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Dynamic capabilities, subnational environment, and university technology transfer

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Changhong Yuan and Yang Li
Xi'an Jiaotong University, China

Cristina O. Vlas and Mike W. Peng
University of Texas at Dallas, USA

Abstract

University technology transfer allows universities to extract benefits from their research. We examine how universities can create and capture value from their technology creation and technology commercialization efforts by embracing a dynamic capabilities perspective. Our longitudinal analysis involves 829 universities and 3908 university-year observations in 30 subnational regions (provinces) in China during a 6-year period. Our findings reveal (1) that universities create more ideas and capture more licensing value through dynamic management and active orchestration of assets, (2) that a developed factor market accelerates value creation and commercialization, and (3) that a developed institutional environment at the subnational level stimulates value creation but inhibits value capture. These interesting findings justify a dynamic capabilities perspective of the university technology transfer process while opening avenues for future research.

Keywords

dynamic capabilities, factor market environment, institutional environment, subnational level, university technology transfer

Introduction

As an important method to link universities and industries, university technology transfer (UTT) is the process of transferring, converting, and commercializing basic research conducted in universities as new technologies (Siegel et al., 2007). While universities are first and foremost academic organizations, a considerable body of research recognizes that universities are also enterprises undertaking significant commercially oriented activities such as UTT (Ambos et al., 2008; Bozeman et al., 2015; Lockett et al., 2005; Mindruta, 2013; O'Kane et al., 2015; Siegel and Phan,

Corresponding author:
Yang Li, School of Management, Xi'an Jiaotong University, 28 Xianning Road West, Xi'an, Shaanxi 710049, China.
Email: liyanghero@gmail.com

2005; Siegel and Wright, 2015). Why do some universities enjoy better UTT performance than other universities?

Universities obviously do not operate in a vacuum. Embedded in national and subnational (as well as global) environments, universities integrate resources and coordinate strategies to deal with challenges posed by environments and take advantage of opportunities provided by environments (Bozeman et al., 2015; Chai and Shih, 2016; Leih and Teece, 2016). The UTT process represents a set of activities that use universities' resources first to generate value-added products and services, second to commercialize them, and third to reconfigure them to adapt to environmental shifts. Our conceptualization of UTT activities draws on Leih and Teece's (2016) definition of dynamic capabilities as "an organization's (or institution's) abilities to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments" (p. 187). Initially, universities' research and development (R&D) activities use financial and human resources to *sense* opportunities and create technologies. Once technologies are created, universities' technology transfer offices (TTOs) engage in activities designed to *seize* value from these efforts. To maximize the value captured from technology creation and commercialization activities, universities must continuously align their capabilities to the constraints and/or opportunities offered by the external environments (Leih and Teece, 2016; Maietta, 2015; Siegel et al., 2004, 2007). These efforts require universities to *reconfigure* capabilities according to the pressures imposed by factor markets and institutions if they endeavor to enhance the effectiveness of UTT (Bozeman et al., 2015).

Although originated in the strategic management literature focusing on for-profit organizations (Teece, 2007; Teece et al., 1997), we argue that a dynamic capabilities perspective can be extended to conceptualize the UTT process. Dynamic capabilities not only enable universities to "orchestrate" their activities to generate superior benefits but also help them maintain their leadership in innovation-based competitive environments (Leih and Teece, 2016). The UTT literature has focused on isolated determinants of UTT performance, in both internal environments and external environments (Grimm and Jaenicke, 2012; Huggins and Kitagawa, 2012; Sternberg, 2014). But it has not paid attention to the relationships among different components of UTT activities or to the reinforcing nature of UTT-related capabilities developed by universities.

To the best of our knowledge, no previous UTT research has used a dynamic capabilities approach. Inspired by Leih and Teece's (2016) recent work on extending this perspective to the overall strategic management of universities, we leverage a dynamic capabilities perspective in the context of UTT. Specifically, we address two questions: (1) How do universities dynamically deploy their R&D capabilities for a more effective UTT process? (2) How do they adapt to the changing institutional environment to increase the effectiveness of their UTT process?

Extending Leih and Teece (2016), we argue that through integrating, building, and reconfiguring resources and strategies, universities—similar to commercial enterprises—may develop strong dynamic capabilities that allow them to adjust as environments change. Thus, for the first question, we focus on universities' abilities to integrate and build resources and strategies that make the UTT process more effective. To address the second question, we focus on universities' abilities to reconfigure resources according to the within-country (or subnational) environment variation. In large and complex emerging economies, significant subnational environmental differences may constrain or facilitate local UTT processes (Asheim and Coenen, 2005; Cooke, 2001; Cooke et al., 1997). As research with a focus on large and complex emerging economies (particularly Brazil, Russia, India, and China (BRIC)) continues to flourish (Meyer and Peng, 2016), a focus on their subnational environment may enable us to probe deeper into the mechanisms underpinning UTT.

Overall, two important motivations fuel this research. First, theoretically, few studies integrate the dynamic capabilities perspective with the subnational environment when analyzing UTT. Liu and Jiang (2001) argue that "new theories and policy frameworks [of UTT] may need to be developed and tested" (p. 186). We agree and argue that focusing on an integration of dynamic capabilities and subnational perspectives may be a particularly insightful way to advance UTT research. Second, empirically, research has explored the effects of external environment on UTT in developed economies (Maietta, 2015; Mowery and Ziedonis, 2015; Sternberg, 2014; Walsh and Huang, 2014). But in emerging economies, very little is known about how UTT works, especially at a subnational level. With a large number of subnational regions (provinces), China features significant subnational differences, thus enabling us to investigate how UTT differs in different regions.

Universities as entrepreneurial organizations

In today's knowledge-driven economy, universities—beyond serving their two classical missions, research and education—have increasingly important contributions to society's economic development, which is known as a "third mission" (Kwiek, 2016; Laredo, 2007). Universities recognize value in this third mission in that they can not only create wealth for societies, but also generate more funding for their first two missions (Cai et al., 2015; Chai and Shih, 2016; Guerrero et al., 2015). As organizational actors focused on attaining research, education, and economic goals, universities are regarded as "triple helix" organizations with important contributions to economic activities worldwide (Cai, 2014; Etzkowitz and Leydersdorff, 2000; Liu and Jiang, 2001).

As part of an innovation system, universities add value to the university–industry–government triple helix by generating tangible, fiduciary returns from their research (Chai and Shih, 2016; Hong, 2008; Jongbloed, 2015; Rothaermel et al., 2007). Nowadays, universities earn a significant part of their revenues from collaborating with industries. Universities are heterogeneous in their expectations, performance, and preferences (Guerrero et al., 2015; Jongbloed and Zomer, 2012). Similar to for-profit organizations, universities must balance their resources with their objectives, thus justifying a dynamic capabilities approach (Leih and Teece, 2016).

Governmental policies, increasing global competition, and increasing pressures for innovation have pushed universities to become economic players simultaneously "mission-centered and market-smart" (Massy, 2009). As a result, universities are not only economic players that have to achieve internal efficiency but are also social players that are part of networks of collaboration with the public and private spheres (Hong, 2008). In sum, universities have to become *entrepreneurial* organizations aimed at doing the right things, instead of simply doing things right (Guerrero et al., 2015). This attitude enables them to remain dynamic by building, commercializing, and reconfiguring valuable resources as needed to respond to changes in the market (Leih and Teece, 2016).

