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Exclusive licensing of university technology: The effects of university prestige, technology transfer offices, and academy-industry collaboration

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A R T I C L E I N F O

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A B S T R A C T

Exclusivity is a key concern when designing a licensing contract, yet the organizational factors that influence the exclusive provision of university licenses remain underexplored. This study provides a deeper understanding of this question by developing a balanced framework that considers both licensors (universities) and licensees (companies) in licensing deals. Furthermore, we posit that university prestige affects both a university's ability to conduct non-exclusive licensing and a firm's incentive to obtain an exclusive license, thereby shaping their joint willingness to license (non-)exclusively. We also examine how technology transfer office (TTO) experience and prior collaboration between a university and a firm moderate this relationship. To test the hypotheses, we use a dataset consisting of 6653 licensed patents owned by 117 representative Chinese universities. We find that an inverted U-shaped relationship exists between university prestige and the likelihood that two parties choose exclusive licensing. Moreover, the moderating effect of TTO experience is partially supported while that of prior collaboration is fully supported. Our findings generate important implications for the relative social impacts of exclusive and non-exclusive licensing of technology inventions as well as the management of university licensing.

1. Introduction

The licensing of universities' patented technologies to firms in various industries represents an important technology-transfer channel (Rothaermel et al., 2007; Mowery and Ziedonis, 2015; Thursby and Thursby, 2002). This phenomenon has drawn much attention in academia since licensing activities in US universities began proliferating after the passage in 1980 of the Bayh–Dole Act (Grimaldi et al., 2011; Mowery et al., 2001, 2004). A rich body of literature has examined how technological characteristics, organizational features, and institutional factors influence the incidence of university licensing as well as the economic revenues derived from licensing deals (Chen et al., 2016; Elfenbein, 2007; Grimaldi et al., 2011; Bradley et al., 2013).

Although the design of licensing contracts between universities and firms is considered important in this stream of literature (Buenstorf and Schacht, 2013; Dechenaux et al., 2011), the contractual features of university licenses merit further investigation (Laursen et al., 2017). Exclusivity in particular is a feature of a licensing deal that demands attention (Somaya et al., 2011). An exclusive license "grants a licensee the monopoly rights to a licensed technology within a time period" (Khoury et al., 2019). The right to issue licenses to additional licensees is reserved for a licensor if a license is non-exclusive (Jiang et al., 2007). In practice, exclusivity is a key concern when a university and a firm seek agreement on the terms of a license (Colyvas et al., 2002; Jensen and Thursby, 2001). For instance, when licensing DNA patents from US academic institutions, licensee firms require exclusive licensing as a precondition before making further investments to commercialize a technology (Soucy et al., 2006).

Moreover, the exclusivity of university–firm licenses influences social welfare. Exclusive licenses are adopted to induce requisite downstream R&D investments, which are essential for commercializing university inventions that remain off the market without sufficient incentives (Mazzoleni, 2006; Mowery et al., 2001; Drivas et al., 2017). An exclusive license creates monopoly power, however, and it may be granted to a firm that is unable to fully realize the technology's potential, thus preventing the most capable firm from exploiting that technology (Mowery et al., 2001). Therefore, exclusive licenses may restrict effective diffusion and application of scientific discoveries, reducing

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social welfare (Lemley, 2008), while more "open access" regimes such as joint publications and other forms of academic engagement facilitate knowledge exchange and lead to a wider use of those scientific discoveries (Mazzoleni, 2006; Hayter et al., 2020). A trade-off may exist between the incentive required to commercialize university technologies and the social costs associated with exclusive university–firm licensing.

While exclusivity is one of the most critical contractual features of university–firm licensing, its determinants have been underexplored (Somaya et al., 2011). Prior studies propose that exclusive licenses are used primarily because they motivate firms to invest in university-generated technologies, many of which are in the embryonic stages of development (Mowery et al., 2001). Contrary to the theoretical predictions associated with this finding, a recent study by Öcalan-Özel and Pénin (2019) shows that invention characteristics, including stage of development and specificity, are not significant determinants of the degree of exclusivity that is observed in university licenses. The authors suggest that exclusive licenses may result simply from universities' incapacity to negotiate with licensee firms to design optimal licensing contracts that match the features of licensed inventions (Öcalan-Özel and Pénin, 2019). These inconclusive findings imply that further studies are needed to shed light on the antecedents of the exclusivity of university licenses.

In studies on inter-firm licenses, organization-level features, including a licensee's technological potential, the relative size of the companies involved, and product overlap between a licensor and a licensee, affect the exclusivity of licenses (Aulakh et al., 2013; Khoury et al., 2019; Kim and Vonortas, 2006). These factors provide limited explanatory power, however, regarding the exclusivity of university–firm licenses. For example, the competitive relationship between a licensor and its licensees is a major concern in inter-firm licensing, whereas such tensions are absent from license agreements between universities and firms (Aulakh et al., 2013; Barirani et al., 2017). Therefore, we must investigate additional organization-level factors to reveal the determinants of exclusive university–firm licensing. Among the organization-level features that have an impact on university technology transfer, university prestige in particular has drawn attention (Battistella et al., 2016; Elfenbein, 2007; Sine et al., 2003). For instance, it has been found that prestigious universities enter into licensing agreements more frequently and also receive higher revenues from licensing (Elfenbein, 2007; Sine et al., 2003). Yet whether university prestige plays a role in negotiations over contractual provisions in university licensing remains uninvestigated.

To fill these gaps, we complement existing studies by focusing on organization-level features that affect the exclusivity of university licensing. First, drawing on theoretical arguments from transaction cost economics (Williamson, 1979, 1981; Shane, 2002), we develop a framework showing how exclusivity is jointly determined by the willingness of both universities and prospective licensees to license exclusively. We then examine, adding insights from status research (Podolny, 2005; Jensen and Roy, 2008; Bothner et al., 2012), how university prestige affects both parties' willingness to form exclusive licensing partnerships. We are also interested in examining how TTO experience and prior collaboration between a university and a licensee firm moderates the relationship between university prestige and the exclusivity of university licenses. To test our hypotheses, we use a sample of 6653 licensed patents owned by 117 Chinese universities and licensed by 3938 firms. The empirical results confirm the existence of an inverted U-shaped relationship between university prestige and exclusive licensing as well as a moderating effect of prior collaboration; the moderating effect of TTO experience is only partially supported.

This study makes the following contributions to the literature. First, we complement the current literature on academy–industry knowledge exchange by revealing the influence of prestige on contract design in university technology transfer. The literature in this field has focused largely on several types of outcomes, including the occurrence of technology transfer and related financial performance (Rothaermel et al., 2007; Bradley et al., 2013; Siegel and Wright, 2015), while factors shaping the contractual outcome of licensing negotiations have received only limited attention (Bradley et al., 2013). Our study enriches this literature stream by investigating the design of licensing contracts based on empirical evidence derived from Chinese universities' technology transfer activity.

Second, we extend the existing research stream on the exclusivity of university licenses (Mazzoleni, 2006; Mowery et al., 2001) which, despite its importance, remains underexplored. Differing from most prior studies, which analyze the issue from either a supplier's or a purchaser's perspective alone (Aulakh et al., 2010; Khoury et al., 2019; Kim and Vonortas, 2006), this study develops a balanced framework that considers licensors, licensees, and the combined effects of their respective willingness to license exclusively. We thereby deepen our understanding of how a university and a licensee firm jointly determine such a contractual specification.

Third, we contribute to the literature on status by investigating how university prestige affects the exclusive provision of university licensing. Broadening the scope of existent research, which often focuses on the features of inventions as antecedents to explain university licensing exclusivity (Drivas et al., 2017), we demonstrate that *organization*-level features such as university prestige also play a role. Previous studies have also considered the effects of *status* on an organization's decision regarding whether and with whom to collaborate (Jensen and Roy, 2008; Sine et al., 2003). We further extend this research stream by revealing that status also shapes *how* organizations collaborate. In particular, this study shows how university prestige influences the willingness of universities and licensing firms to enter into exclusive relationships in university technology transfer.

This paper continues as follows. In Section 2, we describe the theoretical background against which we conceptualize the distinction between exclusive and non-exclusive licenses and introduce a framework within which to analyze the exclusivity of university licenses. Section 3 continues with theorization regarding the presence of an inverted U-shaped relationship between university prestige and exclusive licensing, following which we propose hypotheses reflecting the potential for TTO experience and prior collaboration between a university and a licensee firm to moderate the inverted U-shaped relationship. In Sections 4 and 5, we explain our methodology and provide empirical evidence using data for patent licenses between Chinese universities and firms that are registered in the China National Intellectual Property Administration (CNIPA). Section 6 concludes by summarizing the study's findings and discussing their implications for both theory and practice.

2. Theoretical background

2.1. Exclusive versus non-exclusive licenses

Attention to the distinction between exclusive and non-exclusive licenses dates back to early studies on licensing in the market for technology, which discuss how a technology holder (usually a manufacturer) determines the optimal number of licenses to issue to other firms (Arora and Fosfuri, 2003). Here, exclusive licensing is considered a licensor's tactic for structuring the downstream production market to obtain monopoly rents (Anand and Khanna, 2000). A firm owning a technology takes advantage of licenses to constrain competition with licensees as well as between licensees (Arora and Fosfuri, 2003; Gallini, 1984).

Inter-firm and university–firm licenses differ from one another, however, and consequently the factors that licensors and licensees consider when deciding whether to make licenses exclusive also differ in the two contexts. First, universities are specialized technology providers with no manufacturing capabilities (Arora and Fosfuri, 2003) and they rely on licensee firms to earn revenue from a technology (Barirani et al., 2017). Therefore, there is no competition between licensors and licensees to complicate negotiations. Second, in the context of inter-firm licensing, a licensor typically has experience introducing products to

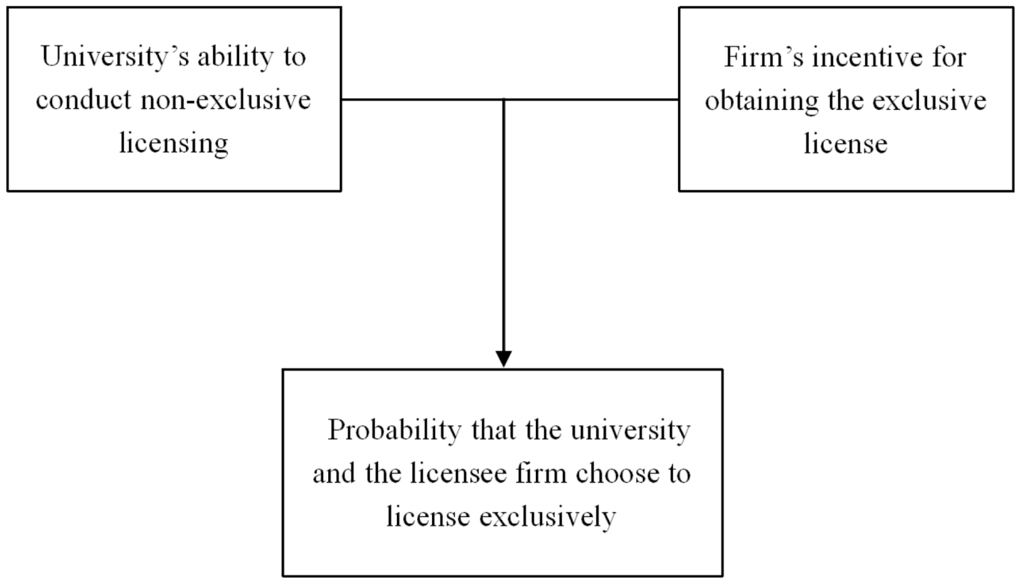

Fig. 1. Conceptual framework.

markets and has accumulated related knowledge to support product development and manufacturing (Gambardella et al., 2007). In the context of university–firm licensing, however, licensee firms have to invest considerable resources in product development and market introduction in light of the immaturity of university technologies (Jensen and Thursby, 2001; Mowery et al., 2001). Finally, university technologies are typically based on basic rather than applied science, and it is critical for firms to engage with scientists and acquire tacit knowledge to assimilate and integrate such technologies in industrial applications (Agrawal, 2006). Therefore, licensee firms face moral hazard without adequate involvement of a university's faculty during the commercialization process (Crama et al., 2008).

