checks

5.1. Other measurements

To reinforce the baseline findings, we further decompose the impact of USPs on UI collaborative patents by examining the extensive and intensive margins from a technology field perspective, which provides deeper insights into the breadth and depth of innovation activities facilitated by USPs. For the extensive margin, we measure the number of technological fields involved in UI collaborative patents at the university level, identified using the first four digits of the IPC code (IPC-4). Column (1) of Table 9 shows that USPs increase the number of technological fields by 45.4 %.

Moving on to the intensive margin, we assessed the annual collaboration intensity by calculating the number of patents each university collaborates with firms in each technological field. Constructing panel data with three dimensions—university, technological field, and year—we conducted regression using eq. (1), incorporating fixed effects for technological fields. As shown in Column (2) of Table 9, USPs lead to a 0.3 % annual increase in collaboration intensity. These results demonstrate the significant and multifaceted impact of USPs on both the breadth (extensive margin) and depth (intensive margin) of UI collaboration.

Table 9
Robustness: extensive margin and intensive margin.

	(1)	(2)
	Extensive margin Ln(1 + Technological fields)	Intensive margin Ln(1 + Patents)
USPs	0.454***	0.003***
	(0.104)	(0.001)
University FE	Y	Y
Year FE	Y	Y
City # Year FE	Y	Y
IPC-4 FE	N	Y
Observations	3496	2,583,544

Notes: The table shows the USPs' impact on UI patents by examining extensive and intensive margins across technology fields. The extensive margin is defined as the number of technological fields involved in all the UI collaborative patents at the university level. The intensive margin is defined as the number of patents each university collaborates with firms in each technological field annually. In Column (2), the data structure is a three-dimensional panel with university, technological field, and year. Standard errors are clustered at the university level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.2. Confounding factors

Despite our efforts to control for potential biases through university, year, and city-year fixed effects, there remains a possibility of biased results stemming from specific university-level policies. To investigate this concern, we specifically focus on the *National Key Discipline Project* (NKDP), initiated by the Chinese Ministry of Education in 2010. This project targets the advantageous disciplines of 84 universities to enhance their innovation capabilities, with financial support provided by both the central and local governments. To address this potential confounding factor, we introduce a dummy variable indicating whether a university is supported by NKDP in Appendix Table A1. However, including this variable does not significantly alter our main results. This reinforces the credibility and robustness of our findings, suggesting that the observed effects of USPs on collaborative patents are not materially influenced by NKDP.

Since 2000, the Chinese government implemented a multitude of policies to foster the development of higher education, raising the concern that our findings might be influenced by other confounding policies. Many of these policies primarily target the enhancement of basic research capabilities in Chinese universities. However, it's essential to distinguish USPs from these policies, as USPs' primary objective is to expedite the transformation of scientific and technological achievements and foster technological entrepreneurship, rather than directly enhancing basic research.

Theoretically, the establishment of USPs should not significantly affect university-based basic research. To explore this possibility and ensure that observed effects on UI collaborative patents are not confounded by undisclosed factors influencing basic research, we measure university basic research using Chinese journal publications and Web of Science (WOS) journal publications. The results presented in Appendix Table A2 indicate that both measurements yield small and statistically insignificant coefficients, suggesting that USPs have no discernible impact on the quantity of academic papers. These findings bolster our confidence that other concurrent confounding policies have not substantially affected our estimation of the impact of USPs on collaborative patents.

5.3. Outlier observations

As depicted in Fig. 1, there are noticeable variations in the distribution of USPs across provinces, with Beijing and Shanghai hosting the most significant number of parks and being areas with the highest concentration of high-tech firms in China. To address concerns about potential influences from outlier provinces with unobservable factors, we adopt a rigorous approach by excluding one province at a time and recalculating the regression equation. The results presented in Appendix Fig. A2 show that all the estimates remain consistently positive and statistically significant.

5.4. Randomly generated USP status

To rigorously assess the impact of omitted variables on the results, we randomly assign the USP status to universities and conduct the regression using Eq. (1). This random data generation and regression process are iterated 1000 times. The results, as illustrated in Appendix Fig. A3, depict the distribution of estimates from the 1000 runs alongside the baseline estimate. The distribution of estimates from random assignments is centered around zero, indicating no discernible effect on the randomly constructed USP implementation. These observations strongly suggest that unobserved factors do not account for the significant impact of USPs on UI collaborative patents, reinforcing the robustness of our findings and providing confidence in the causal relationship identified.

6. Further discussion: The quality effects of USPs on UI collaborative patents

In the previous section, we analyzed the impact and mechanisms of USPs on UI collaborative patents. However, given the significant variation in patent value, merely counting patents does not adequately distinguish breakthrough innovations from incremental ones. Patent citations offer a more nuanced measure of impact, capturing knowledge flows and identifying pivotal points of technological learning (e.g., Almeida and Kogut, 1999). Drawing on the frameworks established by Trajtenberg (1990), Anton-Tejon et al. (2024b), and Kong et al. (2022), we use forward citation counts as a proxy for innovation quality to assess the effects of USPs on the quality of UI collaborative patents.