While UTT goes beyond patenting, our focus is on patenting. This chosen focus helps us deploy the dynamic capabilities vocabulary (Leih and Teece, 2016). Specifically, patenting is basically the by-product of universities' abilities to "sense" opportunities for recognition, licensing is the result of their abilities to "seize" opportunities through commercialization, and adapting to subnational environments represents universities' capabilities to dynamically align ("reconfigure") internal procedures with their ecosystem. Next, we turn to a dynamic capabilities view of the UTT process.

A dynamic capabilities perspective on UTT

Universities are part of an innovation system that continuously change and hence need to remain flexible in order to address the fluid, increasingly blurred boundaries between public and private realms (Chai and Shih, 2016; Goduscheit and Knudsen, 2015). We argue that the UTT process consists of a bundle of dynamic capabilities and that its performance is a function of the university's abilities to orchestrate these capabilities.[1] Dynamic capabilities are reflected in an entity's abilities to (1) sense opportunities, (2) seize opportunities, and (3) reconfigure assets and business models to address the challenges of changing environments (Augier and Teece, 2009; Teece, 2007). In UTT, universities that develop and strengthen unique and difficult-to-imitate dynamic capabilities are more likely to be more effective than those that do not possess such capabilities (Ambos et al., 2008; Leih and Teece, 2016).

Sensing refers to universities' abilities to discover opportunities (Gratton and Ghoshal, 2005). Sensing capabilities are not uniformly distributed among universities (Leih and Teece, 2016; Teece, 2014b). Enhanced R&D, financial, and human investments stimulate and complement "[university's] scanning, creation, learning, and interpretive ability" (Teece, 2007: 1322), but the end result also depends on the university's abilities to employ the appropriate strategy to coordinate them (Teece, 2014b).

Seizing refers to the exploitation of universities' knowledge and technologies through commercialization. Exploiting the patent stock is more efficiently done in concert with the right business models (Teece, 2010a) and abundant complementary innovations (Teece, 2007). The effectiveness of commercialization depends on the synchronization of business models with the environment. This is a learning process through which universities learn about customers' needs and build internal capabilities needed to satisfy those needs. From a customer's (licensee's) point of view, an innovation that is licensed is a "system" that reflects the seller's (licensor's) capabilities to integrate and coordinate a number of interrelated inventions. The request to license an innovation, which is usually expressed before a patent is granted, is based on a licensee's appreciation of the innovation's potential and a licensor's existing pool of complementary knowledge. Licensees can correctly appreciate the quality of a patent when the patenting activity reveals more information. More patented innovations reflect sounder business models, stronger abilities to learn, and higher potential for commercialization (Belderbos et al., 2016). Compared with universities with a small pool of patents, universities with a large pool of patents are more likely to license more, have more flexible business models, and be more effective at seizing their innovations' potential (Teece, 2010a).

Reconfiguring refers to universities' abilities to remain flexible by redesigning business models, realigning assets, and revamping routines (Teece, 2007, 2010a). Reconfiguration enables universities to capture increased value from their innovations by shaping their strategy in ways that support external ecosystems (Pitelis and Teece, 2015; Teece, 2014a). Reconfiguration improves the external fitness of universities in part by aligning with the environment and in part by shaping it (Helfat et al., 2009). Universities' abilities to reconfigure themselves are grounded in proper governance and appropriate asset combinations (Leih and Teece, 2016; Teece, 2012a). While individual managers at TTOs play a significant role, the larger environments are also crucial (Teece, 2010a). More developed factor markets and institutional environments may facilitate effective UTT because they minimize the factor constraints and information asymmetries (Peng, 2003). Reconfiguration is an essential ingredient for adaptation and change. Therefore, it is critical for organizations such as universities facing changing rules of the game during institutional transitions (Li et al., 2013; Peng et al., 2009). In sum, universities must continuously align their assets to play in tandem with the relevant players (Siegel et al., 2004, 2007) and the collaboration between universities and industry can be more effective when supported by developed institutions and strong factor markets.

Next, we formulate hypotheses drawing on the dynamic capabilities perspective on UTT along three key dimensions—sensing, seizing, and reconfiguration. For composition simplicity, we divide the UTT process in two stages: (1) technology creation and (2) technology commercialization.

Sensing opportunities in the technology creation stage

In the first stage of UTT—technology creation—universities use their financial and human resources to create knowledge. The process starts with academic scientists who endeavor to rapidly disseminate their ideas to achieve peer recognition or pecuniary rewards that can be reinvested in their research to pay for equipment or students (Siegel et al., 2007). This process involves "search[ing], scan[ning], and explor[ing]" (Teece, 2007: 1322) for opportunities that can later be harnessed. For various reasons, some researchers are reluctant to disclose their inventions to TTOs (Siegel et al., 2004). Therefore, TTOs encourage researchers to disclose inventions by having royalty regimes in place or by informing researchers of industry demand. Hence, searching, scanning, and exploring involve both investing in R&D and probing customer demand. The end result is the intellectual property (IP) rights over that specific technology (often a patent). Because patenting is costly (Baum and Silverman, 2004), probing customer demand is important. In most cases, having an industry partner interested in that technology constitutes sufficient ground for patenting the invention (Belderbos et al., 2016). If no customers are interested, universities may decide not to patent the technology.

The amount of resources that universities invest in R&D may be positively related to universities' technology creation as reflected in the number of patent applications (Anderson et al., 2007; Heisey and Adelman, 2011; Zhang et al., 2013). Despite these arguments that suggest a positive relationship between R&D investment and technology creation, research also points out that too much R&D spending may hurt innovation (an inverted U-shaped relationship; Arvanitis, 1997; Bonaccorsi et al., 2006; Fukugawa, 2013; Schmoch and Schubert, 2009). Therefore, R&D investment may be a double-edged sword in technology creation.

We argue that a dynamic capabilities framework may provide an insightful explanation for the nonlinear effect of R&D investment on universities' technological creation. Given the benefits of R&D investment, increasing R&D investment can improve the freedom of researchers in technological creation. In the process of transforming R&D investment into technology creation, universities use their sensing capabilities to identify patentable technologies. The abilities to sense such opportunities depend both on the abilities of researchers and TTO managers and on the effectiveness of coordination of R&D activities orchestrated by TTOs (O'Kane et al., 2015). Allowing researchers to retain royalties from their patented inventions often stimulates them to search for ideas that can be patented but cannot control which ideas will be patented. Therefore, a high level of monetary and human resources allows for higher freedom in scanning, searching, and exploring.

However, considering the disadvantage of R&D investment in technology creation, having more than enough human and financial resources available for R&D projects may result in an overabundance of ideas, may waste resources on mediocre inventions, or may delay the decision to patent one invention over another. Also, having too many researchers scanning the market for ideas may also impede the innovation process by creating communication and coordination difficulties. This is where TTOs, especially those equipped with strong sensing capabilities, can play a crucial role in strategizing and orchestrating search (O'Kane et al., 2015). TTOs with strong sensing capabilities can avoid wasting resources to work on low-quality and/or low-potential patents.