Prior research on university technology transfer has investigated factors influencing the exclusivity of university licensing. First, university technologies develop in stages and the stage a particular technology has reached can exert an impact. Early-stage university inventions require firms to undertake costly additional development to introduce products to consumer markets, encouraging firms to ask for exclusive licenses to secure their returns on what are often considerable investments (Jensen and Thursby, 2001; Drivas et al., 2017; Mazzoleni, 2006). The generality and appropriability of technology may affect the exclusivity of university licensing as well (Colyvas et al., 2002; Mazzoleni, 2006). Mowery et al. (2001) find that, when a technology is highly general—that is, the invention has the potential for widespread use—exclusive licenses are less common. When the return on investment in an invention can be appropriated by tacit knowledge or complementary assets other than patents, a firm's incentive to obtain an exclusive license from a university weakens (Colyvas et al., 2002).

In addition, licensing exclusivity varies across technological fields (Mazzoleni, 2006). For instance, biomedical inventions are often licensed exclusively, while exclusive licenses for software inventions are less common (Mowery et al., 2001). Organizational factors can affect exclusivity in university licensing as well, as exclusivity in licensing varies across universities. For instance, regarding licenses granted during the 1986–1990 period, licenses for 90% of inventions developed by the University of California were exclusive, while only 59% of licenses granted by Stanford University were exclusive (Mowery et al., 2001).

In summary, the lessons learned from studies of exclusivity in interfirm licensing cannot be readily applied to the case of university–firm licensing, which thus far has received little attention. Furthermore, the organizational features that affect contractual arrangements between universities and firms remain unclear. To address this question, we develop a distinctive framework within which to analyze exclusivity in university–firm licensing and use this new framework to investigate the effects of university prestige, TTO experience, and prior collaboration on such exclusivity.

2.2. *A framework for analyzing the exclusivity of university-firm licensing*

In this study, we hold that negotiations (or bargaining) between a university and a prospective licensee determine the contractual specification of a license (Bradley et al., 2013). Therefore, the willingness of both parties to agree to specific terms should be taken into account, as each party is influenced by its respective motivations and considerations. In the next two sections, we analyze the willingness of universities and firms to license exclusively or non-exclusively.

2.2.1. *University preference for non-exclusive licensing*

In general, universities want to license *non-exclusively*. They prefer collaborating with multiple licensees over relying on a single partner to transfer technology because doing so maximizes revenue (Mowery et al., 2001). Also, when non-exclusive licenses are adopted, universities can better mitigate the risk of failure resulting from the inadequate capabilities or opportunism of a single partner, as it is difficult for a university to assess *ex ante* whether a firm will be able to successfully commercialize a licensed technology (Savva and Taneri, 2015). If a licensee firm is incapable of applying a newly developed technology in the market, the non-exclusive provision makes it possible for the university to seek alternative partners. In addition, when the technology is licensed to multiple firms, competition from other licensee firms further drives innovation and stimulates widespread applications of the licensed technology (Aulakh et al., 2010). This implies that multiple licensees can contribute to increasing the total market share of the technology and that the university can increase the associated revenues (Khoury et al., 2019). For instance, Mowery et al. (2001) showed that inventions accounting for the largest shares of revenues at Stanford, Columbia University, and the University of California are licensed non-exclusively. Moreover, universities emphasize that making their knowledge accessible to multiple firms maximizes social welfare and the diffusion of their research outcomes (Mazzoleni, 2006; Mowery and Ziedonis, 2015).

The benefits that non-exclusive licenses can bring may, however, be outweighed by the additional costs. In particular, higher transaction costs, including search and contracting costs, constitute the primary barrier discouraging universities from adopting non-exclusive licenses

(Aulakh et al., 2010). First, search costs, which are costs related to identifying trading partners, can be high, as universities need to invest in searching and building connections with multiple prospective licensees (Khoury et al., 2019). Second, contracting costs—the costs involved in drafting contracts and reaching agreements with trading partners on specifications—are also salient. Overcoming these contracting costs requires universities to reach bilateral agreements with not one but multiple firms, and they need sufficient bargaining power to persuade those firms to accept non-exclusive provisions (Khoury et al., 2019). Therefore, universities seeking to successfully conduct non-exclusive licensing must be able *to* manage and absorb significant transaction costs.

2.2.2. Firm preference for exclusive licenses

Unlike universities, firms want to license technologies *exclusively* from universities. Exclusive licenses mitigate transactional hazard, including appropriability and moral hazard. First, owning a legal exclusive right over a technology reduces appropriability hazard, which relates to the inability to enforce exclusive rights owing to weak property rights (Oxley, 1997; Teece, 1986). Exclusive restrictions enable firms to secure control over access to and the use of knowledge and they enhance the value appropriated by a licensee firm (Siegel et al., 2003; Mazzoleni, 2006; Bradley et al., 2013). Moreover, a well-designed exclusivity clause helps to align the actions of the involved parties. When a license is exclusive, university faculty and their administrations are more likely to prevent knowledge leakage, deter imitations, and sue infringers, as in this case a university and its inventors depend exclusively on their sole licensee to share the revenue generated by a licensed invention (Drivas et al., 2017).

Second, exclusive licenses can reduce moral hazard, which occurs when actors behave opportunistically, for example by shirking their responsibility to invest adequate resources in a technology when executing a contract. This is a form of *ex-post* transactional hazard that is often inherent to technology licensing agreements (Dechenaux et al., 2011; Laursen et al., 2017). Firms need to work closely with university faculty to prevent or respond to unforeseen problems when applying transferred technologies (Agrawal, 2006; Dechenaux et al., 2011). When encountering difficulties, a licensee firm is less likely to obtain sufficient support or resources if a university can turn to alternative industrial partners. An exclusive license can guarantee adequate engagement by the university and thus reduce the moral hazard the licensee firm faces.

In light of the abovementioned factors that cause differences between licensor universities and licensee firms, we offer a framework for analyzing the probability that exclusive licensing occurs. Illustrated in Fig. 1, this framework considers the combined effects of a university's ability and a firm's incentive with respect to a (non-)exclusivity outcome. Next, we use this framework to examine the effects of actors' features on this outcome. Specifically, we analyze how university prestige affects whether a university technology is licensed exclusively by influencing either a university's ability and/or a firm's incentive. Furthermore, we consider how TTO experience and prior collaboration between two parties to a licensing agreement moderate this relationship.

3. Hypothesis development

3.1. University prestige and exclusive licensing

Prestige reflects "an actor's position in a hierarchical social order that is tied to the pattern of relations and affiliations in which the actor does and does not choose to engage" (Acharya and Pollock 2013, p.1398; Podolny 2005, p.13) and it is synonymous with the term "status" as often used in organizational research (Acharya and Pollock, 2013). For instance, Jensen and Roy (2008) (p. 496) define status as "prestige accorded firms because of the hierarchical positions they occupy in a social structure". An organization's prestige shapes an external appraiser's perception of the goods produced by that organization (Sine et al., 2003). Because the value of university inventions is usually uncertain and difficult to assess by external parties (Shane, 2002), firms tend to infer the quality of such inventions from a university's status (Azoulay et al., 2014). They are more likely to have faith in and seek to appropriate the value of such technologies if they are developed by prestigious universities, because such universities typically have greater access to resources and opportunities such as top faculty and funding (Bothner et al., 2012; Merton, 1968). In other words, a university's prestige impacts the attractiveness of its technologies and can influence the willingness of both a university and a firm to license exclusively.

From the university perspective, higher prestige weakens the willingness to license exclusively. Prestigious universities are better able to license technologies to multiple firms because they can better meet the transaction costs associated with non-exclusive licensing. First, prestige helps universities reduce their search costs. Technologies developed at prestigious universities naturally experience greater visibility and media exposure and they are also more likely to be perceived as advanced and valuable (Azoulay et al., 2014; Sine et al., 2003). Therefore, they draw greater attention from industry and it is easier for them to attract multiple prospective licensees (Sine et al., 2003). Second, prestigious universities incur lower contracting costs because they have greater bargaining power (Thye, 2000). If a prestigious university fails to reach an agreement with one firm, it can turn relatively easily to alternative prospective licensees.

In summary, prestigious universities find it easier to persuade firms to accept non-exclusive licenses because of the attractiveness of the licensing opportunities they encounter (Khoury et al., 2019). Conversely, less prestigious universities lack the resources they would need to attract firms and it is more costly for them to search for and contract with multiple licensees. As gains may be offset by costs, less prestigious universities tend to opt more often for exclusive licensing that enables them to command higher prices for their technologies and also create mutual commitments that induce adequate investments from licensee firms (Mowery et al., 2001; Somaya et al., 2011).

From the firm perspective, the willingness to obtain an exclusive license is stronger when a university possesses higher prestige, because the firm wants to mitigate the additional transactional hazard associated with licensing from prestigious universities. First, because there are likely more firms competing to license technology owned by prestigious universities (Sine et al., 2003), the appropriability hazard is more severe. To mitigate this hazard, firms are more likely to opt for exclusive licenses to prevent competitors from obtaining the same technology (Dechenaux et al., 2008). Second, the attraction of a licensed technology can exacerbate the moral hazard faced by a licensee firm (Somaya et al., 2011), as other firms can distract the prestigious university from fully engaging in transferring the technology to the licensee firm. To mitigate this moral hazard, the licensee firm prefers an exclusive license to ensure sufficient support from the prestigious university.