Specifically, we calculate the average number of forward citations of UI collaborative patents of university i in year t. To address the truncation problem in patent citation data (where earlier patents tend to have higher citations), we divide the average number of citations by the patent age to obtain annual citations. Columns (1)–(3) in Table 10 display the results regarding the impact of USPs on annual citations for collaborative patents, collaborative invention patents, and utility model patents. Our findings indicate that USPs significantly increase the quality of UI collaborative patents, which is consistent with Anton-Tejon et al. (2024b). The annual citations for collaborative patents increased by 12.2 %, primarily driven by a 16.8 % average increase in invention patents. These results align with our previous conclusion that invention patents are more challenging to develop and possess more excellent technical content than others.

Further, considering the heterogeneity in different technological fields, we standardized the number of forward citations according to Hall et al. (2001). As shown in eq. (3), $Citation^s_{ut}$ represents the standardized citations for university u in year t, $Citation_i$ denotes the number of patent i citations that applied in year t, $Mean\ citation_{ft}$ is the average citations to patents in the same technology field as patent i in year t, $Number_{ut}$ corresponds to the count of patents affiliated with university u in year t, Age_i is the age of patent i, calculated as 2021 minus t (our data is collected in 2021). Columns (4) to (6) in Table 10 display that the impact of USPs on collaborative patents, invention patents, and utility model patents is significantly positive when accounting for heterogeneity across various technological fields. Similar to the findings presented in Columns (1) to (3), a more pronounced effect is observed on invention patents.

$$Citation^s_{ut} = \frac{\sum Citation_i / Mean\ citation_{ft}}{Number_{ut}} \Big/ Age_i \tag{3}$$

7. Conclusion

UI collaboration is vital for industrial and economic development. Governments worldwide have increasingly implemented USPs as a strategy to facilitate such collaboration. By analyzing the staggered establishment of China's USPs from 2006 to 2016, this study provides robust causal evidence of their impact. Specifically, USPs significantly boost the quantity of UI collaborative patents, particularly invention and utility model patents, while also enhancing their quality, as reflected in increased citations. These effects are driven by mechanisms such as spatial proximity, intermediary services, and knowledge complementarity, which collectively foster interaction, reduce search and matching costs, and align university expertise with industrial needs.

The findings hold significant implications for policymakers. First, USPs should be regarded as an indispensable component of national innovation ecosystems. They serve as bridges connecting academic and industrial sectors, thereby addressing structural inefficiencies in knowledge transfer. This is particularly critical for emerging economies, where firms often lack the innovative capacities needed to compete in global markets. Policymakers should consider providing financial incentives, infrastructure support, and governance mechanisms to optimize the functioning of USPs. Second, given the importance of spatial proximity, strategic location planning for USPs is essential to maximize their impact on UI collaboration. Third, governments should encourage small and medium-sized enterprises to engage in USP-facilitated collaborations, as these firms often benefit the most from university knowledge spillovers.

This paper offers significant contributions to the academic literature and provides valuable implications for scholars studying UI collaboration. First, with respect to extant research (e.g., Colombo and Delmastro, 2002; Bakouros et al., 2002), it establishes a robust empirical framework for evaluating the impact of USPs on collaborative innovation. It is the first to examine the gradual introduction of science parks at Chinese universities and to apply the DID method to quantitatively identify the causal impact of USPs on UI collaboration. Second, based on the existing research (e.g., Vedovello, 1997; Phan et al., 2005; Anton-Tejon et al., 2024a), the study advances the understanding of the mechanisms through which USPs foster UI collaboration, identifying spatial proximity, intermediary services, and knowledge complementarity as key channels. These insights provide a more nuanced view of how USPs bridge the gap between academia and industry. Moreover, extending current literature (Huang et al., 2012; Albahari et al., 2017; Lamperti et al., 2017; Ünlü et al., 2023; Anton-Tejon

Table 10
The effects of USPs on UI collaboration: quality effect.

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln (1 + Citations of collaborative patents)					
	Total	Invention	Utility	Total_std	Invention_std	Utility_std
USPs	0.122***	0.168***	0.051***	0.039***	0.052***	0.018***
	(0.036)	(0.043)	(0.016)	(0.009)	(0.011)	(0.005)
University FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
City # Year FE	Y	Y	Y	Y	Y	Y
Observations	3496	3496	3496	3496	3496	3496

Notes: This table explores the impact of USPs on the quality of collaborative patents. The dependent variables, Ln (1 + Citations of collaborative patents), are the natural logarithm of one plus citations of collaborative patents. Columns (1)–(3) present estimates for collaborative patents, collaborative invention patents, and collaborative utility model patents with university, year, and city-year fixed effects. Similarly, the results in Columns (4)–(6) are standardized citations by Hall et al. (2001). Standard errors are clustered at the university level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

et al., 2024a, 2024b), our use of patent citations as a proxy for quality highlights the broader implications of USPs beyond mere patent quantity, emphasizing their role in enhancing innovation outcomes. Collectively, this study seeks to add to the growing literature on UI collaboration by providing causal evidence, methodological insights, and a perspective on the dynamics within innovation ecosystems.