Additionally, the disadvantage of R&D investment may reflect the existence of resource and capability constraints (Huergo, 2006). Since R&D resources are path dependent, technology creation is stuck with universities' resource endowment, at least in the short run (Teece, 1986). Therefore, universities' technology creation critically depends on the balance between R&D resources and capabilities to respond to the needs of patenting. Overall, we suggest that having more R&D resources is good but only up to a point. In summary, *Hypothesis 1*. There is an inverted U-shaped relationship between university R&D investment and university technology creation.

Seizing opportunities in the technology commercialization stage

In the second stage of UTT, commercializing technology creation reflects universities' abilities to *seize* opportunities (Teece, 2010b). Seizing requires universities to capture value by leveraging asset combinations and building new competencies. We use this mechanism to explain how universities use dynamic capabilities first to capture value and second to create new value from patents.

Once a patent is awarded, the technology can be transferred through licensing. The performance of this process, usually measured by the number of license agreements or amount of licensing revenues, reflects how well the university seizes the opportunities it identifies. In general, in the technology commercialization stage, the patent stock of a university directly affects the number of license agreements (Heisey and Adelman, 2011; Ho et al., 2014). We argue that behind the successful licensing of patented inventions rests universities' capabilities to incorporate asset combinations. Assets are idiosyncratic in nature and depend on the organizational context (Teece, 2010b). Universities' pool of patents, pool of researchers, and the relationships between researchers and TTO managers are examples of such assets. The combination of these assets is what gives universities a unique, non-tradable advantage. We suggest that universities' capacity to attract interested industry partners to license patents reflects universities' unique asset combinations.

Interested industry partners are attracted by the entire "system" of capabilities that the technology represents (Teece, 2007, 2010b). A patented technology is a family of related innovations. The wider the family of patents, the higher the technology's potential. Patented technologies reflect the existence of inimitable, non-tradable combinations of assets and have an important role in increasing the visibility of a university's technological potential. Interested parties can obtain more information by analyzing the patents a university is applying for and by analyzing how these patents fit or complement other existing patents in the university's patent portfolio. In general, TTOs are reluctant to license inventions that they believe are undervalued as those may not be sold and may damage the university's reputation. The larger the pool of patents generated by specific asset combinations, the higher the likelihood that those combinations would create high-quality competencies. A large patent portfolio not only offers information to potential licensees about the university's innovation potential but also suggests a high-quality, stable, and reliable "system" of dynamic capabilities in R&D. In short, a high level of technology creation, which results in a large patent portfolio, may enable universities to better seize opportunities and enhance UTT's performance. Therefore,

Hypothesis 2. A high level of technology creation by a university has a positive effect on the performance of UTT.

Reconfiguring capabilities to fit the subnational environment

At both the national and subnational levels, the environment in an emerging economy can be conceptualized along two dimensions: (1) factor markets and (2) institutions (Hoskisson et al., 2013). The challenges that organizations must face during institutional transitions are significant (Cai et al., 2015; Li et al., 2013; Meyer and Peng, 2016; Peng, 2003). The dynamic capabilities view takes these issues one step further and explains how organizations deal with challenges to sustain their competitive advantage (Teece, 2010a, 2012a). Universities are an active part of the innovation system and face pressures both from country-level institutions and markets (Walsh and Huang,

2014) and from within-country institutions and markets (Asheim and Coenen, 2005; Casper, 2013; Cooke, 2001; Cooke et al., 1997; Fini et al., 2011; Jung and Lee, 2014; Leih and Teece, 2016). Overall, the effectiveness of UTT depends on environmental and institutional factors as well as internal and organizational factors (Goldfarb and Henrekson, 2003; Grimm and Jaenicke, 2012; Gulbrandsen and Rasmussen, 2012; Haeussler and Colyvas, 2011; Siegel et al., 2003).

In the context of UTT, reconfiguration refers to universities' dynamic capabilities to revamp themselves in order to achieve a better fit with the factor market and institutional environments (Leih and Teece, 2016).[2] As formulated by Teece (2016), reconfiguration involves periodical reconsideration of how well internal processes and structures fit with the requirements of the environment. This fit is more easily achieved when factor constraints and information asymmetries imposed by the external context are smaller. When more constraints are in place, less reconfiguration is likely. As institutional transitions allow for more autonomy, access to broader factor markets, and lower informational asymmetries (Meyer and Peng, 2016; Peng, 2003), universities can transform themselves more easily and can achieve better technological and environmental fitness (Teece, 2016).

For large economies, institutional development facilitates changes differently across subnational regions (Liu et al., 2014; Shi et al., 2012, Sun et al., 2015), such that development takes place faster for regions that are more ready to embrace these transitions and slower for regions that are not ready for these transitions (Cai et al., 2015). Since subnational regional environments may be very dissimilar despite being part of the same national environment (Mowery and Ziedonis, 2015), regional innovation systems within the same country may differ significantly (Asheim and Coenen, 2005; Cooke et al., 1997; Li, 2009). Therefore, significant heterogeneity among universities in different regions is likely to appear (Cooke, 2001; Etzkowitz and Leydesdorff, 1999).

The differences in development along both factor markets and institutions highlight how much reconfiguration needs to be implemented by universities (Hoskisson et al., 2013). Factor markets refer to markets where services of the factors of production are bought and sold. The factor market environment includes financial market, labor market, and market for technology. The factor market environment determines a country's economic opportunity set (Porter, 1990; Wright, 1990). It has been identified as having important effects on UTT (Bozeman, 2000; Bozeman et al., 2015; Etzkowitz and Leydesdorff, 2000) and on universities' need for adaptation and reconfiguration (Landry et al., 2007). The institutional environment "defines property rights, enforces contracts, and creates the rule of law necessary for market" (North et al., 2009: 110).

Overall, factor markets and institutional development shape the opportunities and challenges not only for the whole country, but also for each subnational region.[3] Regions with developed factor markets (such as developed infrastructure and well-trained human resources) and strong institutional development (such as favorable policies and legal systems) may facilitate UTT by allowing for more diversity in opportunities and more options to capture value from these opportunities (Cooke, 2001; Mowery and Ziedonis, 2015). These rapidly evolving contexts necessitate quick adaptation and reconfiguration capabilities because they stimulate better value creation and better value capture (Teece, 2016).

Factor market development, reconfiguring capabilities, and technology creation

In changing environments, reconfiguring is not only necessary, but also critical (Leih and Teece, 2016). Absent expert talent or generous financial endowments, universities can create only inventions limited in scope or design (Feng et al., 2012; Muscio et al., 2013). Expert talent and funding are critical to support technology creation in universities (Hess and Rothaermel, 2011) and only a developed factor market environment can provide both. A well-endowed financial market, for example, provides universities with more opportunities for funding that supports their reconfiguration capabilities, further facilitating the effectiveness of UTT (Fini et al., 2011; Muscio et al., 2013). An open labor market as opposed to a closed one also provides the necessary supply of star scientists for technology discovery (Feng et al., 2012; Hess and Rothaermel, 2011; Teece, 2012b).