In summary, licensee firms have a stronger incentive to obtain exclusive licenses from prestigious universities to mitigate transactional hazard. Conversely, when a technology is developed by a less prestigious university, firms have less faith in its potential to be commercialized successfully (Elfenbein, 2007) and the risks of appropriability and moral hazard associated with licensing the technology are also lower. Firms are thus less interested in becoming exclusive partners with less

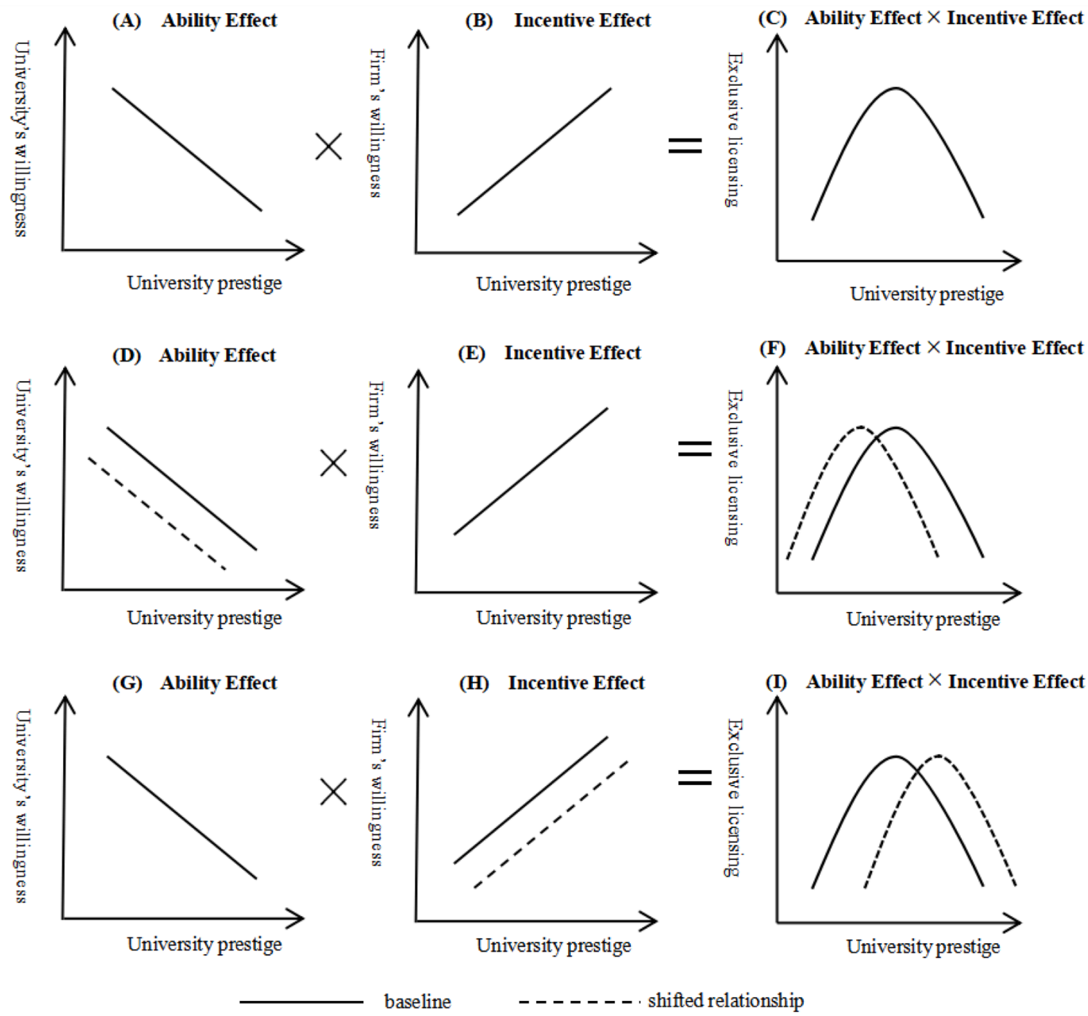

Fig. 2. Predicted inverted U-shaped relationship and moderating effects.

prestigious universities (Sine et al., 2003).

Combining both perspectives implies that, when a university's prestige is higher it can more easily issue a non-exclusive license. This means that the university's willingness to license exclusively is negatively related to university prestige—we label this the "ability effect". In this case, however, the firm's incentive to obtain an exclusive license strengthens. Therefore, the firm' willingness to license exclusively is positively related to the university's prestige—we call this the "incentive effect". Taking both effects into consideration, namely interacting the two underlying linear functions, we expect to find a curvilinear (inverted U-shaped) relationship between university prestige and exclusive licensing (Haans et al., 2016). In other words, the probability that a given technology will be licensed exclusively is highest when university prestige is moderate. Following the example of Haans et al. (2016), we present three simplified graphs to illustrate the emergence of a curvilinear relationship (see Fig. 2). The combination of two distinct effects—that is, a negative linear ability effect (graph A) interacting with a positive linear incentive effect (graph B)—leads to an inverted U-shaped relationship (graph C). These considerations inform our first hypothesis:

H1. Patents owned by moderately prestigious universities are more likely to be licensed exclusively than those owned by universities with relatively high or relatively low prestige.

3.2. *The moderating effect of TTO experience*

Prior studies have long recognized the important role that TTOs play in university technology transfer (Siegel et al., 2003; Battistella et al., 2016; Siegel and Wright, 2015). A TTO serves as an intermediary for a university, and its duties are to manage and take part in university–firm licensing (Shane, 2004; Wu et al., 2015). Moreover, a TTO typically contributes to the evaluation of university technologies, connecting the university with industry, organizing marketing and promotional activities, and participating in the design of licensing contracts (Shane, 2004; Markman et al., 2005). Yet, we know too little about how TTOs affect the likelihood of exclusivity in university licensing.

We posit that TTO experience makes it easier for universities to license non-exclusively. TTOs can, over time, accumulate knowledge and experience from technology transfers (Bianchi and Lejarraga, 2016; Khoury et al., 2019; Kotha et al., 2013). Therefore, TTOs with prior

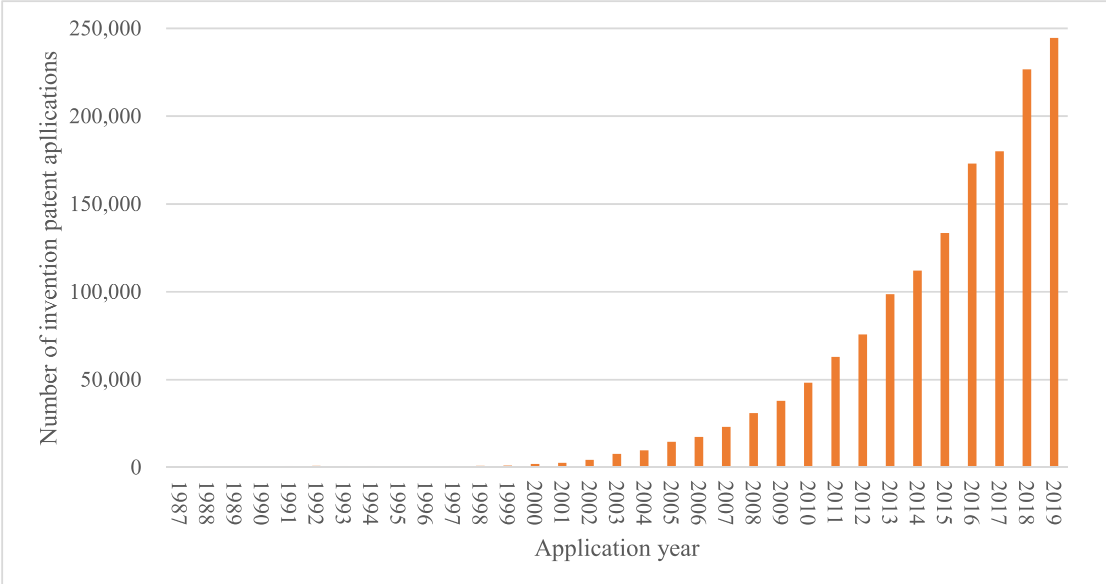

Fig. 3. Invention patent applications filed by Chinese universities.

experience are better able to reduce transaction costs, including search and contracting costs (Mowery et al., 2004). Moreover, experienced TTOs maintain closer and longer-lasting connections with industry and thus have less difficulty identifying multiple prospective licensees (Khoury et al., 2019; Markman et al., 2005; Wu et al., 2015). Repeated engagement also helps TTOs practice and acquire negotiating skills, which in turn improves contractual outcomes favoring universities and their faculty (Bianchi and Lejarraga, 2016; Gambardella et al., 2007).

Conversely, it is more difficult for universities lacking experienced TTOs to manage the transaction costs associated with non-exclusive licensing. When there is no TTO or a TTO has little experience, the university with which it is affiliated lacks the requisite ability to identify prospective licensees and reach multiple licensing agreements and thus finds it difficult to meet transaction costs (Khoury et al., 2019; Wu et al., 2015).

Based on these insights, we suggest that TTO experience enhances a university's ability to conduct non-exclusive licensing and thus reduces the university's willingness to license exclusively. In other words, TTO experience shifts the linear ability effect downward, as illustrated by graph D in Fig. 2. At the same time, TTO experience does not influence a firm's incentive to obtain an exclusive license from a university. Thus, the positive linear curve stays the same, as illustrated in graph E. Combining the two mechanisms leads to a leftward shift of the multiplicative turning point, as shown by graph F. These considerations reflect our next hypothesis:

H2. The inverted U-shaped relationship between university prestige and exclusive licensing is moderated by TTO experience, such that its turning point occurs at lower levels of university prestige as TTO experience increases.

3.3. *The moderating effect of prior collaboration*

Universities and firms interact with each other in various ways to develop formal and informal collaborative relationships (Mowery and Ziedonis, 2015). Specifically, prior collaboration between universities and firms has been found to correlate strongly with university technology transfer (Battistella et al., 2016; Wu et al., 2015). We expect prior collaboration between a university and a licensee firm to weaken the latter's incentive to license exclusively because it helps to mitigate transactional hazard. First, because past collaboration provides a shared language and established collaborative routines between the university and the firm, less friction is expected during the coordination of the partnership (Kotha et al., 2013). Second, when a technology originates from external sources, a firm often lacks trust in the technology provider. As a consequence, the two parties are reluctant to invest the resources needed to realize the technology's potential, increasing the risk that the firm fails to innovate by means of licensing-in (Chesbrough, 2003). Partners lacking connections typically use formal agreements to cope with moral hazard while parties that have cooperated in the past are more likely to rely on trust (Nooteboom et al., 1997; Poppo and Zenger, 2002). Prior collaborations and exclusive licenses mitigate transactional hazard in a similar fashion (Dyer et al., 2018; Somaya et al., 2011). Thus, a licensee's incentive to use contractual provisions to guarantee a university's commitment weakens if the licensee firm and the university have collaborated previously.

Based on these insights, we suggest that past collaboration between a university and a firm weakens the firm's incentive to obtain an exclusive license. In other words, the presence of prior collaboration will shift the linear incentive effect down, as illustrated by graph H in Fig. 2. At the same time, prior collaboration does not influence the university's ability effect, because a single relationship established with a firm has little impact on a university's long-standing visibility or attractiveness. Therefore, a university's overall ability to conduct non-exclusive licensing remains the same, as illustrated by graph G. Combining the two mechanisms leads to a rightward shift of the multiplicative turning point, as shown by graph I. Our third hypothesis reflects these insights into the effects of collaboration.

H3. The inverted U-shaped relationship between university prestige and exclusive licensing is moderated by prior collaboration between a university and a licensee firm, such that its turning point occurs at higher levels of university prestige when there is prior collaboration.

4. Method

4.1. Research setting: Chinese university technology transfer

From the establishment of the People's Republic of China in 1949 to the reform and opening-up that commenced in 1978, China operated with a planned economic system. During this period, universities' scientific research outcomes were state-owned and trade in such outcomes was not allowed (Liu and Jiang, 2001). After 1978 the Chinese government, seeking to create at least a partially market-orientated economic system, reformed its science and technology policies, bringing significant change to the transfer of Chinese universities' technology (Liu and Jiang, 2001; Chen et al., 2016; Cheng and Huang, 2016, 2021).