While our study provides valuable insights into the impact of USPs on UI collaboration, it is not without limitations. First, the analysis is based on data from China, which may limit the generalizability of the findings to countries with different institutional and cultural contexts. Comparative studies across countries could shed light on how these contextual differences influence the effectiveness of USPs. Second, this study uses patent citations as a proxy for patent quality, which, while widely accepted, cannot fully capture the practical application or commercialization of patents. Future research could explore alternative metrics, such as licensing revenues or the formation of high-growth firms, to provide a more comprehensive view of USP impacts. Third, this study primarily examines the short- to medium-term effects of USPs, leaving the long-term impacts on regional innovation and economic development an open question. Longitudinal studies could help understand how USP contributions evolve over time, particularly in supporting emerging technologies and fostering sustainable innovation ecosystems. Lastly, future research could also investigate the interplay between USPs and other innovation policies, such as tax incentives or intellectual property reforms, to better understand how these initiatives complement or substitute one another in promoting UI collaboration.

CRediT authorship contribution statement

Yankun Kang: Writing – review & editing, Formal analysis, Data curation, Conceptualization. **Ruiming Liu:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Bingyan Yang:** Writing – original draft, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ruiming Liu reports financial support was provided by National Social Science Foundation of China. Yankun Kang reports financial support was provided by National Natural Science Foundation of China. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

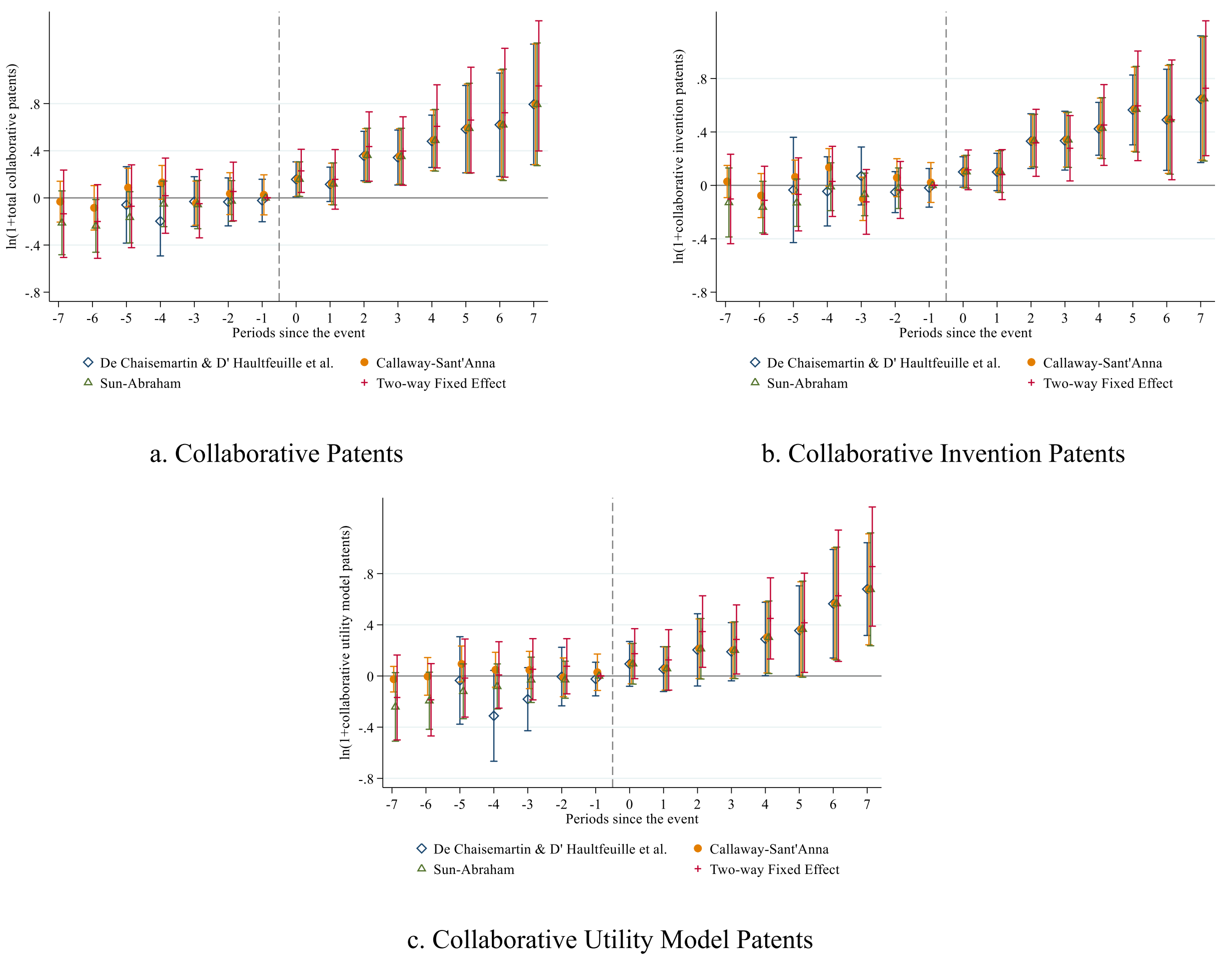
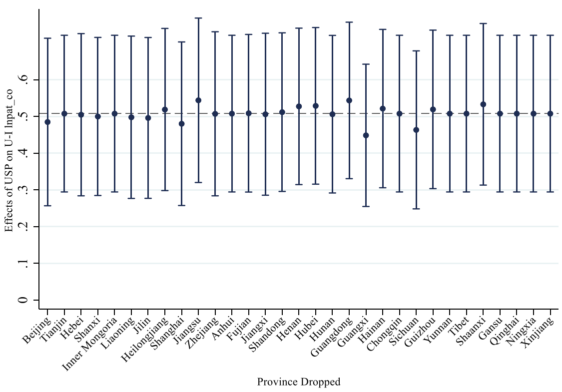
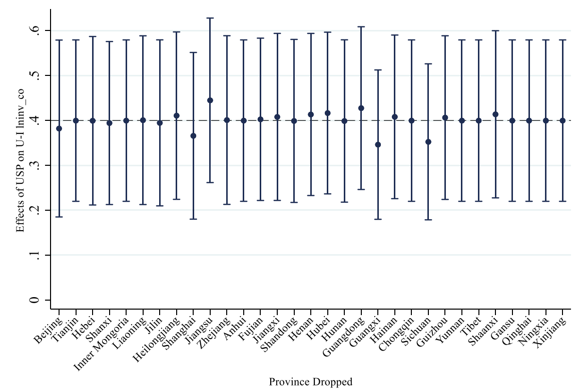