In emerging economies such as China, subnational differences in factor market development and institutions are significant (Chan et al., 2010; Shi et al., 2012, 2014; Sun et al., 2015). Universities tend to attract expert talent mostly from the provinces where they are located (Cai et al., 2015).[4] Moreover, as technology markets develop, more opportunities are available locally, making it easier to find innovation opportunities (Landry et al., 2007; Sedaitis, 2000).

In sum, different degrees of regional factor market development influence the link between R&D and technology creation efforts at local universities. In regions with more developed factor markets, universities not only benefit from easier access to advanced financial, human, and technological resources, but also have more appropriate and capable means to reconfigure their internal processes and structures so that they can keep up with innovation challenges. Therefore,

> *Hypothesis 3a*. The higher the level of subnational factor market development, the higher the effect of university R&D on university technology creation.

Factor market development, reconfiguring capabilities, and technology commercialization

A higher level of factor market development lowers information asymmetries, allowing universities to commercialize more inventions and also stimulating them to capture more value from commercialization. More developed factor markets for human capital provide better prepared personnel to work within the TTO who can be better prepared to understand the needs of industries and customers and be more capable of negotiating and drafting better licensing contracts (Zucker and Darby, 2007). More developed factor markets for financial and technological capital also add flexibilities in capturing the "spillovers" (Friedman and Silberman, 2003). These spillovers include better access to lawyers, venture capitalists, consultants, entrepreneurs, and external scientists. In this sense, a developed factor market encourages universities to transform themselves to better collaborate with industries (Casper, 2013). Conversely, a less-developed factor market environment does not seem conductive to improve the effectiveness of UTT. Therefore,

> *Hypothesis 3b*. The higher the level of subnational factor market development, the higher the effect that commercializing university technology creation has on UTT performance.

Institutional development, reconfiguring capabilities, and technology creation

The context of emerging economies presents a fruitful ground for studying how dynamic capabilities affect organizational performance (Meyer and Peng, 2016). Emerging economies pass through a set of institutional transitions that create opportunities as well as uncertainties and risks (Peng, 2003). Organizations such as universities have to reconfigure their assets and structures and adapt their strategies and processes to fit the changing institutional environment (Cai et al., 2015; Markman et al., 2005; Phan and Siegel, 2006). A high level of institutional development implies better developed legal systems and monitoring mechanisms (Peng, 2003; Shi et al., 2012).

In emerging economies such as China, universities in different subnational regions face different levels of institutional development (Shi et al., 2012, 2014; Sun et al., 2015). In regions with more mature institutions, the establishment of concrete regulations and clear policies gives universities clarity about the right things to do. In such regions, universities' focus becomes "doing the right things" (Teece, 2014a) and reconfiguration allows universities to achieve higher conformance and recognition. A more developed institutional environment introduces IP protection at the regional level, reducing the risk of disclosing inventions and increasing inventors' and universities' enthusiasm to conduct research (Grimaldi et al., 2011; Markman et al., 2005).

Developed institutional environments stimulate reconfiguration that further helps opportunity discovery by establishing rules and mechanisms against expropriation. Autonomous discovery is pervasive when rules of the game are present and appropriability hazards are mitigated when property rights can be established in a cost-effective way (Teece, 2016). Underdeveloped regions may pose difficulties to reconfiguration by impeding coordination of complementary technologies and allowing expropriation and divergent rules of the game among parties (Thursby et al., 2001). Thus,

Hypothesis 4a. The higher the level of subnational institutional development, the higher the effect of university R&D on university technology creation.

Institutional development, reconfiguring capabilities, and technology commercialization

Institutional environments at both national and subnational levels have an important role on the performance of UTT's commercialization stage by formalizing processes and allowing the organization to reconfigure itself to mitigate the risk of opportunistic behavior (Goldfarb and Henrekson, 2003; Grimm and Jaenicke, 2012). In response to subnational institutional pressures, universities adopt appropriate commercialization practices in order to enhance legitimacy (Friedman and Silberman, 2003). Developed institutional settings contribute to productive reconfiguration that helps universities capture increased value through better enforcement mechanisms, formalization of licensing processes, and mitigation of opportunistic behavior in commercialization (Phan and Siegel, 2006; Pries and Guild, 2011). In sum, well-established public policies and strong IP protection at the subnational regional level may help ensure that researchers and TTOs can safely commercialize technologies. The upshot is likely to be better UTT performance. In summary,

Hypothesis 4b. The higher the level of subnational institutional development, the higher the effect that commercializing university technology creation has on UTT performance.

Methods

Research context

Our choice to focus on how dynamic capabilities help shape UTT in China is theoretically and practically justified for three reasons. First, China has recently undergone a series of institutional transitions that stimulated a number of transformations of its universities (Cai et al., 2015). Since the 1980s, the central government initiated reforms, emphasizing that research should meet the needs of economic development and that every university should develop market-oriented R&D projects. Since then, universities are allowed to retain the funds generated from successful technology transfer, thus incentivizing them to engage in successful UTT (Cai et al., 2015; Liu and Jiang, 2001).

Second, the institutional environments have also experienced significant regulatory transitions (Peng, 2003). Improvements in factor markets and institutions at the subnational regional level have created a rapidly moving and turbulent environment, pushing universities to develop dynamic capabilities in UTT (Hoskisson et al., 2013; Li et al., 2013).

Third, the diversity that exists in large economies such as China encouraged the decentralization of universities' internal processes, stimulating the role that dynamic capabilities have in the creation and capture of value within universities (Hong, 2008).

Data and sample

Our sample was drawn from the universities listed on the Science and Technology Statistical Data of Higher Education Institutions from 2005 to 2011 (inclusive). We first identified 829 universities and 5569 university-year observations. Technology transfer contract and R&D investment data were extracted from the same source. Patent information was collected from China's State Intellectual Property Office. Information regarding subnational-level (provincial) environment (factor market environment and institutional environment) was provided by the National Economic Research Institution (NERI) Index (2006–2009). We obtained control variables from various editions of the China Statistical Yearbook (2005–2011), Science and Technology Statistical Data of Higher Education Institutions (2005–2011), and university websites. Due to data limitations, our final sample contains 829 universities and 3908 university-year observations.

Variables

Dependent variable. In the technology creation stage, our dependent variable is the number of patent applications by universities (in thousands). We focus on the number of patent applications instead of patents granted for two reasons. First, there is a substantial lag between patent application and granting, making it difficult to track the effects of R&D investments on universities' patenting activity. Second, patent applications better reflect universities' interest in commercialization, offering more information on the purpose of R&D investments. In the technology commercialization stage, our dependent variable is the number of license contracts. This variable has been traditionally used to capture the performance of UTT (Thursby and Thursby, 2002).

Independent variables. In the technology creation stage, our independent variable is investment in R&D projects, including management and services (Zhong et al., 2011). Greater R&D investment, on average, is associated with the employment of a larger number of researchers (Feinberg and Gupta, 2004). Thus, we use the number of full-time R&D personnel for every 100 employees as a proxy of R&D investment. In the technology commercialization stage, our independent variable is the number of patent applications.