First, the government's growing R&D expenditures and policy stimulation have increased university innovation output dramatically. In the 1980s and 1990s the Chinese government launched national R&D programs such as the 863 Project and the 973 Project and technology transfer and commercialization programs such as the Torch Program to promote collaboration between universities and firms to generate technological innovations (Cai et al., 2015; Chen et al., 2016). The Chinese government started a program titled the "211 project" in 1995 with the goal of developing 100 key universities and another program called the "985 project" in 1998 to develop several world class universities. Both programs provide substantial financial support to a group of leading universities to enhance their educational and research capabilities. In 2008, the National Intellectual Property Strategy Outline was issued by the State Council. It aimed at boosting the number of patent applications filed by Chinese entities. These programs and the ensuing policies provided financial support that strengthened scientific research and technological innovation by Chinese universities and also provided incentives as well as subsidies for university patenting. Since then, university innovation output has increased greatly, as exemplified by the rapid increase in the number of invention patent applications in recent decades (see Fig. 3). In the earliest year in which this study's sampled patents were applied for, namely 1999, the total number of invention patent applications filed by Chinese universities was 988, a number that had increased to 173,049 in 2016, representing a staggering 175-fold level of growth. Whether the quality of Chinese university patents has also improved during this period is however up for debate (Chen et al., 2016).

Second, technology transfer by Chinese universities has been promoted by legislative and policy changes. In 1993, the Science and Technology Progress Law was promulgated, providing a legal framework for managing intellectual property rights (IPRs) generated from research in universities and public research institutes (Chen et al., 2016, 2021). In May 2002, the Regulations on the Administration of IPR in State-funded Research Projects issued by the State Council permitted universities to hold the IPRs generated by state-funded research projects. In 2007, the Science and Technology Progress Law was amended to further promote university technology transfer. Article 20 of the Law clearly states that IPRs generated by universities from government funding belong to universities, except when the IPRs involve national security or clearly benefit the social or public interest.

In 1996, the Law on Promoting the Transformation of Scientific and Technological Achievements was promulgated, permitting universities to license or sell technology to industry, although universities did not have full autonomy and their technology transfer transactions were subject to government approval. In 2015, the Law was amended and granted universities autonomy to negotiate prices with potential licensees and retain revenues from technology transfer. This law also incentivized universities to engage in technology transfer activities by stipulating that no less than 50% of profits from technology transfer should go to the inventors of technology as compensation (Huang, 2017). The amendment is seen as important legislation removing barriers to university technology transfer in China (Chen et al., 2021).

Although the transfer of university-generated technologies in China has improved significantly in recent years, it is still regarded as inefficient (Gong and Peng, 2018). For instance, according to CNIPA survey reports, the shares of licensed invention patents in total invention patents owned by universities were merely 3.3% and 5.8%, respectively, in 2014 and 2015 (CNIPA, 2016). There are two main explanations for these low figures. On the one hand, the stock of patented inventions grows continually, while Chinese universities struggle to maintain a fast pace of transfer technology to industry (Huang et al., 2020). On the other hand, TTOs in most universities, which are non-profit institutions funded entirely by their affiliated universities, often lack the knowledge, capability, and human resources needed to effectively administer technology transfers (Rotenberg, 2016; Li et al., 2020).

In summary, full development of the Chinese university technology transfer landscape is ongoing, making improvement of Chinese technology transfer performance an important policy issue. Seeking to shed light on this process, this study therefore focuses on Chinese universities' licensing activity and examines theoretical predictions based on evidence gathered from this context.

4.2. Data

For this study we selected licenses between representative Chinese universities and firms to test our hypotheses. First, we chose mainland China's top 100 universities, as listed in at least one ranking for at least one year according to authoritative domestic as well as foreign university rankings.[1] Next, we collected all licensed patents filed by these universities and registered with the CNIPA between January 2008 and June 2017. In December 2001, the CNIPA released the Regulations on Administration of Record Filing of Technology Licensing, which became effective 1 January 2002. Since the regulation came into force, patent licenses must be registered with the CNIPA within three months after a licensor and licensee sign a licensing contract (Wang et al., 2015). The registered information includes the patent number, licensor and licensee names, the contract number, the date when the license contract took effect, and the license type (i.e., simple, sole, or exclusive). A simple license is non-exclusive and the licensor reserves the right to issue additional licenses. A sole license excludes additional licensees but permits the licensor to use the licensed patent. An exclusive license grants only a single licensee the right to use the patent, prohibiting any other entity (including the licensor) from using it.

Furthermore, we collected additional public information on the licensee firm associated with each licensed patent by searching TianYanCha.com, an authoritative online enterprise database.[2] The information in the database includes, among other things, firm ownership, industry, amount of registered capital, and firm address. The final

[1] These rankings include the QS World University Rankings, The Times Higher Education World University Rankings, WuShulian Chinese University Rankings (available at websitehttp://blog.sina.com.cn/wushulian), and Ruanke Chinese University Rankings (available at www.zuihaodaxue.com). The WuShulian Chinese University Rankings and the Ruanke Chinese University Rankings are the two most influential Chinese university rankings and are frequently cited by major domestic media. The WuShulian Chinese University Rankings issue the domestic university rankings with the longest history. In 1993, Mr. Sulian Wu, a former researcher at the China Academy of Management Science, released China's first university rankings based on comprehensive evaluations. The Ruanke Chinese University Rankings was first published in 2015 by the organization that releases the influential Academic Ranking of World Universities (ARWU).

[2] TianYanCha.com collects information from the National Enterprise Credit Information Publicity System, China Judgement Online, Enforcement of Court Decisions, and other governmental public information portals. Because of the quality of its enterprise credit information service, TianYanCha.com is referenced by the Chinese Central Bank–People's Bank of China.

sample consists of 6653 licensed patents owned by 117 public universities and licensed to 3938 firms.

4.3. Variables

4.3.1. Dependent variable

To investigate the determinants of exclusive licensing we use a dummy variable, *Exclusive license,* as the dependent variable. In China, a licensor and licensee can choose from among three types of licenses: a simple license, a sole license, and an exclusive license. Our sample includes 1197, 247, and 5209 simple, sole, and exclusive licenses, respectively. Although the degree of exclusivity involved in sole and exclusive licenses differs slightly, we categorize both types into one group.[3] The variable *Exclusive license* equals 1 when a license is a sole or exclusive license and 0 when the license is a simple license.

4.3.2. Independent variables

We use information from both domestic and foreign university rankings to construct the independent variable *University prestige*. First, we calculated the average rank of each university for the 2015–2017 period and generated a new ranking of the 117 universities in our sample.[4] We then converted the ranks to scores to proxy for prestige. For ease of interpretation, we assigned 1 point to the lowest-ranked university in our sample (i.e., Huaqiao University) and 117 points to the highest-ranked university (i.e., Tsinghua University). The university with ranking N is assigned 118 minus N points, ensuring that the higher the score, the more prestigious the university. For a robustness check, we also introduce *Level of university prestige* as a variable. Specifically, according to the calculated ranking, we divide all universities in our sample into five categories: Universities in the top quintile are assigned the value of 5 while universities in the bottom quintile are assigned the value of 1, with the corresponding values for universities in the second, third, and fourth quintiles denoted as 4, 3, and 2, respectively. In other words, the higher the value of *Level of university prestige*, the more prestigious are the universities in that category.

Next, we introduce the two moderating variables: *TTO experience* and *Prior collaboration.* Following Markman et al. (2005), we use the tenure of a TTO's operations in the year when a patent is licensed as the proxy for *TTO experience.* We count the number of years between the year when the TTO was established and the year when the patented technology was licensed. For instance, if a patent was licensed in 2012 and the university established a TTO in 2010, the value of *TTO experience* is 2. *Prior collaboration* is a dummy variable that equals 1 if collaborative interactions between a university and a licensee firm existed before the observed licensing between the two parties and 0 otherwise. We collected this information by searching publicly available sources on the internet. In particular, we used the names of a firm and a university with a licensing partnership as keywords in online search engines to collect news of their collaborative activities (either released on their official websites or reported in the media). Such collaborative interactions include forming a strategic alliance, building joint laboratories, conducting joint R&D projects, a university's providing a consulting service to a firm, a firm's being located in a university's science park university, a firm's funding of a university, and so on. If such an interaction was found to have occurred before the licensing deal, prior collaboration is considered present.

4.3.3. Control variables

We control in the first instance for patent-level features. Firms tend to monopolize valuable technological resources, so we use several indicators that are typically used to value patented technologies, including number of claims, number of forward citations, and patent age (Gambardella et al., 2007). The variable *Claims* is defined as the number of claims on a licensed patent. The *Forward citations* variable is the number of examiners' forward citations received by a licensed patent. *Patent age* is measured by the number of years between the year of a patent application and the year when the associated license takes effect. *Application year* is defined as the application year of the licensed patent. Because the adoption of exclusive licenses varies across technological fields (Colyvas et al., 2002; Mazzoleni, 2006), we follow the WIPO IPC-Technology concordance table (Schmoch, 2008) to categorize 35 technological fields and construct *Technological field* dummies to control for unobserved heterogeneity across separate technology fields.

We also control for firm-level variance. Universities may prefer licensing to prestigious firms because such licensees usually have more abundant resources and superior capabilities for technology commercialization. Prestigious firms can also leverage greater bargaining power in licensing negotiations (Thye, 2000). Because most firms want to license exclusively, prestigious firms are more likely to persuade universities to accept an exclusive license. Therefore, holding all else equal, we expect that the probability of adopting an exclusive license will be higher when the licensee firm is more prestigious. To control for firm prestige, we use two proxies. First, we consider that the age of a licensee firm is, to some extent, a proxy for its prestige. Firms with a long history generally have greater prestige than newly founded firms (Rhee and Valdez, 2009). We control for the age of a licensee firm by constructing the variable *Firm age*. We count the number of years between the firm's founding year and the year when the license was issued, and we use this number as the value of *Firm age.* Second, to further indicate a licensee firm's level of prestige, we control for whether the firm is listed on the stock exchange. Listed firms generally have greater prestige than non-listed firms (Chemmanur and Paeglis, 2005), so we expect that exclusive licensing is more likely when the licensee firm is listed. We construct the dummy variable *Listed firm*, which equals 1 if the licensee firm was listed on the Shanghai, Shenzhen, or Hong Kong stock exchange at the time when the license occurred and 0 otherwise. We also control for the licensee firm's registered capital. We use the logarithmic value of the amount of registered capital in units of ten thousand RMB as the value of the variable *Licensee registered capital*.

In addition to accounting for firm prestige, we consider whether firm ownership type influences the exclusivity of licensing. Firms with distinct ownership structures typically set different strategic goals, face different resource constraints, and adopt distinct managerial practices, especially in China (Aharoni, 1981; Xu, 2011; Jia et al., 2019). Because exclusive licensing is often significantly more expensive than non-exclusive licensing, firm ownership type can influence this decision. For instance, private firms may be less likely to choose exclusive licensing because they typically face tighter financial constraints than state-owned firms (Tsai, 2002). In addition, because Article 21 of the Science and Technology Progress Law stipulates that IPRs generated by government-funded R&D programs should be used first in China and funding-agency approval must be secured before IPRs can be sold or licensed exclusively to foreign entities or individuals, we expect universities to be less likely to license technologies exclusively to foreign firms.

[3] To verify whether this merger is appropriate, we construct a categorical variable with the three categories of licenses and use it as a dependent variable to conduct additional analyses. We use a multinomial logit model to run the regressions, and the results show that the coefficients for the exclusive license groups and the sole license groups are not significantly different. This indicates the appropriateness of grouping the two types of licenses together.

[4] We use rankings only from the 2015–2017 period because this is the period covered by all four rankings. The Chinese university rankings are generally stable during our observation period, although we observe slight fluctuations for some universities over time. To investigate whether university ranking changes would influence our result, we use a single domestic university ranking, which is published by the Alumni Association Network (Cuaa.Net) and is available from 2008 through 2017 to generate a variable to measure university prestige. We use the ranking of each university to measure its prestige in the year in which a licensing deal occurred. The results are consistent with what we found earlier when using the original variable *University prestige*.