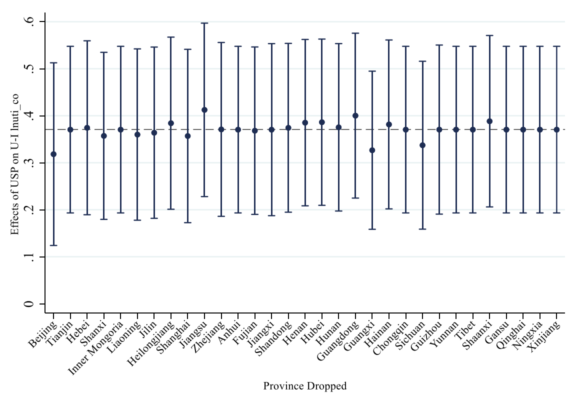
Fig. A1. Event study using alternative estimators.
Notes: The figure shows event study results using estimators from traditional two-way fixed effects, De Chaisemartin and d'Haultfoeuille (2020), Callaway and Sant'Anna(2021), and Sun and Abraham (2021). Figs. A1a to A1c represent the event study of the number of patents, invention patents, and utility model patents, respectively. All dependent variables are the natural logarithm of one plus the patent count. The X-axis represents the relative time, while the Y-axis shows the coefficients. Points in each panel represent estimated effects at each event time, with blue dotted lines indicating 95 % confidence intervals.



a. Collaborative Patents

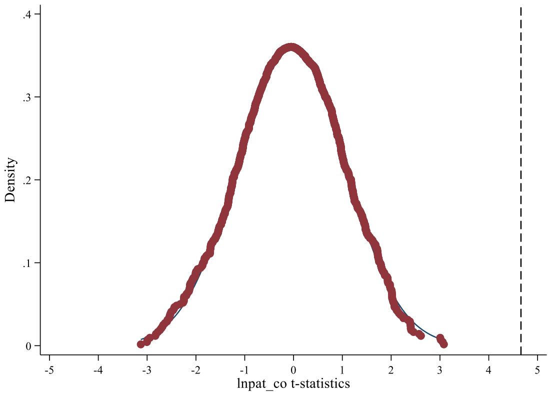


b. Collaborative Invention Patents

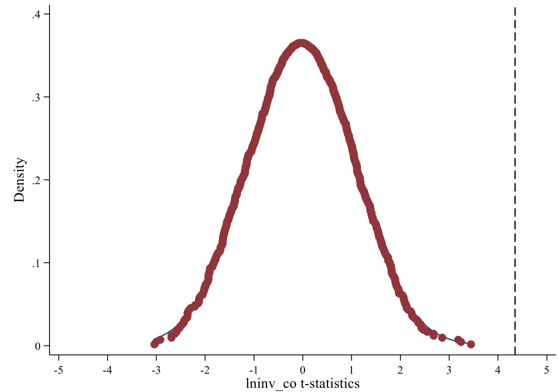


c. Collaborative Utility Model Patents

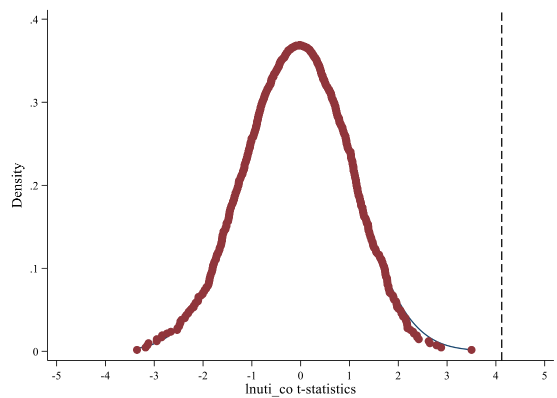
Fig. A2. Robustness: excluding the effect of *outlier observations.*
Notes: As the distribution of science parks varies across regions, we control for outliers by excluding one province at a time and re-estimating. The dependent variable, Ln (1 + Patents), is the natural logarithm of one plus the number of patents. The points in each figure represent the estimated effects when we drop a province, and the dotted blue lines represent the 95 % confidence intervals. All the regressions control the university, year, and city-year fixed effects. We excluded each province from our sample one at a time. Standard errors are clustered at the university level.



a. Collaborative Patents



b. Collaborative Invention Patents



c. Collaborative Utility Model Patents

Fig. A3. Robustness: randomly generated USP status.
Notes: The figures show the cumulative distribution density of the t-statistics from 1000 simulations randomly assigning USP status to universities. The vertical line presents the t-statistics of Column (5) to (7) in Table 2.