Moderating variables. Our moderating variables are regional factor market development and regional institutional development. Our measures are derived from the subnational regional-level (provincial) index of marketization developed by the NERI (Fan et al., 2011) and have been extensively used in earlier research (Chan et al., 2010; Shi et al., 2012; Sun et al., 2015).

Based on subnational-level data, the NERI index for the factor market environment captures four aspects: (1) the degree of marketization of financial markets using both the ratio of deposits of non-state financial institutions to all financial institutions and the proportion of non-state loans of financial institutions, (2) the degree of foreign investment using the ratio of foreign investment to province gross domestic product (GDP), (3) the degree of labor market development using the proportion of new rural labor in all new labor in cities and towns, and (4) the degree of development of science and technology (S&T) market using the number of local technology market turnover adjusted by the number of local technical personnel. By adopting Fan et al.'s (2011) NERI index of factor market environment, we computed a measure for the degree of development of the factor market environment, which is produced using the proportion of the above four aspects to capture the factor market environment at the subnational level. A higher value indicates a more developed and mature factor market in the region.

For the institutional environment, the NERI index captures (1) the development of market intermediaries using both the ratio of the number of lawyers and registered accountants to population and the degree of help provided by industry association, (2) the protection of the legal rights and interests of producers using managers' rating on local legal right protection in a countrywide survey conducted by NERI, (3) IP rights enforcement using the total number of patents applied and approved adjusted by the number of engineers, and (4) consumer rights protection using the reversed frequency of consumer complaints received by the Consumer Association of China (adjusted by province GDP). We adopted Fan et al.'s (2011) NERI index of institutional environment, which is a factor score of the above four spheres to capture the legal and institutional environment at subnational level. A higher value indicates the more developed legal and institutional environment in a subnational region.

Control variables. We control for five variables at the university level. First, universities' technology orientation is expected to influence UTT efficiency. We code this variable 1 if the university is a polytechnic and 0 if it is not. Second, since over 60% of university licenses result from biomedical inventions (Pressman et al., 1995), we take into account whether the presence of medical schools significantly drives the evolution of universities' capabilities and, therefore, performance. Specifically, we include a medical school dummy variable. Third, using a dummy variable of 1, we consider a "211 Project" control for those top 103 universities whose dynamic capabilities could be favored by special financial support from the government (Wu and Robinson, 2015). Fourth, university type (comprehensive versus specialist) is also important in UTT (Grimm and Jaenicke, 2014). Compared to universities that specialize in narrow knowledge domains, universities with more comprehensive curricula may have already developed dynamic capabilities to support the creation and capture of value from UTT. In order to isolate the relationships of interest, we create a university type dummy variable that takes the value of 1 if the university is comprehensive and the value 0 if it is specialized. Finally, collaboration experience may affect how open or attractive universities are for industrial partners, underscoring the role that developing dynamic capabilities has in the UTT process (Edler et al., 2011). Universities more experienced in collaborating with industries are likely to be more effective in UTT. We use the proportion of industrial funding in the total external funding that universities receive as a proxy for collaboration experience.

In addition, we include three control variables at the subnational (regional) level. On the demand side, we consider local industrial potential—measured by local industrial capacity with the log of gross industrial product (GIP). To minimize the role that local absorptive capacity may play in creating and commercializing value, we include the log of total regional transaction value in the technical market. This variable also accounts for local industrial scale and size of regions. On the supply side, we control for local innovation capability using regional S&T density (regional S&T expenditures or regional total revenue).

Analytical strategy

Since the dependent variables are count variables (the number of university patents and the number of technology transfer contracts) ranging from zero to a certain positive number, we may use Poisson regression. However, because the variances of our dependent variables exceed their mean, Poisson regression may thus result in over dispersion and may bias the estimated standard errors downward. The general linear mixed model (LMM) is more appropriate and allows unbiased and generalizable estimates. The recommended sample size for a cross-level model with two levels is not less than 30 groups (level 2) and 20 observations (level 1) per group (Hox, 2010). Following this recommendation, we adjust our sample to 24 universities or more (level 1) for each of the 30 subnational regions (level 2). Accordingly, the final sample size is adjusted to 3908 university-year observations.

Our dynamic capabilities conceptualization of the UTT process raises two important aspects that we have to take into consideration. First, the UTT process seems to be a two-stage process (Ho et al., 2014) with a time lag between stages (Friedman and Silberman, 2003). In the first stage, universities engage in R&D and patent their ideas. In the second stage, universities commercialize patents via licensing. To model this two-stage process, in the technology creation stage, we use the number of patent applications as a dependent variable and lag all independent and control variables by 1 year compared to the dependent variable. Therefore, in the first stage, our sample size is reduced from 3908 to 3868 university-year observations. In the second stage, we use the number of technology transfer contracts as a dependent variable and lag the independent and control variables by 1 year (except R&D investments). Given this time-lag effect, the R&D investment in the technology creation stage may also affect the performance of technology transfer in the commercialization stage. Thus, in the second stage regression, we lag R&D investments by 2 years compared to the number of licensing contracts variable. As a result, our sample size is reduced from 3908 to 3028 university-year observations.

The second aspect that must be accounted for is correctly identifying the environmental level. Inter-regional (regional) and intra-regional (university) environmental effects must be clearly distinguished. If universities are nested within the same region, the factor market and institutional environment of these universities may share similarities. Sharing the same subnational context may cause dependency among observations (Sun et al., 2015). Regional-level and university-level effects are distinct but not necessarily independent, and error terms may be correlated across universities within the same region (province). To mitigate these cross-level effects and address potential correlation among observations, we use a hierarchical LMM with mixed effects (Banalieva et al., 2015; Ghosh et al., 2014; McCulloch et al., 2011). Additionally, although our theoretical framework is a two-stage model, we do not estimate our model with a two-step approach. Because technology creation is implemented at least 1 year earlier than technology commercialization, there is an obvious difference in the external environment between the technology creation and commercialization stage. Thus, the two-stage models are estimated separately.

Findings

Tables 1 and 2 present descriptive statistics. Ranging from 1.12 to 3.59, all variance inflation factors (VIFs) are below the recommended level of 10, suggesting that multicollinearity is not significant.

Table 3 reports mixed regression models in the technology creation stage. Model 1 is the base model. We enter the linear effect of R&D investments in model 2 and enter the squared term of R&D investment in model 3. Hypothesis 1 predicts an inverted U-shaped relationship between university R&D investment and university technology creation. The coefficients for R&D investment ($\beta = 0.17$, $p < 0.00$) and R&D investment squared ($\beta = -0.01$, $p < 0.00$) in model 3 support Hypothesis 1.