Table 1
Summary statistics.

Variable	Observations	Mean	Std. Dev.	Min	Max
Exclusive license	6653	0.820	0.384	0	1
University prestige	6653	72.845	35.112	1	117
Level of university prestige	6653	3.485	1.485	1	5
TTO experience	5642	5.082	5.019	0	33
Prior collaboration	6653	0.366	0.482	0	1
Control variables:					
Claims	6653	5.188	3.032	0	37
Forward citations	6653	1.017	0.287	1	17
Patent age	6653	4.073	1.846	0	14
Firm age	6653	8.685	7.580	0	110
Listed firm	6653	0.025	0.155	0	1
Licensee registered capital	6636	8.226	1.585	2.303	13.445
Foreign	6636	0.070	0.256	0	1
HKMT	6636	0.070	0.256	0	1
State-owned	6636	0.015	0.122	0	1
Domestic private	6636	0.844	0.363	0	1
Geographic distance	6653	3.657	2.969	0	7.168
Policy change 2015	6653	0.182	0.386	0	1

We control for licensee firm ownership by adding four dummy variables: *State-owned* is an indicator variable that equals 1 if a patent is licensed to a state-owned firm; *Foreign* equals 1 if a licensee firm is foreign-owned; *HKMT* equals 1 if a licensee firm is a Hong Kong-, Macau-, or Taiwan-owned enterprise; *Domestic private* equals 1 if a licensee firm is a domestic private firm; otherwise, these indicator variables equal 0. *Domestic private* is used as the reference group for ownership type in our regression analyzes. We include robust standard errors clustered by firms in all our models to control for possible correlations in the errors for each licensee firm.[5]

Furthermore, we posit that geographic proximity shapes firms' willingness to preclude other licensees, as it is more difficult for a remote licensee firm to collaborate with a university because of the higher barriers (e.g., extra costs) they must hurdle to interact with university faculty (Buenstorf and Schacht, 2013). If a university reserves the right to license non-exclusively to additional partners, it may turn more easily to licensees that are located closer to campus and thus less costly to work with, and the hazards associated with non-exclusive licenses become more salient for remote licensees. Therefore, we expect that geographic distance increases a firm's incentive to obtain an exclusive license and that the probability that exclusive licensing is contracted rises when the geographic distance is greater. We construct a *Geographic distance* variable by computing the logarithmic value of one plus the distance in one-kilometer units between the city where the licensor university is located and the city of the licensee firm. When a licensor and licensee are from the same city, the distance between them is 0 and thus the value of *Geographic distance* is 0.

Finally, as mentioned in Section 4.1, the amended Law on Promoting the Transformation of Scientific and Technological Achievements came into force in October 2015. This law constitutes one of the most significant policy changes regarding technology transfer in our sample observation period. The amended law grants greater autonomy to universities, which are more likely to reach contractual agreements favoring them when making licensing deals with firms. We thus expect that the probability that exclusive licenses are adopted drops after 2015. To control for this policy impact, we construct a dummy variable, *Policy change 2015*, to measure the influence of the legislative action. This variable equals 1 if the license occurred after 2015 and 0 otherwise.

Table 1 provides the descriptive statistics for our data. The mean of the dependent variable is 0.820, which implies that 82% of the licenses in our sample are exclusive. The means of *University prestige* and *Level of university prestige* are 72.845 and 3.485, respectively. The mean of *TTO experience* is 5.082, which implies that, on average, TTOs have been operating for about 5 years when patents are licensed. The mean of *Prior collaboration* is 0.366, which implies that 36.6% of patents in our sample are licensed to firms that cooperated with universities before their licensing transactions were completed. The correlation matrix presented in Table 2 shows that the absolute values of the correlations between the dependent variable and each of the independent variables are all below 0.7 and that the absolute values of the correlation coefficients between any two independent variables entering the regressions are lower than 0.46. For additional descriptive statistics for the sample, such as the number of licenses at each prestige level and the number of licenses that are issued in each license year, we refer to Appendix A.

5. Empirical results and discussion

Our dependent variable is categorical and comprises only two categories, so we use a binary logit model to estimate the probability that a university license is exclusive. In Table 3 we report the estimation results for the binary logit model with *University prestige* as the independent variable. Model 1 includes only the control variables. To test hypothesis 1, we add the independent variable *University prestige* to Model 2 and the squared term of *University prestige* to Model 3. The coefficient of *University prestige* from Model 3 is 0.0753, with a marginal effect of 0.0045 ($p < 0.01$ and the 95% confidence interval is [0.00308, 0.00594]),[6] while the coefficient of the squared term is −0.000506, with a marginal effect of −0.0000303 ($p < 0.01$ and the 5% confidence interval is [−0.0000418, −0.0000189]). We follow the steps suggested by Haans et al. (2016) to test the existence of the inverted U-shaped relationship that we hypothesize. The results show that the slope at the lower bound (1) is 0.074 ($p < 0.01$) while at the upper bound (117) the slope is −0.044 ($p < 0.01$), implying that exclusive licensing first increases as university prestige rises and then decreases. The result of the overall test for the presence of an inverted U shape is also significant (t-value is 3.61 and $p < 0.01$). Furthermore, the estimated turning point is 74.439 (the 95% confidence interval is [66.253, 82.626]), which is within the range of the independent variable *University prestige* and very close to the mean of the variable, 72.845. Hypothesis 1, which predicts an inverted-U relationship between university prestige and exclusivity, is thus supported. We plot the probability of exclusive licensing across the range of university prestige ratings in Fig. 4.

We use Models 4 and 5 to test the moderating effects of *TTO experience* and *Prior collaboration*, respectively, and Model 6 is the fully specified model. Estimating Model 4, we find that the coefficient of the interaction term between *University prestige* and *TTO experience* is −0.00582, which is significant ($p < 0.05$), while the coefficient of the interaction term between the squared term of *University prestige* and *TTO experience* is 3.32e-05 and is nonsignificant ($p = 0.108$). As explained by Haans et al. (2016), the significance of the above two interaction terms is neither necessary nor sufficient to prove the occurrence of a turning point shift. Therefore, we follow their suggested steps to analyze the results obtained with Model 4. We find that, when the value of *TTO experience* is 0, 1, or 2, the leftward shift of the turning point is significant, with $p = 0.014$, $p = 0.034$ and $p = 0.069$, respectively. The corresponding turning points are 67.377, 65.753 and 63.847, respectively. When the value of *TTO experience* is greater than 2, the leftward turning point shift is no longer significant. Therefore, hypothesis H2 is partially supported. To facilitate interpretation of the results, in Fig. 5 we plot the relationship between *University prestige* and *Exclusive license* at the values

[5] We also conduct an additional analysis with robust standard errors clustered by universities and the results are consistent with those that include robust standard errors clustered by firms.

[6] The marginal effects in our regression are average marginal effects (AME).

Table 2
Pairwise correlation matrix.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Exclusive license																
2	University prestige	0.3986*															
3	Level of university prestige	0.4340*	0.9834*														
4	TTO experience	−0.1467*	0.3004*	0.2878*													
5	Prior collaboration	−0.3650*	−0.2019*	−0.2227*	0.0539*												
6	Claims	0.1107*	0.1127*	0.1103*	0.0899*	−0.0915*											
7	Forward citations	−0.0096	0.0241	0.0223	0.0568*	0.02	0.0537*										
8	Patent age	−0.0554*	0.0819*	0.0672*	0.1108*	−0.008	−0.0154	−0.0009									
9	Firm age	0.0779*	0.0508*	0.0584*	−0.0236	−0.0885*	−0.0028	0.0009	0.0206								
10	Listed firm	−0.0164	0.0403*	0.0453*	0.0401*	−0.014	0.0470*	0.0279	0.0268	0.1196*							
11	Licensee registered capital	0.1067*	0.0897*	0.0953*	0.0205	−0.0640*	0.0092	0.0144	0.0038	0.1729*	0.2519*						
12	Foreign	0.0660*	0.0760*	0.0743*	−0.017	−0.0996*	−0.0068	−0.0119	0.0079	0.0418*	0.0018	0.1400*					
13	HKMT	0.1044*	0.0612*	0.0580*	−0.0474*	−0.1070*	0.0308	−0.0016	−0.0129	0.0144	−0.0096	0.1739*	−0.0755*				
14	State-owned	0.0455*	−0.004	0.0019	−0.0332	0.013	−0.0114	0.0056	−0.0386*	0.1280*	−0.0198	−0.0376*	−0.0342*	−0.0342*			
15	Domestic private	−0.1355*	−0.0954*	−0.0939*	0.0569*	0.1412*	−0.0131	0.0076	0.0166	−0.0828*	0.0121	−0.2085*	−0.6400*	−0.6400*	−0.2895*		
16	Geographic distance	0.3755*	0.2419*	0.2589*	0.0159	−0.3426*	0.0927*	−0.0054	0.0369*	0.0800*	0.0504*	0.2082*	0.0642*	0.1157*	−0.0932*	−0.0953*	
17	Policy change 2015	−0.6986*	−0.4291*	−0.4532*	0.2809*	0.3717*	−0.0830*	−0.0044	0.0632*	−0.0872*	0.0378*	−0.1057*	−0.1255*	−0.1056*	−0.0302	0.1731*	−0.3421*

[*] $p < 0.1$. All correlation coefficients of a magnitude greater than 0.031 are significant at the 0.1 level.

Table 3
Estimation results of binary logit regressions (with *University prestige* as the independent variable).