Table A1
Robustness: controlling the impact of national key discipline project.

	(1)	(2)	(3)
	Ln (1 + Collaborative Patents)		
	Total	Invention	Utility
USPs	0.508***	0.400***	0.371***
	(0.109)	(0.092)	(0.090)
National Key Discipline Project	−0.059	0.004	−0.091
	(0.123)	(0.107)	(0.091)
University FE	Y	Y	Y
Year FE	Y	Y	Y
City # Year FE	Y	Y	Y
Observations	3496	3496	3496

Notes: This table excludes the impact of the *National Key Discipline Project* (NKDP). The project was initiated by the Chinese Ministry of Education in 2010 and targets the advantageous disciplines of 84 universities to enhance their innovation capabilities. The dependent variables, Ln (1 + Patents), are the natural logarithm of one plus the number of patents. Columns (1)–(3) present estimates of the number for collaborative patents, collaborative invention patents, and collaborative utility model patents with university, year, and city-year fixed effects. Standard errors are clustered at the university level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A2
Robustness: excluding the impact of unobserved cofounding policies.

	(1)	(2)
	Ln (1 + Papers)	
	Chinese journal papers	WOS journal papers
USPs	−0.023	0.043
	(0.047)	(0.098)
University FE	Y	Y
Year FE	Y	Y
City # Year FE	Y	Y
Observations	3496	3496

Notes: This table examines the impact of USPs on academic papers. The dependent variables, Ln (1 + Papers), are the natural logarithm of one plus the number of papers. Columns (1) and (2) present estimates of the number of Chinese journal papers and WOS journal papers with university, year, and city-year fixed effects. Standard errors are clustered at the university level. *** p < 0.01, ** p < 0.05, * p < 0.1.

Data availability

Data will be made available on request.