Hypothesis 3a states that the development of subnational factor market environment in which the university is embedded positively moderates the inverted U-shaped relationship noted in

Table 1. Descriptive statistics.[a]

Variable	Mean	SD	Minimum	Maximum
1. University technology transfer	0.10	0.43	0	10.30
2. University technology creation	0.04	0.13	0	2.31
3. R&D investment	0.27	0.50	0	7.17
4. Factor market environment	5.33	2.07	1.70	11.90
5. Institutional environment	7.03	3.53	1.90	19.90
6. Polytechnic university	0.36	0.48	0	1
7. Medical school	0.11	0.31	0	1
8. 211 Project	0.13	0.34	0	1
9. University type	0.81	0.40	0	1
10. Collaboration experience	0.17	0.23	0	0.97
11. Local industrial capacity	13.00	0.90	10.28	15.39
12. Local absorptive capacity	0.03	0.01	0.01	0.09
13. Local innovation capability	8.19	0.88	5.05	9.80

SD: standard deviation.
[a]$n = 3908$ university-years.

Hypothesis 1. Model 4 shows that both the linear interaction term ($\beta = 0.03$, $p < 0.00$) and the quadratic cross-product term ($\beta = -0.00$, $p < 0.05$) for university R&D investment and university technology creation are significant. Therefore, Hypothesis 3a is supported.

Hypothesis 4a states that the development of institutional environment of the province in which the university is embedded positively moderates the inverted U-shaped relationship noted in Hypothesis 1. Model 5 yields a significant coefficient for the interaction between university R&D investment and university technology creation ($\beta = 0.03$, $p < 0.00$) and shows a significant coefficient for the interaction between squared university R&D investment and university technology creation ($\beta = -0.00$, $p < 0.00$). Thus, Hypothesis 4a is supported. Visually, Figures 1 and 2 plot the relationship between university R&D investment and university technology creation with different degrees of development in the external environment (factor market environment and institutional environment). Model 6 suggests that the moderating effect of institutional environment on the inverted U-shaped relationship between university R&D investment and technology creation is more significant than the moderating effects of factor market environment.

Table 4 reports mixed regression models for the technology commercialization stage with performance of UTT as dependent variable. Model 7 is the base model for this stage. Model 8 supports Hypothesis 2, showing that university technology creation has a significant and positive effect on the performance of UTT ($\beta = 1.51$, $p < 0.00$).

We further test the moderating effect of subnational institutional environment on the relationship between university technology creation and technology transfer. Hypothesis 3b states that the development of factor market environment in subnational regions positively moderates the relationship between university technology creation and performance of technology transfer. We find that the moderating effect of factor market environment is significant in model 9 ($\beta = 0.12$, $p < 0.00$) and model 11 ($\beta = 0.16$, $p < 0.00$), thus supporting Hypothesis 3b. Figure 3 supplements such support.

Hypothesis 4b states that the subnational institutional environment positively moderates the relationship between university technology creation and transfer. Model 10 ($\beta = -0.02$, $p < 0.10$) and model 11 ($\beta = -0.04$, $p < 0.00$) show that Hypothesis 4b is not supported.

Table 2. Pearson correlation matrix.[a,b]

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. University technology transfer	1.00												
2. University technology creation	0.46	1.00											
3. R&D investment	0.34	0.64	1.00										
4. Factor market environment	0.09	0.24	0.18	1.00									
5. Institutional environment	0.10	0.35	0.21	0.70	1.00								
6. Polytechnic university	0.10	0.10	−0.02	0.12	0.11	1.00							
7. Medical school	−0.06	−0.10	0.07	−0.03	−0.03	−0.27	1.00						
8. 211 Project	0.30	0.51	0.56	0.18	0.17	0.02	−0.10	1.00					
9. University type	0.11	0.15	0.25	0.14	0.10	−0.20	0.02	0.19	1.00				
10. Collaboration experience	0.18	0.26	0.22	0.22	0.22	0.41	−0.19	0.21	0.22	1.00			
11. Local industrial capacity	0.12	0.27	0.21	0.74	0.72	0.15	−0.04	0.21	0.15	0.24	1.00		
12. Local absorptive capacity	0.04	0.22	0.14	0.36	0.52	0.06	−0.01	0.15	−0.04	0.02	0.34	1.00	
13. Local innovation capability	0.05	0.13	0.09	0.47	0.58	0.06	−0.01	−0.02	0.15	0.18	0.63	0.01	1.00

[a] $n = 3908$ university-years.
[b] Correlations $\geqslant 0.04$ in absolute value are significant at the 0.05 level.

Table 3. Technology creation stage: mixed regression models.[a,b]

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Main effects						
R&D investment (H1)		0.15***	0.17***	0.15***	0.14***	0.14***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R&D investment squared (H1)			−0.01***	−0.01**	−0.01***	−0.01***
			(0.00)	(0.00)	(0.00)	(0.00)
Interaction effects						
R&D investment × factor market environment (H3a)				0.03***		0.00
				(0.00)		(0.00)
R&D investment squared × factor market environment (H3a)				−0.00*		0.00
				(0.00)		(0.00)
R&D investment × institutional environment (H4a)					0.03***	0.03***
					(0.00)	(0.00)
R&D investment squared × institutional environment (H4a)					−0.00***	−0.00***
					(0.00)	(0.00)
Moderating variables						
Factor market environment	−0.00†	−0.00†	−0.00†	−0.01**	−0.00	−0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Institutional environment	0.02***	0.01***	0.01***	0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Control variables						
Level 1 (university)						
Polytechnic university	0.01*	0.02***	0.02**	0.02***	0.02***	0.02***
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
Medical school	−0.01	−0.04***	−0.04***	−0.04***	−0.04***	−0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)

(Continued)

Table 3. (Continued)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
211 Project	0.21***	0.10***	0.09***	0.09***	0.09***	0.09***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
University type	0.01*	−0.01	−0.01*	−0.01	−0.01	−0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Collaboration experience	0.08***	0.05***	0.05***	0.06***	0.06***	0.06***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Level 2 (province)						
Local industrial capacity	0.00	−0.00	−0.01	0.00	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Local absorptive capacity	−0.01	−0.01	−0.01	−0.01*	−0.01*	−0.01*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Local innovation capability	0.58†	0.07	0.10	0.18	−0.20	−0.17
	(0.33)	(0.30)	(0.30)	(0.29)	(0.28)	(0.28)
Intercept	0.05	0.18**	0.18**	0.14*	0.14*	0.14*
	(0.07)	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)
Level 2 (province) variance RE	0.02	0.02	0.02	0.02	0.02	0.02
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Number of level 1 units (university)	3868	3868	3868	3868	3868	3868
Number of level 2 units (province)	30	30	30	30	30	30
Log likelihood	2505.53	2958.20	2963.96	3092.32	3232.39	3235.18
Wald χ^2	1671.41***	3117.78***	3129.75***	3618.88***	4169.95***	4183.65***
LR test	38.61***	48.85***	52.32***	43.66***	43.35***	42.62***

R&D: research and development; LR: likelihood ratio; RE: random effects.
[a]Standard errors are in parentheses.
[b]Dependent variable = university technology creation. †p < 0.10; *p < 0.05; **p < 0.01; ***p < 0.001.