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Dependent Variable	Exclusive licensing					
University prestige		0.0105**	0.0753***	0.0602***	0.0390***	0.0651***
		(0.00516)	(0.0172)	(0.0180)	(0.0145)	(0.0187)
University prestige square			−0.000506***	−0.000447***	−0.000325***	−0.000477***
			(0.000119)	(0.000153)	(0.000110)	(0.000158)
TTO experience				0.238**		0.236**
				(0.104)		(0.103)
TTO experience * University prestige				−0.00582**		−0.00567**
				(0.00292)		(0.00289)
TTO experience * University prestige square				3.32e-05		3.20e-05
				(2.07e-05)		(2.04e-05)
Prior collaboration					−3.522***	1.095
					(1.136)	(1.004)
Prior collaboration * University prestige					0.0706**	−0.0290
					(0.0341)	(0.0331)
Prior collaboration * University prestige square					−0.000326	0.000176
					(0.000239)	(0.000244)
Claims	0.0268	0.00883	−0.000976	−0.0341	−0.00978	−0.0341
	(0.0284)	(0.0247)	(0.0242)	(0.0220)	(0.0235)	(0.0219)
Forward citations	−0.156	−0.179	−0.209	−0.218*	−0.228*	−0.214*
	(0.138)	(0.137)	(0.131)	(0.122)	(0.127)	(0.120)
Patent age	−0.384***	−0.412***	−0.419***	−0.501***	−0.443***	−0.503***
	(0.0754)	(0.0687)	(0.0711)	(0.0761)	(0.0699)	(0.0764)
Firm age	−0.0116	−0.0117	−0.0167	−0.0271**	−0.0246**	−0.0271**
	(0.0144)	(0.0139)	(0.0134)	(0.0115)	(0.0121)	(0.0113)
Listed firm	−0.249	−0.427	−0.341	−0.418	−0.315	−0.438
	(0.549)	(0.530)	(0.522)	(0.466)	(0.505)	(0.455)
Licensee registered capital	0.0233	0.0178	−0.00410	0.00503	0.00292	0.00249
	(0.0670)	(0.0675)	(0.0666)	(0.0611)	(0.0629)	(0.0604)
Foreign	−0.603	−0.669*	−0.591	−0.631**	−0.697**	−0.621*
	(0.392)	(0.395)	(0.361)	(0.322)	(0.351)	(0.324)
HKMT	0.451	0.353	0.378	0.319	0.375	0.331
	(0.462)	(0.444)	(0.440)	(0.414)	(0.438)	(0.410)
State-owned	1.719**	1.616**	1.604**	1.007	1.320**	1.036
	(0.703)	(0.697)	(0.713)	(0.629)	(0.609)	(0.630)
Geographic distance	0.218***	0.198***	0.177***	0.0731**	0.135***	0.0736*
	(0.0655)	(0.0544)	(0.0509)	(0.0367)	(0.0411)	(0.0378)
Policy change 2015	−1.917***	−1.671***	−1.579***	−0.633*	−1.164***	−0.633*
	(0.614)	(0.484)	(0.471)	(0.348)	(0.363)	(0.347)
Application year dummies	Added	Added	Added	Added	Added	Added
Technological field dummies	Added	Added	Added	Added	Added	Added
Constant	0.0191	−0.422	−1.205	1.441	0.918	1.315
	(1.095)	(1.181)	(1.194)	(1.418)	(0.907)	(1.407)
Observations	6594	6594	6594	5563	6594	5563
Wald chi2	307.06	324.57	317.22	259.75	327.82	276.76
Prob > chi2	0	0	0	0	0	0
Pseudo R2	0.5293	0.5367	0.5513	0.2526	0.5731	0.2535
Log likelihood	−1469.4817	−1446.4332	−1401.016	−1153.5345	−1332.8705	−1152.1016

Notes: Robust standard errors, clustered by licensee firms, are shown in parentheses. All tests are two-tailed.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

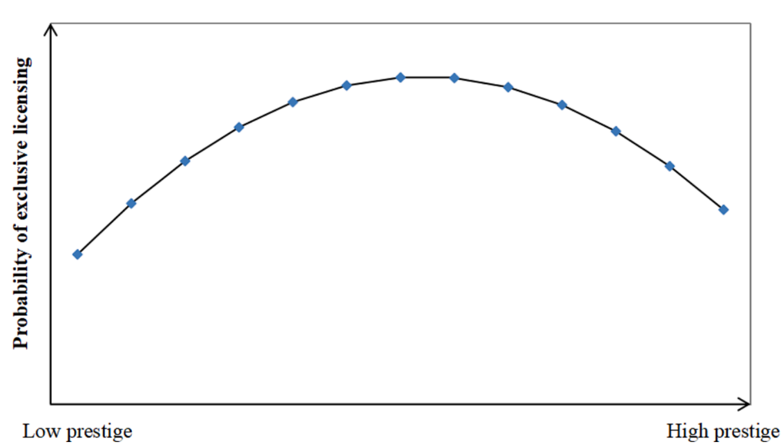

Fig. 4. University prestige and the exclusivity of university licensing.

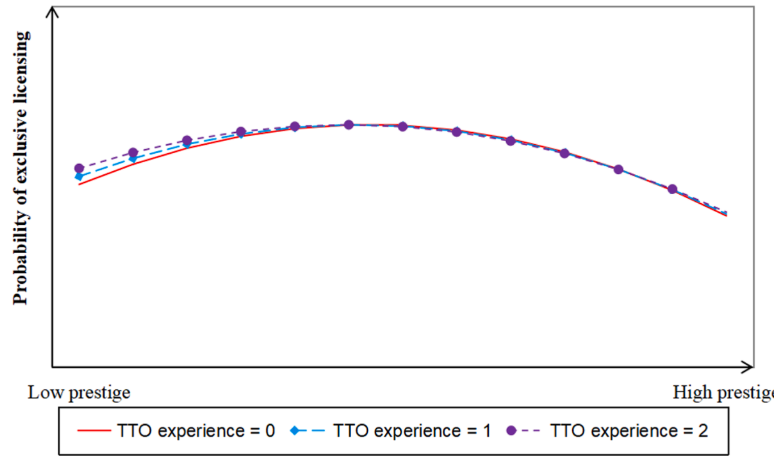

Fig. 5. University prestige and the exclusivity of university licensing moderated by TTO experience.

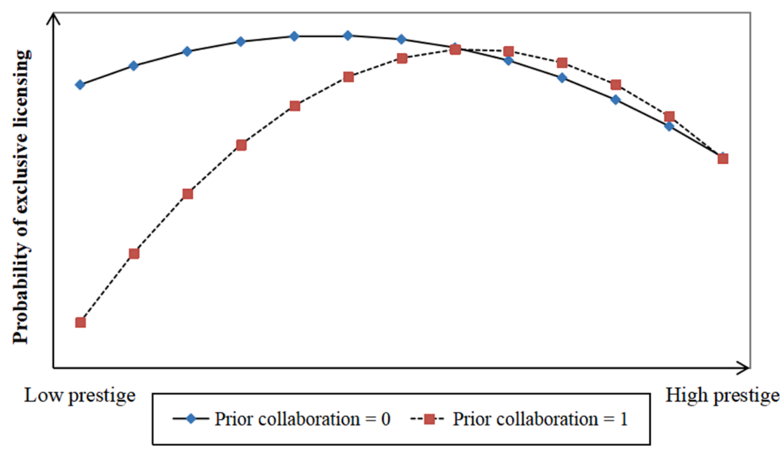

Fig. 6. University prestige and the exclusivity of university licensing moderated by prior collaboration.

0, 1, and 2 of *TTO experience* and find that the turning points shift leftward with the increase in *TTO experience.* The shifts of the turning points are so small, though, that the four curves almost overlap.

When we estimate Model 5, the coefficient of the interaction term between *University prestige* and *Prior collaboration* is 0.0706, which is significant ($p < 0.05$), while the coefficient of the interaction term between the squared term of *University prestige* and *Prior collaboration* is −0.000326, which is nonsignificant ($p = 0.173$). Following the same approach used for Model 4, we find that when the values of *Prior collaboration* are 0 and 1, the rightward shifts of the turning points are significant ($p = 0.100$ and 0.000, respectively). These results support H3. We calculate the estimation of inflection points under varying values of *Prior collaboration.* When *Prior collaboration* is 0, the turning point is 60.014, and when it is 1, the turning point is 84.157. To facilitate interpretation of these results, in Fig. 6 we plot the relationship between *University prestige* and *Exclusive license* in the absence (=0) and presence (=1) of *Prior collaboration* and see that the turning point occurs at higher levels of *University prestige* when there is prior collaboration between a university and a licensee firm.

To check robustness, we replace the independent variable *University prestige* with *Level of university prestige*. The results are shown in Table 4 and are generally consistent with those reported in Table 3. When estimating Model 3, the coefficient of *Level of university prestige* is 2.493 with a marginal effect of 0.146 ($p < 0.01$ and the 95% confidence interval is [0.100, 0.193]) and the coefficient of the squared term is −0.353 with a marginal effect of −0.0207 ($p < 0.01$ and the 95% confidence interval is [−0.028, −0.013]). We use the same method (Haans et al., 2016) to confirm the existence of the inverted-U-shaped relationship. The estimated turning point is 3.532 within the range of the variable (the 95% confidence interval is [3.270, 3.795]). H1 is thus again supported. We estimate Models 4 and 5 to test the moderating effects of *TTO experience* and *Prior collaboration*, respectively, and Model 6 is the fully specified model. We follow the same steps used to obtain the results reported in Table 3 and find that H2 is also partially supported (i.e., the leftward shifts in the turning points are significant only when *TTO experience* is 0, or 1) while H3 is also supported.

We discuss the regression results for the control variables as follows. First, among the three patent-level features, only the coefficient of *Patent age* is significantly negative across all models, as shown in Tables 3 and 4. These results indicate that the probability that an exclusive license is adopted decreases as patent age increases. Since patent value diminishes with age, firms are less likely to license those patents exclusively. The coefficient of *Claims* is nonsignificant across all models, as are almost all the coefficients of *Forward citations*. A potential explanation for these results is that, although the number of claims and forward citations reflect patent value to some extent, they are not a core concern when licensors and licensees negotiate the exclusivity of a license. As for the technological fields, the results show that exclusivity in university

Table 4
Estimation results of binary logit regressions (with the *Level of university prestige* as the independent variable).

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Dependent Variable	Exclusive licensing					
Level of university prestige		0.319**	2.493***	1.689***	0.989**	1.761***
		(0.127)	(0.578)	(0.538)	(0.415)	(0.548)
Level of university prestige square			−0.353***	−0.249***	−0.160**	−0.256***
			(0.0843)	(0.0908)	(0.0651)	(0.0909)
TTO experience				0.322**		0.323**
				(0.151)		(0.149)
TTO experience* Level of university prestige				−0.173*		−0.173*
				(0.0893)		(0.0891)
TTO experience * Level of university prestige square				0.0212		0.0212
				(0.0129)		(0.0129)
Prior collaboration					−5.326***	1.078
					(1.539)	(1.200)
Prior collaboration * Level of university prestige					2.944***	−0.478
					(1.027)	(0.833)
Prior collaboration * Level of university prestige square					−0.373**	0.0514
					(0.153)	(0.131)
Claims	0.0268	0.00347	−0.0148	−0.0353	−0.0208	−0.0352
	(0.0284)	(0.0244)	(0.0230)	(0.0221)	(0.0226)	(0.0220)
Forward citations	−0.156	−0.187	−0.221*	−0.212*	−0.252**	−0.211*
	(0.138)	(0.136)	(0.127)	(0.122)	(0.127)	(0.122)
Patent age	−0.384***	−0.420***	−0.443***	−0.497***	−0.464***	−0.499***
	(0.0754)	(0.0684)	(0.0705)	(0.0742)	(0.0699)	(0.0745)
Firm age	−0.0116	−0.0118	−0.0190	−0.0269**	−0.0255**	−0.0266**
	(0.0144)	(0.0138)	(0.0122)	(0.0111)	(0.0113)	(0.0111)
Listed firm	−0.249	−0.495	−0.366	−0.444	−0.382	−0.471
	(0.549)	(0.521)	(0.512)	(0.467)	(0.495)	(0.458)
Licensee registered capital	0.0233	0.0148	−0.0167	0.00432	−0.00147	0.00329
	(0.0670)	(0.0670)	(0.0661)	(0.0612)	(0.0628)	(0.0605)
Foreign	−0.603	−0.681*	−0.669*	−0.671**	−0.755**	−0.658**
	(0.392)	(0.392)	(0.364)	(0.334)	(0.355)	(0.335)
HKMT	0.451	0.347	0.361	0.295	0.354	0.298
	(0.462)	(0.440)	(0.429)	(0.410)	(0.429)	(0.406)
State-owned	1.719**	1.573**	1.436**	0.997	1.190*	1.010
	(0.703)	(0.695)	(0.680)	(0.627)	(0.614)	(0.631)
Geographic distance	0.218***	0.190***	0.159***	0.0735**	0.117***	0.0739*
	(0.0655)	(0.0517)	(0.0460)	(0.0367)	(0.0392)	(0.0381)
Policy change 2015	−1.917***	−1.589***	−1.379***	−0.565	−0.980***	−0.567*
	(0.614)	(0.460)	(0.425)	(0.344)	(0.342)	(0.344)
Application year dummies	Added	Added	Added	Added	Added	Added
Technological field dummies	Added	Added	Added	Added	Added	Added
Constant	0.0191	−0.653	−2.321*	0.777	0.776	0.613
	(1.095)	(1.200)	(1.320)	(1.426)	(0.976)	(1.432)
Observations	6594	6594	6594	5563	6594	5563
Wald chi2	307.06	328.26	311.21	264.01	339.45	275.29
Prob > chi2	0	0	0	0	0	0
Pseudo R2	0.5293	0.5415	0.5587	0.2494	0.5799	0.2501
Log likelihood	−1469.4817	−1431.3764	−1377.7326	−1158.4932	−1311.6186	−1157.3537

Notes: Robust standard errors, clustered by licensee firms, are shown in parentheses. All tests are two-tailed.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

licensing is impacted by technological field type. The baseline group is *Electrical machinery, apparatus, energy*, with 428 observations, of which 87.4% are exclusive licenses (see Table A3). Compared with patents in the baseline group, patents in the four other fields (i.e., *Digital communication, Computer technology, IT methods for management*, and *Measurement*) are less likely to be licensed exclusively.