References

Abramovsky, L., Simpson, H., 2011. Geographic proximity and firm–university innovation linkages: evidence from Great Britain. J. Econ. Geogr. 11, 949–977.
Acosta, M., Coronado, D., Martínez, M.Á., 2012. Spatial differences in the quality of university patenting: do regions matter? Res. Policy 41, 692–703.
Albahari, A., Pérez-Canto, S., Barge-Gil, A., Modrego, A., 2017. Technology parks versus science parks: does the university make the difference? Technol. Forecast. Soc. Chang. 116, 13–28.
Albahari, A., Barge-Gil, A., Pérez-Canto, S., Landoni, P., 2023. The effect of science and technology parks on tenant firms: a literature review. J. Technol. Transf. 48, 1489–1531.
Allen, F., Qian, M., Xie, J., 2019. Understanding informal financing. J. Financ. Intermed. 39, 19–33.
Almeida, P., Kogut, B., 1999. Localization of knowledge and the mobility of engineers in regional networks. Manag. Sci. 45, 905–917.
Alshumaimri, A., Aldridge, T., Audretsch, D.B., 2010. The university technology transfer revolution in Saudi Arabia. J. Technol. Transf. 35, 585–596.
Amin, A., Wilkinson, F., 1999. Learning, proximity and industrial performance: an introduction. Camb. J. Econ. 23, 121–125.
Ankrah, S.N., Burgess, T.F., Grimshaw, P., Shaw, N.E., 2013. Asking both university and industry actors about their engagement in knowledge transfer: what single-group studies of motives omit. Technovation 33, 50–65.
Anton-Tejon, M., Barge-Gil, A., Martínez, C., Albahari, A., 2024a. Science and technology parks and their heterogeneous effect on firm innovation. J. Eng. Technol. Manag. 73, 101820.
Anton-Tejon, M., Martinez, C., Albahari, A., Barge-Gil, A., 2024b. Science and technology parks and their effects on the quality of tenants' patents. J. Technol. Transf. 1–34.
Arundel, A., Geuna, A., 2004. Proximity and the use of public science by innovative European firms. Econ. Innov. New Technol. 13, 559–580.
Bakouros, Y.L., Mardas, D.C., Varsakelis, N.C., 2002. Science park, a high tech fantasy?: an analysis of the science parks of Greece. Technovation 22, 123–128.
Baldini, N., 2010. Do royalties really foster university patenting activity? An answer from Italy. Technovation 30, 109–116.
Bercovitz, J., Feldman, M., 2006. Entpreprenerial universities and technology transfer: a conceptual framework for understanding knowledge-based economic development. J. Technol. Transf. 31, 175–188.
Bikard, M., Vakili, K., Teodoridis, F., 2019. When collaboration bridges institutions: the impact of university-industry collaboration on academic productivity. Organ. Sci. 30, 426–445.
Bishop, K., D'Este, P., Neely, A., 2011. Gaining from interactions with universities: multiple methods for nurturing absorptive capacity. Res. Policy 40, 30–40.
Borusyak, K., Jaravel, X., Spiess, J., 2024. Revisiting event-study designs: robust and efficient estimation. Rev. Econ. Stud. rdae007.
Broekel, T., 2019. Using structural diversity to measure the complexity of technologies. PLoS One 14, e0216856.
Bruneel, J., d'Este, P., Salter, A., 2010. Investigating the factors that diminish the barriers to university-industry collaboration. Res. Policy 39, 858–868.
Caldera, A., Debande, O., 2010. Performance of Spanish universities in technology transfer: an empirical analysis. Res. Policy 39, 1160–1173.
Callaway, B., Sant'Anna, P.H., 2021. Difference-in-differences with multiple time periods. J. Econ. 225, 200–230.
Carbonell, P., Rodriguez, A.I., 2006. Designing teams for speedy product development: the moderating effect of technological complexity. J. Bus. Res. 59, 225–232.
Chai, S., Shih, W., 2016. Bridging science and technology through academic-industry partnerships. Res. Policy 45, 148–158.
Cohen, W.M., Nelson, R.R., Walsh, J.P., 2002. Links and impacts: the influence of public research on industrial R&D. Manag. Sci. 48, 1–23.
Colombo, M.G., Delmastro, M., 2002. How effective are technology incubators?: evidence from Italy. Res. Policy 31, 1103–1122.
De Chaisemartin, C., d'Haultfoeuille, X., 2020. Two-way fixed effects estimators with heterogeneous treatment effects. Am. Econ. Rev. 110, 2964–2996.
D'este, P., Perkmann, M., 2011. Why do academics engage with industry? The entrepreneurial university and individual motivations. J. Technol. Transf. 36, 316–339.
Díez-Vial, I., Fernández-Olmos, M., 2015. Knowledge spillovers in science and technology parks: how can firms benefit most? J. Technol. Transf. 40, 70–84.
Felsenstein, D., 1994. University-related science parks—'seedbeds' or 'enclaves' of innovation? Technovation 14, 93–110.
Ferguson, R., Olofsson, C., 2004. Science parks and the development of NTBFs—location, survival and growth. J. Technol. Transf. 29, 5–17.
Fontana, R., Geuna, A., Matt, M., 2006. Factors affecting university-industry R&D projects: the importance of searching, screening and signaling. Res. Policy 35, 309–323.
Fransman, M., 2008. Disaggregating firms in analysing the costs and benefits of the university-industry relationship: based on an analytical and empirical study from Scotland. Econ. Innov. New Technol. 17, 123–136.
Fukugawa, N., 2006. Science parks in Japan and their value-added contributions to new technology-based firms. Int. J. Ind. Organ. 24, 381–400.
Gertler, M.S., 2003. Tacit knowledge and the economic geography of context, or the undefinable tacitness of being (there). J. Econ. Geogr. 3, 75–99.
Gilly, J.P., Torre, A., 2000. Proximity relations. Elements for an analytical framework. Industrial Networks and Proximity 1–16.
Goodman-Bacon, A., 2021. Difference-in-differences with variation in treatment timing. J. Econ. 225, 254–277.
Guan, J.C., Yam, R.C., Mok, C.K., 2005. Collaboration between industry and research institutes/universities on industrial innovation in Beijing, China. Tech. Anal. Strat. Manag. 17, 339–353.
Gulbrandsen, M., Smeby, J.C., 2005. Industry funding and university professors' research performance. Res. Policy 34, 932–950.
Hall, B.H., Jaffe, A.B., Trajtenberg, M., 2001. The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools. National Bureau of Economic Research Cambridge, Mass., USA.
Hausman, N., 2022. University innovation and local economic growth. Rev. Econ. Stat. 104, 718–735.
Hellmann, T., 2007. The role of patents for bridging the science to market gap. J. Econ. Behav. Organ. 63, 624–647.
Hemmert, M., Bstieler, L., Okamuro, H., 2014. Bridging the cultural divide: trust formation in university-industry research collaborations in the US, Japan, and South Korea. Technovation 34, 605–616.
Henderson, R., Jaffe, A.B., Trajtenberg, M., 1998. Universities as a source of commercial technology: a detailed analysis of university patenting, 1965–1988. Rev. Econ. Stat. 80, 119–127.
Hervas-Oliver, J.-L., Albors-Garrigos, J., 2009. The role of the firm's internal and relational capabilities in clusters: when distance and embeddedness are not enough to explain innovation. J. Econ. Geogr. 9, 263–283.
Howells, J.R., 2002. Tacit knowledge, innovation and economic geography. Urban Stud. 39, 871–884.
Hsu, D.H., Hsu, P.H., Zhou, K., Zhou, T., 2024. Industry-university collaboration and commercializing Chinese corporate innovation. Manag. Sci. In Press.
Hu, M.-C., Mathews, J.A., 2008. China's national innovative capacity. Res. Policy 37, 1465–1479.
Huang, K.-F., Yu, C.-M.J., Seetoo, D.-H., 2012. Firm innovation in policy-driven parks and spontaneous clusters: the smaller firm the better? J. Technol. Transf. 37, 715–731.