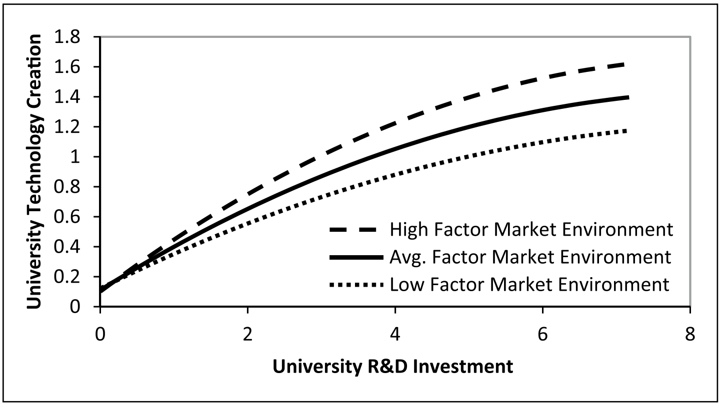

Figure 1. The moderating effect of factor market environment (H3a).

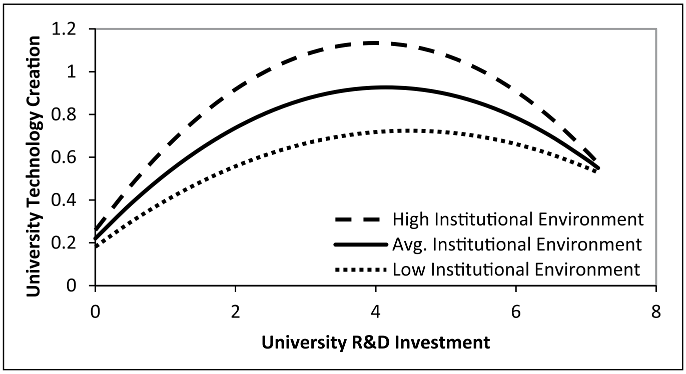

Figure 2. The moderating effect of institutional environment (H4a).

Robustness tests

We have conducted further analyses to test the robustness of our results. First, we use ordinary least squares (OLS) instead of generalized mixed model procedure. Second, we split the dataset into two estimation subsamples (subsample A including the years 2005, 2007, 2009, and 2011; subsample B including the years 2006, 2008, and 2010) and lag all independent and control variables by one period in each stage. Finally, we use alternative measures of the dependent variable. We use the number of granted patents to quantify the value created by universities in the technology creation stage and the revenues of technology transfer agreements as the performance of technology transfer in the commercialization stage. Our main results remain consistent throughout the robustness checks.

Discussion

Contributions

This study has embarked on a challenging quest to frame UTT as a process that can benefit from a dynamic capabilities lens. At least three contributions emerge. First, leveraging a dynamic

Table 4. Technology commercialization stage: mixed regression models.[a,b]

	Model 7	Model 8	Model 9	Model 10	Model 11
Main effects					
Technology creation (H2)		1.51***	1.23***	1.70***	1.50***
		(0.08)	(0.10)	(0.12)	(0.13)
Interaction effects					
Technology creation × factor market environment (H3b)			0.12***		0.16***
			(0.03)		(0.03)
Technology creation × institutional environment (H4b)				−0.02†	−0.04***
				(0.01)	(0.01)
Moderating variables					
Factor market environment	−0.00	0.00	0.00	0.00	−0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Institutional environment	0.00	−0.02**	−0.02**	−0.01**	−0.01**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Control variables					
Level 1 (university)					
R&D investment (T-2)	0.36***	0.12**	0.12**	0.09*	0.09*
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
R&D investment squared (T-2)	−0.01	−0.01	−0.01	−0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Polytechnic university	0.05**	0.03†	0.03†	0.03	0.03†
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Medical school	−0.08**	−0.03	−0.03	−0.02	−0.02
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
211 Project	0.11***	−0.00	0.01	−0.01	−0.00
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
University type	0.02	0.04†	0.04†	0.04†	0.04*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Collaboration experience	0.08†	0.03	0.04	0.03	0.03
	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)
Level 2 (province)					
Local industrial capacity	0.01	0.02	0.03	0.02	0.02
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Local absorptive capacity	−0.01	−0.00	−0.01	−0.00	−0.01
	(0.02)	(−0.02)	(−0.02)	(0.02)	(0.02)
Local innovation capability	0.85	0.67	0.81	0.69	0.89
	(1.25)	(1.19)	(1.20)	(1.19)	(1.19)
Intercept	0.02	−0.11	−0.16	−0.07	−0.11
	(0.25)	(0.25)	(0.25)	(0.24)	(0.25)
Level 2 (province) variance RE	0.05	0.05	0.05	0.05	0.05
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Number of level 1 units (university)	3028	3028	3028	3028	3028
Number of level 2 units (province)	30	30	30	30	30
Log likelihood	−1691.68	−1500.56	−1492.38	−1498.712	−1486.76
Wald χ^2	567.43***	1048.91***	1069.83***	1054.29***	1085.38***
LR test	15.50***	21.54***	24.72***	20.28***	22.93***

R&D: research and development; LR: likelihood ratio; RE: random effects.
[a]Standard errors are in parentheses.
[b]Dependent variable = performance of technology transfer. †$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

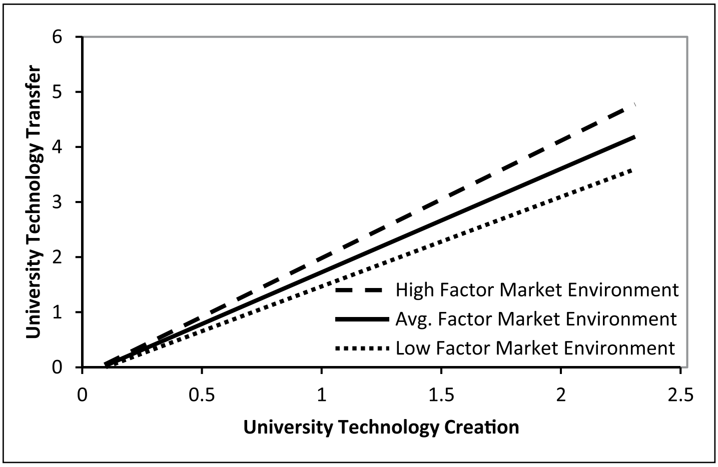

Figure 3. The moderating effect of factor market environment (H3b).

capabilities perspective (Teece, 2007, 2014a, 2014b, 2016), we have developed a new theoretical framework to probe the mechanisms of UTT in an emerging economy. Fostering universities' entrepreneurial thinking in creating and capturing value has a great deal of potential to explain the drivers behind UTT performance. This study highlights how unique abilities possessed by universities to continuously shape, reshape, and orchestrate assets can help them to create new technologies, to enhance the value extracted from collaborating with industries, and to respond to changes in the subnational regional institutional environment. Overall, we join Leih and Teece's (2016) recent work to advocate that a dynamic capabilities perspective contributes to a better understanding of UTT.