The majority of the coefficients of *Firm age* are nonsignificant, and our prediction (i.e., exclusive licensing is more likely to be adopted when a firm is older) is not proven. This may be because *Firm age* is not a very effective indicator of firm prestige. The coefficients of *Listed firm* and *Licensee registered capital* are also nonsignificant across all models, showing that, regarding the exclusivity of licensing deals, it does not matter whether a firm is listed on stock exchanges or how much registered capital a firm has when it is established. In terms of firm ownership, the coefficients of *Foreign*(-owned) are significantly negative with some models, while those for *HKMT* are all non-significant and those for *State-owned* are significantly positive only with some models. The baseline group is *Domestic private,* so these results imply that exclusive licenses are less likely to be adopted when foreign-owned licensee firms are involved, as such licenses are more likely to be adopted when firms are state-owned. These results are consistent with the abovementioned theoretical predictions.

Finally, the coefficient of *Geographic distance* is significantly positive across all models. This is consistent with our prediction that exclusive licensing is more likely to be adopted when the distance between a university and a licensee firm is greater. The coefficient of *Policy change 2015* is, finally, significantly negative across all models, which is consistent with the prediction that exclusive licensing became less likely after the Law on Promoting the Transformation of Scientific and Technological Achievements was amended. Universities were granted greater autonomy in technology transfer by the amended Law, and thus are more likely to obtain favorable non-exclusive contractual agreements in negotiations with licensee firms.

6. Conclusion and directions for future research

6.1. Conclusions and implications

This study aims to provide a deeper understanding of university technology transactions by focusing on how organizational antecedents influence the exclusivity of university–industry licensing contracts. Specifically, we propose that university prestige is an organizational antecedent of exclusivity. Using a novel framework, we disentangle the ability of a university and the incentive for a firm to license (non-)exclusively as a function of university prestige and examine how these factors jointly shape this contractual provision. Combining both ability and incentive effects, we demonstrate that an inverted U-shaped relationship exists between university prestige and exclusive licensing. This study also investigates how this relationship depends on TTO experience as well as prior collaboration between a university and a licensee firm. When there is prior collaboration, the turning point of the inverted U-curve occurs at higher levels of university prestige, but the moderating effect of TTO experience is supported empirically only when TTOs have less than three years' experience.

The study offers the following three theoretical contributions to the literature. First, our study complements other studies on academy–industry knowledge exchange by revealing factors that influence contractual design in university licensing. Prior studies have found that university licensing is influenced by technological (e.g., patent), organizational (e.g., university prestige, TTOs) and environmental (e.g., policy) factors (Rothaermel et al., 2007; Siegel et al., 2003; Battistella et al., 2016), but they typically focus on outcomes such as the quantity of licensing deals and volume of licensing revenue (Mowery et al., 2004), whereas the contractual design of university licensing is not well understood (Bradley et al., 2013). This study attempts to fill this gap by examining specifically the role of university prestige in negotiating exclusivity clauses. Furthermore, by conducting our investigation in the Chinese university context, we provide important empirical evidence pertaining to the underexplored research setting of university technology transfer in China.

Second, most studies that examine exclusive licensing conduct their analyzes from either the licensor's or licensee's perspective alone (e.g., Aulakh et al. 2010, Khoury et al. 2019, Kim and Vonortas 2006) while, in practice, contractual specifications result from negotiations between the two parties. Therefore, drawing on transaction cost economics theory, we propose a balanced framework that considers the perspective of both the licensor and the licensee. This framework deepens our understanding of how the joint willingness of a university and firm to license (non-)exclusively is determined by, on the one hand, the former's ability to reduce the additional transaction costs associated with non-exclusive licensing and, on the other hand, the latter's incentive to mitigate transactional hazard. The combination of these two factors ultimately shapes the design of a licensing contract regarding exclusivity.

Third, this study contributes to the literature on status by showing that status affects not only whether and with whom organizations collaborate in university technology transfer (Rothaermel et al., 2007; Jensen and Roy, 2008; Sine et al., 2003) but also *how* they collaborate. We explain how university prestige influences both a university's and a licensing firm's willingness to license exclusively and how this relationship is further shaped by other factors, such as whether the university's TTO has much experience and whether there has been prior collaboration between the licensor and the licensee. This study thus also sheds light on how not only patent features (Drivas et al., 2017) but also organizational features shape the exclusivity of a licensing contract.

This study provides implications for the relative social impacts of exclusive and non-exclusive licensing of university inventions as well as the management of university licensing. Studies have indicated that limited access to exclusively licensed inventions causes a loss in social welfare by preventing effective diffusion of new technologies (Drivas et al., 2017; Kenney and Patton, 2009). In many cases, an exclusive license is not even a necessary condition for inducing a private firm's follow-up on R&D activities (Colyvas et al., 2002; Mazzoleni, 2006). For instance, Öcalan-Özel and Pénin (2019) show that, even if the features of licensed inventions do not satisfy the conditions under which exclusive licensing incentivizes a firm, exclusive licenses are adopted nonetheless. Their study suggests that this inefficiency may result from universities' failure to convince firms to accept non-exclusive contract designs, which are better suited to optimizing a country's social welfare.

Our results imply that exclusive licensing is most likely to occur at moderately prestigious universities. In their cases, universities do not possess sufficient bargaining power to influence the final outcome, while firms have sufficient willingness to obtain exclusive licenses. The odds of licensing exclusively are highest here. Therefore, we conjecture that knowledge dissemination by moderately prestigious universities may be sub-optimal, and, insofar as their technologies are applied to only a limited extent, their economic and social impact is constrained, making it more difficult for them to accomplish their public mission. However, technologies from top universities, which are less likely to be licensed exclusively, have a greater chance of being fully applied and are thus more likely to generate economic and social impacts. In the interest of enhancing social welfare, we suggest that governments consider implementing policies that encourage the adoption of non-exclusive licenses, such as giving additional preferential tax treatments or providing subsidies for subsequent commercialization to firms that accept non-exclusive licenses. We also suggest that governments consider further empowering universities, especially those that are moderately prestigious, via policies similar to the policy reform of 2015, which strengthened universities' autonomy and capacity in licensing negotiation. As we can see from the regression results, following this reform the propensity to license exclusively declined significantly compared with the pre-2015 situation.

Our results also indicate that Chinese TTOs exert only limited influence on licensing exclusivity.[7] Although experience can help TTOs build the skills they need to reduce the transaction costs associated with non-exclusive licensing, its marginal returns diminish over time (Bianchi and Lejarraga, 2016). That is why we no longer see a significant moderating effect of *TTO experience* after two or more years. Moreover, the moderating effect of TTO experience is very small, as illustrated in Fig. 5. These results show that the influence of Chinese TTOs on the exclusive licensing of university technology remains weak. A TTO's mission is to help universities commercialize their technologies, yet it has been reported that Chinese universities' TTOs lack the experience and skills needed to fulfill such a mission (Chen et al., 2016; Rotenberg, 2016; Li et al., 2020). Our results are consistent with this assessment.

Following these results, we conjecture that a lack of expertise in a TTO can impede negotiations over licensing contracts that otherwise would support the public interest and diminish the contributions of efficient university technology transfer to economic development. Therefore, we suggest that university administrators consider at least two measures to improve the current situation. First, for universities that lack sufficient capacity for formal technology transfer, other pathways for knowledge exchange, such as co-publication, consulting, and informal relationships with industry, may serve as remedies that would help them accelerate the diffusion of scientific discoveries (Hayter et al., 2020; Perkmann et al., 2021). Universities should encourage and support academics who are seeking to engage with industry through alternatives to licensing. Second, universities do not necessarily have to

[7] To further investigate the effects of TTO, we also construct another variable, *Existence of TTO*, a dummy variable that equals 1 if a university has established a TTO in the licensed year and 0 otherwise. We substitute *Existence of TTO* for *TTO experience* in the regressions that inform Tables 3 and 4. We find no statistically significant moderating effect of *Existence of TTO*.

limit TTOs as agents specialized in formal technology transfer. They can create a more flexible role for them, so that TTOs can diversify their practices in ways that favor better innovation outcomes. For instance, TTOs can act as broader intermediaries for knowledge exchange and linkage creation by organizing workshops and seminars to better connect scientists with engineers and entrepreneurs (Bramwell and Wolfe, 2008; Hayter et al., 2020).

6.2. Limitations and future research directions

Despite its contributions, this study is subject to several limitations. First, although we investigate two contingencies that moderate the nonlinear effects of university prestige on exclusive licensing, we do not identify any factors that might influence the ability and incentive effects simultaneously. Future studies could consider departmental or faculty prominence as another moderator. For instance, when university prestige is low but a patented technology is produced by a well-known department (or “star” scientists), it may enhance the incentive for prospective licensees to monopolize the technology as well as a university’s bargaining power to enter into licensing deals with multiple firms. This interaction effect between university prestige and departmental prominence can, however, be complex and requires further examination.

Second, our investigation into the effects of prior collaboration between a university and a licensee firm is rudimentary. While we know that an established collaborative relationship as well as the heterogeneity of relationship types may make a difference, the perceived sources of transactional hazard associated with non-exclusive licenses for licensee firms can vary across types of prior collaboration. For instance, some partnerships may facilitate the formation of strong ties between a university and a firm and thereby the formation of long-lasting relationships, while others bring about only short-term interactions that are insufficient for building close linkages. The transactional hazard that firms perceive when strong ties are present can be made less severe than when only weak ties are established. Thus, further investigation of the heterogeneity of collaborative relationships may lead to a better understanding of how relational factors may affect the exclusivity of university licensing.

Third, this study does not consider specific restrictions regarding exclusivity because of the limited unavailability of relevant data. Exclusivity can be restricted to a certain use, sector, or geographic market (Bercovitz and Feldmann, 2006). For instance, Somaya et al. (2011) and Öcalan-Özel and Pénin (2019) differentiate between specific restrictions when investigating factors influencing license exclusivity, but we could find information only regarding whether a license is granted exclusively or not, so we cannot conduct analyzes similar to theirs. Future studies, however, could analyze restrictions on the exclusivity clause when such data are available.