Hvide, H.K., Jones, B.F., 2018. University innovation and the professor's privilege. Am. Econ. Rev. 108, 1860–1898.
Jaffe, A.B., 1989. Real effects of academic research. Am. Econ. Rev. 957–970.
Jaffe, A.B., Trajtenberg, M., Henderson, R., 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. Q. J. Econ. 108, 577–598.
Jensen, R., Thursby, M., 2001. Proofs and prototypes for sale: the licensing of university inventions. Am. Econ. Rev. 91, 240–259.
Kafouros, M., Wang, C., Piperopoulos, P., Zhang, M., 2015. Academic collaborations and firm innovation performance in China: the role of region-specific institutions. Res. Policy 44, 803–817.
Kang, Y., Liu, R., 2021. Does the merger of universities promote their scientific research performance? Evidence from China. Res. Policy 50, 104098.
Kato, M., Odagiri, H., 2012. Development of university life-science programs and university-industry joint research in Japan. Res. Policy 41, 939–952.
Knoben, J., Oerlemans, L.A., 2006. Proximity and inter-organizational collaboration: a literature review. Int. J. Manag. Rev. 8, 71–89.
Kong, D., Lin, C., Wei, L., Zhang, J., 2022. Information accessibility and corporate innovation. Manag. Sci. 68, 7837–7860.
Lach, S., Schankerman, M., 2008. Incentives and invention in universities. RAND J. Econ. 39, 403–433.
Lamperti, F., Mavilia, R., Castellini, S., 2017. The role of science parks: a puzzle of growth, innovation and R&D investments. J. Technol. Transf. 42, 158–183.
Laursen, K., Reichstein, T., Salter, A., 2011. Exploring the effect of geographical proximity and university quality on university-industry collaboration in the United Kingdom. Reg. Stud. 45, 507–523.
Lecluyse, L., Knockaert, M., Spithoven, A., 2019. The contribution of science parks: a literature review and future research agenda. J. Technol. Transf. 44, 559–595.
Li, X., Tan, J., 2020. Exploring the role of university-run enterprises in technology transfer from Chinese universities. Manag. Organ. Rev. 16, 907–943.
Lindelöf, P., Löfsten, H., 2004. Proximity as a resource base for competitive advantage: university-industry links for technology transfer. J. Technol. Transf. 29, 311–326.
Link, A.N., Scott, J.T., 2003. US science parks: the diffusion of an innovation and its effects on the academic missions of universities. Int. J. Ind. Organ. 21, 1323–1356.
Löfsten, H., Lindelöf, P., 2002. Science Parks and the growth of new technology-based firms-academic-industry links, innovation and markets. Res. Policy 31, 859–876.
Löfsten, H., Lindelöf, P., 2003. Determinants for an entrepreneurial milieu: Science Parks and business policy in growing firms. Technovation 23, 51–64.
Mae Phillips, S.-A., Wai-chung Yeung, H., 2003. A place for R&D? The Singapore science park. Urban Stud. 40, 707–732.
Malairaja, C., Zawdie, G., 2008. Science parks and university-industry collaboration in Malaysia. Tech. Anal. Strat. Manag. 20, 727–739.
Mansfield, E., Lee, J.-Y., 1996. The modern university: contributor to industrial innovation and recipient of industrial R&D support. Res. Policy 25, 1047–1058.
Minguillo, D., Tijssen, R., Thelwall, M., 2015. Do science parks promote research and technology? A scientometric analysis of the UK. Scientometrics 102, 701–725.
Morgan, K., 2004. The exaggerated death of geography: learning, proximity and territorial innovation systems. J. Econ. Geogr. 4, 3–21.
Nooteboom, B., 1999. Innovation and inter-firm linkages: new implications for policy. Res. Policy 28, 793–805.
Nooteboom, B., 2002. Trust: Forms, Foundations, Functions, Failures and Figures. Edward Elgar Publishing.
Partha, D., David, P.A., 1994. Toward a new economics of science. Res. Policy 23, 487–521.
Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., 2013. Academic engagement and commercialisation: a review of the literature on university-industry relations. Res. Policy 42, 423–442.
Phan, P.H., Siegel, D.S., Wright, M., 2005. Science parks and incubators: observations, synthesis and future research. J. Bus. Ventur. 20, 165–182.
Phillimore, J., 1999. Beyond the linear view of innovation in science park evaluation an analysis of Western Australian Technology Park. Technovation 19, 673–680.
Phongthiya, T., Malik, K., Niesten, E., Anantana, T., 2022. Innovation intermediaries for university-industry R&D collaboration: evidence from science parks in Thailand. J. Technol. Transf. 47, 1885–1920.
Polanyi, M., 1966. The logic of tacit inference. Philosophy 41, 1–18.
Quintas, P., Wield, D., Massey, D., 1992. Academic-industry links and innovation: questioning the science park model. Technovation 12, 161–175.
Radosevic, S., Myrzakhmet, M., 2009. Between vision and reality: promoting innovation through technoparks in an emerging economy. Technovation 29, 645–656.