Second, theoretically, our efforts broaden the scope of the dynamic capabilities perspective, which has originated from a focus on for-profit organizations. Only recently has this perspective been extended to probe deeper into universities' entrepreneurial activities (Leih and Teece, 2016). Recent conceptualization of universities as a hybrid organization (Jongbloed and Zomer, 2012; Rothaermel et al., 2007) is conducive to an understanding of universities not only as task-oriented and mission-centered enterprises, but also as "market-smart" organizations (Massy, 2009). The hybridity of universities—especially their interest in generating funding from UTT—brings universities conceptually closer to for-profit organizations, thus allowing for the application of the dynamic capabilities perspective in the context of universities (Leih and Teece, 2016).

Third, we contribute to the deepening of UTT research and the related work on regional innovation systems. Earlier work on regional innovation systems (Asheim and Coenen, 2005; Cooke, 2001; Cooke et al., 1997) has so far mostly focused on developed economies and has not focused on universities. Extending such earlier work, we focus on universities in different subnational regions within a major emerging economy. Empirically, we leverage Hoskisson et al.'s (2013) two-dimension, national-level model, which deals with emerging multinationals and does not deal with universities, to the subnational level with a focus on UTT. A subnational view is particularly important in emerging economies, given the tremendous heterogeneity among regions within each country (Shi et al., 2012; Sun et al., 2015). Overall, our findings open the door to further understand the dynamics behind UTT among the institutional contexts of different subnational regions.

Methodologically, this study—in one of the first efforts in UTT research—applies multilevel analysis with random coefficients modeling using region-level data (Hitt et al., 2007). Our approach has two benefits: (1) it separates the variance in technology creation and technology commercialization explained by independent variables both at the university level and the subnational (region) level, and (2) it compensates for the data distortion introduced by varying sample sizes across regions (Sun et al., 2015).

Finally, our study suggests important policy implications. Our findings reveal that the performance of UTT varies greatly by the dynamic capabilities possessed by universities and subnational regions in an emerging economy. For policy makers concerned with promoting effective UTT, our findings encourage the development of dynamic capabilities along the sensing, seizing, and reconfiguration dimensions and the improvement of institutional capacity at the subnational level (Bozeman et al., 2015). Focusing on the development of factor markets and institutions is likely to generate significant dividends in the form of more effective UTT.

Limitations and future research directions

The limitations of our research suggest a series of promising future directions. First, despite our emphasis on dynamic capabilities, we do not directly measure them. However, this is not a limitation unique to our study, which is one of the first exploratory efforts to leverage the dynamic capabilities perspective in UTT research. Comprehensive reviews of the dynamic capabilities literature by Barreto (2010), Easterby-Smith et al. (2009), and Wang and Ahmed (2007) have not found direct measures of dynamic capabilities and reported proxies to measure their various dimensions. To the best of our knowledge, no previous measures of dynamic capabilities in a university context exist. The only previous article using the dynamic capabilities perspective in a university context similarly has not directly measured such capabilities. Instead it uses qualitative methods to provide "impressionistic insight" (Leih and Teece, 2016: 203). Clearly, future researchers need to embark on efforts to directly measure dynamic capabilities in a university context and beyond.

Second, although our measurement of marketization is commonly used (Shi et al., 2012; Sun et al., 2015), this index is a coarse-grained measure for several aspects of the subnational environment. Future research employing finer-grained data can allow the detection and examination of further nuances. Third, future research may also examine the possible interaction between university-level variables and subnational region-level variables (Lockett et al., 2005). Finally, an intra-country study inevitably suffers from an inherent lack of generalizability to cross-country contexts. Multi-country comparative studies, involving multiple subnational regions in multiple countries, can shed additional light above and beyond that revealed by our study.

Conclusion

Leveraging a dynamic capabilities framework, this study departs from previous research by examining how universities create and capture value in the UTT process. Successful exploitation of technology creation is made possible by universities' dynamic capabilities to *sense* and *seize* opportunities and to *reconfigure* their assets to enhance a better fit with the changing environments. If properly orchestrated, these capabilities enable higher payoffs for universities operating in subnational environments. We find that the level of subnational factor market and institutional development substantiates the strengths of universities' reconfiguration capabilities such that a more developed subnational environment helps universities in that region to better understand the new rules of the game so that they can develop proper dynamic capabilities to reach strategic goals. In conclusion, a dynamic capabilities perspective moves us closer to a deeper understanding of the intriguing sources of UTT performance during institutional transitions.

Declaration of Conflicting Interests

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Notes

1. Leih and Teece (2016), especially in their section "Dynamic Capabilities in the Context of Higher Education" (pp. 187–188), argue that dynamic capabilities are important for the overall strategic management of the entire university. Here, we focus on a narrower and more specialized domain of university management—UTT.
2. Instead of using "reconfiguration" (Teece, 2007), Leih and Teece's (2016) recent work has used the label "transforming" in the context of university management.
3. Such heterogeneity among subnational regions is observed not only in emerging economies but also in developed economies such as Britain (Guerrero et al., 2015), Italy (Maietta, 2015), Sweden (Asheim and Coenen, 2005), and the United States (Mowery and Ziedonis, 2015).
4. Many Chinese universities have strengthened their efforts to recruit internationally. However, other than a small number of top universities in major cities such as Beijing and Shanghai, the majority of Chinese universities draw a majority of their faculty and researchers from the regions where they are located. This phenomenon is not unique to China. For example, in the United States, Hess and Rothaermel (2011) and Zucker and Darby (2007) find that the factor market for star scientists is mostly local.

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Author biographies

Changhong Yuan is Chairman of the Department of Technical Economics and Management and Professor of management at the School of Management, Xi'an Jiaotong University. He received his PhD in management science and engineering from Xi'an Jiaotong University. His research interests include university–industry collaboration, university technology and knowledge transfer, university-based entrepreneurship, and industry-university-government alliances.

Yang Li is a PhD candidate in innovation and strategy at Xi'an Jiaotong University. His research interests center on the areas of technology innovation, technology transfer, and strategic alliance. His research focuses on the effects of institutional environment on university technology innovation and transfer from the views of institutions and capabilities. His recent research interests are the formation, configuration, and management of strategic alliance portfolio in emerging economies, with a focus on the institution-based view.

Cristina O. Vlas is a PhD candidate in international management studies at the University of Texas at Dallas. Her research interests lie mainly in the areas of innovation, entrepreneurship, and international business. Her research focuses on the antecedents, moderators, and consequences of organizational innovation in knowledge-intensive firms through the lenses of organizational learning, resource-based and knowledge-based perspectives, and dynamic capabilities. Her recent research explores the signaling role of patenting velocity on firms' market valuation, the use of slack resources while simultaneously engaging internal and external knowledge sources, and the interplay of CEO's regulatory focus and top management team's diversity in entrepreneurial firms.

Mike W. Peng is the Jindal Chair of Global Strategy at the University of Texas at Dallas. He is also a National Science Foundation CAREER Award winner and a fellow of the Academy of International Business. His research interests are global strategy, international business, and emerging economies, with a theoretical focus on the institution-based view. He has authored over 130 journal articles and 5 books. His textbooks, *Global Strategy*, *Global Business*, and *Global*, have been translated into Chinese, Portuguese, and Spanish and are used in over 40 countries. This article is his second contribution to *Strategic Organization*.