Fourth, this study did not consider other potential technology transfer channels in investigating decisions regarding exclusivity in university–firm licensing. Specifically, some universities may not regard licensing as the only factor to consider when pursuing the commercialization of an innovation; they may also develop complementary support mechanisms or complete ecosystems for commercializing technology. These support mechanisms may however include exclusive partnerships between these universities and firms. Therefore, we recommend that future studies further investigate this issue within the context of Chinese universities as well as universities from other countries.

Finally, scholars may consider investigating how universities develop and improve their technology transfer capacity by making use of more comprehensive knowledge-exchange mechanisms (both formal and informal) between the academy and industry. For instance, future studies could examine the extent to which joint publications and consulting can cross-fertilize formal technology transfer through licensing and whether there are interactive effects between these various mechanisms during the process of expanding university technology transfer capacity.

CRediT authorship contribution statement

Huijun Shen: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing – review & editing. **Wim Coreynen:** Conceptualization, Methodology, Investigation, Writing – review & editing. **Can Huang:** Conceptualization, Methodology, Investigation, Writing – review & editing, Funding acquisition.

Declaration of Competing Interest

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

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Appendix A. Descriptive statistics for the sample

Table A1 shows the number of licensed patents in each application year in our sample. The licensed patents applied for before 2002 account for only a small share of the total sample because Chinese universities did not apply for many patents before 2002 (see also Fig. 3). The number of licensed patents applied for after 2012 declines because of data truncation. In China, it typically takes two years on average for an invention patent to be granted and university patents are seldom licensed before being granted (however, in the US, university inventions are often licensed before a patent is granted). Since we collected our data in 2017, not many patents for which the application year is close to 2017 (i.e., 2014, 2015 and 2016) had already been granted. There are thus fewer observations for these years.

Table A2 shows the number of patents licensed in each year. After the Science and Technology Progress Law was amended in 2007 to promote technology transfer by universities, the number of licenses doubled between 2008 and 2009. The number however decreased slightly afterwards but rose again in 2016. The rise in 2016 reflects the amendment of the Law on Promoting the Transformation of Scientific and Technological Achievements in October 2015, which removed barriers to

Table A1
Number of patents in each application year.

Application year	Number of patents	Percent
1999	8	0.12
2000	17	0.26
2001	29	0.44
2002	95	1.43
2003	260	3.91
2004	426	6.40
2005	684	10.28
2006	755	11.35
2007	723	10.87
2008	664	9.98
2009	672	10.10
2010	598	8.99
2011	594	8.93
2012	454	6.82
2013	378	5.68
2014	196	2.95
2015	85	1.28
2016	15	0.23
Total	6653	100

Table A2
Number of patents in each license year.

License year	Number of patents	Percent
2008	428	6.43
2009	919	13.81
2010	838	12.60
2011	850	12.78
2012	675	10.15
2013	611	9.18
2014	537	8.07
2015	581	8.73
2016	1038	15.60
2017	176	2.65
Total	6653	100

technology transfer from Chinese universities. The low number of observations for 2017 also reflect data truncation.

Table A3 shows the number of licenses per technological field. This classification recognizes two technology-field levels. The first level covers five main fields—*Electrical engineering, Instruments, Chemistry, Mechanical engineering,* and *Other fields*—and there are 35 s-level fields. We offer two observations. First, the number of licensed patents varies across technological fields. Some fields (e.g., *Electrical machinery, apparatus, energy*) feature hundreds of licensed patents while in others (e.g., *IT methods for management*) only about a dozen licensed patents are issued. Second, there are more exclusive licenses than non-exclusive licenses across all fields, except in *Digital communication* and *Computer technology*. For instance, the share of exclusive licenses is consistently higher in all *Chemistry* fields, which is similar to the case in the US, as reported previously by Anand and Khanna (2000) and Mowery et al. (2001).

Table A4 shows the number of licenses for each prestige level. For licenses involving universities that are accorded the lowest level of prestige (level 1), the share of non-exclusive licenses is larger than that of exclusive licenses, while at the higher prestige levels the share of

Table A3
Number of licenses in each technological field.

Technological field	Non-exclusive license	Exclusive license	Total
I Electrical engineering			
electrical machinery, apparatus, energy	54	374	428
audiovisua technology	6	23	29
Telecommunications	77	104	181
Digital communication	320	102	422
Basic communication processes	11	16	27
Computer technology	112	96	208
IT methods for management	7	4	11
Semiconductors	20	70	90
II Instruments			
Optics	37	66	103
Measurement	123	417	540
Analysis of biological materials	2	19	21
Control	48	86	134
Medical technology	9	67	76
III Chemistry			
Organic fine chemistry	28	271	299
Biotechnology	41	254	295
Pharmaceuticals	2	101	103
Macromolecular chemistry, polymers	20	399	419
Food chemistry	17	137	154
Basic materials chemistry	31	274	305
Materials, metallurgy	53	528	581
Surface technology, coating	12	149	161
Micro-structure and nano-technology	2	8	10
Chemical engineering	27	282	309
Environmental technology	17	268	285
IV Mechanical engineering			
Handling	6	69	75
Machine tools	20	321	341
Engines, pumps, turbines	5	82	87
Textile and paper machines	13	268	281
Other special machines	18	155	173
Thermal processes and apparatus	13	116	129
Mechanical elements	11	101	112
Transport	19	96	115
V Other fields			
Furniture, games	3	7	10
Other consumer goods	2	9	11
Civil engineering	11	117	128
Total	1197	5456	6653

Table A4
Number of licenses for each university prestige level.

Level of prestige	Non-exclusivelicense	Exclusivelicense	Share of non-exclusive licenses	Share of exclusive licenses	Total
1	782	353	69%	31%	1135
2	50	656	7%	93%	706
3	47	960	5%	95%	1007
4	89	1319	6%	94%	1408
5	229	2168	10%	90%	2397
Total	1199	5458	18%	82%	6653

Table A5
Share of exclusive licenses of each university.

University	Prestige	Share of non-exclusive licenses	Share of exclusive licenses
Tsinghua University	117	14%	86%
Peking University	116	14%	86%
Zhejiang University	115	22%	78%
Fudan University	114	0%	100%
Shanghai Jiaotong University	113	3%	97%
Nanjing University	112	4%	96%
Wuhan University	111	10%	90%
National University of Defense Technology	110	0%	100%
Huazhong University of Science and Technology	109	4%	96%
Sun Yat-sen University	108	0%	100%
University of Science and Technology of China	107	0%	100%
Sichuan University	106	0%	100%
Harbin Institute of Technology	105	2%	98%
Jilin University	104	0%	100%
Nankai University	103	0%	100%
Xi'an Jiaotong University	102	7%	93%
Southeast University	101	2%	98%
Shandong University	100	1%	99%
Tongji University	99	15%	85%
Tianjin University	98	8%	92%
Central South University	97	4%	96%
Beihang University	96	33%	67%
Xiamen University	95	12%	88%
South China University of Technology	94	1%	99%
Dalian University of Technology	93	25%	75%
Beijing Institute of Technology	92	40%	60%
Chongqing University	91	0%	100%
East China Normal University	90	0%	100%
Hunan University	89	8%	92%
Northwestern Polytechnical University	88	0%	100%
China Agricultural University	87	2%	98%
University of Electronic Science and technology of China	86	2%	98%
East China University of Science and Technology	85	15%	85%
Northeastern University	84	21%	79%
Soochow University	83	0%	100%
Wuhan University of Technology	82	0%	100%
Nanjing University of Aeronautics and Astronautics	81	16%	84%
North China Electric Power University (Beijing)	80	0%	100%
University of Science and Technology Beijing	79	5%	95%
Nanjing University of Science & Technology	78	10%	90%
Nanjing Agricultural University	77	27%	73%
Southwestern University	76	0%	100%
Xidian University	75	0%	100%
Shanghai University	74	0%	100%
Huazhong Agricultural University	73	7%	93%
Information Engineering University	72	0%	100%
China University of Petroleum, Beijing	71	0%	100%
Beijing University of Chemical Technology	70	7%	93%
Southwest Jiaotong University	69	0%	100%
Nanjing Normal University	68	0%	100%
Ocean University of China	67	0%	100%
Jinan University	66	6%	94%
Harbin Engineering University	65	13%	87%
Jiangnan University	64	5%	95%
Tianjin Medical University	63	0%	100%
Northwest University	62	0%	100%
	61	0%	100%

Table A5 (*continued*)

University	Prestige	Share of non-exclusive licenses	Share of exclusive licenses
China University of Mining and Technology			
Hohai University	60	0%	100%
Beijing University of Posts and Telecommunications	59	0%	100%
Donghua University	58	1%	99%
China University of Geosciences (Beijing)	57	0%	100%
Third Military Medical University	56	0%	100%
Northwest A&F University	55	0%	100%
Jiangsu University	54	5%	95%
The Second Military Medical University	53	0%	100%
Fuzhou University	52	14%	86%
Hefei University of Technology	51	0%	100%
Air Force Medical University	50	0%	100%
North China Electric Power University	49	7%	93%
China University of Geosciences (Wuhan)	48	4%	96%
South China Normal University	47	0%	100%
Capital Medical university	46	0%	100%
Chang'an University	45	0%	100%
Nanchang University	44	0%	100%
Henan University	43	0%	100%
Shaanxi Normal University	42	0%	100%
China Pharmaceutical University	41	8%	92%
Nanjing Medical University	40	25%	75%
Zhejiang University of Technology	39	11%	89%
Southern Medical University	38	0%	100%
Yangzhou university	37	3%	97%
Beijing University of Technology	36	7%	93%
Nanjing Tech University	35	13%	87%
Dalian Maritime University	34	0%	100%
PLA University of Science and Technology	33	33%	67%
South China Agricultural University	32	0%	100%
Shenzhen University	31	0%	100%
Zhejiang Normal University	30	0%	100%
Yanshan University	29	2%	98%
Beijing University of Chinese Medicine	28	0%	100%
Hebei University of Technology	27	0%	100%
Beijing Forestry University	26	0%	100%
Communication University of China	25	0%	100%
Shantou University	24	0%	100%
Ningbo University	23	48%	52%
Hangzhou Normal University	22	20%	80%
Zhejiang Sci-Tech University	21	20%	80%
China University of Petroleum (East China)	20	0%	100%
Shenyang Pharmaceutical University	19	0%	100%
Nanjing University of Posts and Telecommunications	18	96%	4%
Guangxi University	17	0%	100%
Kunming University of Science and Technology	16	0%	100%
Hubei University	15	0%	100%
Shanxi University	14	0%	100%
Nanjing University of Information Science & Technology	13	0%	100%
Anhui University	12	0%	100%
Qingdao University	11	0%	100%
Hangzhou Dianzi University	10	48%	52%
Heilongjiang University	9	0%	100%
Northeast Forestry University	8	14%	86%
Zhejiang Gongshang University	7	8%	92%
Shanghai Normal University	6	13%	87%

(*continued on next page*)

Table A5 (*continued*)

University	Prestige	Share of non-exclusive licenses	Share of exclusive licenses
Shanghai University of Technology	5	0%	100%
Hebei University	4	25%	75%
Tianjin Normal University	3	0%	100%
Xinjiang University	2	0%	100%
Huaqiao University	1	0%	100%
Total		18%	82%

exclusive licenses is larger. Moreover, the share of exclusive licenses is the largest at the third (i.e., medium) level of university prestige.

Table A5 shows the share of exclusive licenses of the total number of licenses issued by each university in our sample. The share of exclusive licenses varies across universities. These differences result from varying licensing practices, for example with respect to the sectors to which universities transfer technology (e.g., engineering, chemistry).

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