Ramírez-Alesón, M., Fernández-Olmos, M., 2018. Unraveling the effects of Science Parks on the innovation performance of NTBFs. J. Technol. Transf. 43, 482–505.
Ryan, J.G., Wafer, B., Fitzgerald, M., 2008. University-industry collaboration: an issue for Ireland as an economy with high dependence on academic research. Research Evaluation 17, 294–302.
Shen, H., Coreynen, W., Huang, C., 2023. Prestige and technology-transaction prices: evidence from patent-selling by Chinese universities. Technovation 123, 102710.
Shi, Y., Liu, R., Kang, Y., 2020. Does a name change attract better students? Evidence from Chinese universities. China Econ. Rev. 60, 101395.
Shi, X., Xi, T., Zhang, X., Zhang, Y., 2021. "Moving umbrella": bureaucratic transfers and the comovement of interregional investments in China. J. Dev. Econ. 153, 102717.
Squicciarini, M., 2009. Science parks: seedbeds of innovation? A duration analysis of firms' patenting activity. Small Bus. Econ. 32, 169–190.
Storey, D.J., Tether, B.S., 1998. Public policy measures to support new technology-based firms in the European Union. Res. Policy 26, 1037–1057.
Sun, L., Abraham, S., 2021. Estimating dynamic treatment effects in event studies with heterogeneous treatment effects. J. Econ. 225, 175–199.
Tan, J., 2006. Growth of industry clusters and innovation: lessons from Beijing Zhongguancun Science Park. J. Bus. Ventur. 21, 827–850.
Tan, Y., Liu, X., Sun, H., Zeng, C.C., 2022. Population ageing, labour market rigidity and corporate innovation: evidence from China. Res. Policy 51, 104428.
Theeranattapong, T., Pickernell, D., Simms, C., 2021. Systematic literature review paper: the regional innovation system-university-science park nexus. J. Technol. Transf. 46, 2017–2050.
Torrisi, S., Gambardella, A., Giuri, P., Harhoff, D., Hoisl, K., Mariani, M., 2016. Used, blocking and sleeping patents: empirical evidence from a large-scale inventor survey. Res. Policy 45, 1374–1385.
Trajtenberg, M., 1990. A penny for your quotes: patent citations and the value of innovations. RAND J. Econ. 172–187.
Ünlü, H., Temel, S., Miller, K., 2023. Understanding the drivers of patent performance of University Science Parks in Turkey. J. Technol. Transf. 48, 842–872.
Van Dierdonck, R., Debackere, K., Rappa, M.A., 1991. An assessment of science parks: towards a better understanding of their role in the diffusion of technological knowledge. R&D Manag. 21, 109–124.
Vásquez-Urriago, Á.R., Barge-Gil, A., Rico, A.M., 2016. Science and technology parks and cooperation for innovation: empirical evidence from Spain. Res. Policy 45, 137–147.
Vedovello, C., 1997. Science parks and university-industry interaction: geographical proximity between the agents as a driving force. Technovation 17, 491–531.
Villasalero, M., 2014. University knowledge, open innovation and technological capital in Spanish science parks: research revealing or technology selling? J. Intellect. Cap. 15, 479–496.
Von Hippel, E., 1994. "Sticky information" and the locus of problem solving: implications for innovation. Manag. Sci. 40, 429–439.
Welsh, R., Glenna, L., Lacy, W., Biscotti, D., 2008. Close enough but not too far: assessing the effects of university-industry research relationships and the rise of academic capitalism. Res. Policy 37, 1854–1864.
Westhead, P., Batstone, S., 1998. Independent technology-based firms: the perceived benefits of a science park location. Urban Stud. 35, 2197–2219.
Westhead, P., Storey, D.J., 1995. Links between higher education institutions and high technology firms. Omega 23, 345–360.
Woerter, M., 2012. Technology proximity between firms and universities and technology transfer. J. Technol. Transf. 37, 828–866.
Wright, M., Liu, X., Buck, T., Filatotchev, I., 2008. Returnee entrepreneurs, science park location choice and performance: an analysis of high–technology SMEs in China. Entrep. Theory Pract. 32, 131–155.
Wu, W., 2010. Managing and incentivizing research commercialization in Chinese universities. J. Technol. Transf. 35, 203–224.
Wu, H., Lin, J., Wu, H.-M., 2022. Investigating the real effect of China's patent surge: new evidence from firm-level patent quality data. J. Econ. Behav. Organ. 204, 422–442.
Yoshihara, M., Tamai, K., 1999. Lack of incentive and persisting constraints: factors hindering technology transfer at Japanese universities. In: Industrializing Knowledge: University-Industry Linkages in Japan and the United States, pp. 348–363.
Zheng, G., Wang, S., Xu, Y., 2018. Monetary stimulation, bank relationship and innovation: evidence from China. J. Bank. Financ. 89, 237–248.
Zucker, L.G., Darby, M.R., Armstrong, J., 1998. Geographically localized knowledge: spillovers or markets? Econ. Inq. 36, 65–86.
Zucker, L.G., Darby, M.R., Armstrong, J.S., 2002. Commercializing knowledge: university science, knowledge capture, and firm performance in biotechnology. Manag. Sci. 48, 138–153.