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Article

Cross-border knowledge pipelines and innovation performance of chinese firms: Evidence from Zhangjiang in Shanghai

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Cross-border knowledge pipelines and innovation performance of chinese firms: evidence from Zhangjiang in Shanghai

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Abstract: It is increasingly emphasized that firms' innovation depends on external knowledge interaction in the field of economic geography. Global knowledge linkages and interaction plays crucial role in gaining competitive advantage for firms in developing countries because of their immature innovation systems, inspiring a wide academic interest around cross-border knowledge pipelines. However, the existing literature has been silent about the type in which firms employ cross-border knowledge pipelines and neglects the potential importance of firm's ownership in this process. Using 2015 survey micro-data of 4685 Chinese firms in Zhangjiang National Innovation Demonstration Zone, we investigate how different types of cross-border knowledge pipelines indicated by foreign R&D investment and returnees influence firm's innovation. The research highlights the positive effects of foreign R&D investment and returnees on firms' patenting activity, while returnees exerts negative influence on firms' product innovation. Moreover, there exists a complementary relation between foreign R&D investment and returnees in facilitating firm's patenting. State ownership negatively affects the relationship between foreign R&D investment and firms' patenting activity.

Keywords: Cross-border knowledge pipelines, Chinese firms, innovation performance

1 Introduction

The crucial role of external knowledge and linkages to trigger innovation has heightened interest to understand

how cross-border knowledge pipelines influence innovation performance of firms (Bathelt & Li, 2020; Fitjar, & Huber, 2015; Grillitsch & Trippel, 2014). The nature of knowledge creation lies at knowledge interaction. Cross-border knowledge pipelines emerge as a distinct form of knowledge interaction to access external knowledge, which have been increasingly emphasized by economic geographers (Henn & Bathelt, 2018; Esposito & Rigby, 2019). Previous studies that focus on knowledge creation stress external knowledge as the important supplement for the existing knowledge, implying a purely local view of firms' innovation and ignoring the importance of international linkages (Cantwell, 1989; Perkmann, 2006;). The local-buzz-and-global-pipelines model proposed by Bathelt et al (2004) opens new dialogue on non-local linkages by equally considering external knowledge as important as internal knowledge. Nevertheless, the widely debate around non-local linkages based on the dichotomy of local interaction and non-local interaction is insufficient to reveal the effect of global knowledge linkages (Cao et al., 2022; Esposito & Rigby, 2019). Building on the conception of cross-border knowledge pipelines (Bathelt & Li, 2020), this paper advances our understanding of global knowledge linkages by investigating the question that how the types of cross-border knowledge pipelines influence the innovation capacity of firms in developing countries.

In the context of a highly interconnected global economy, cross-border knowledge pipelines play a critical role in the acquisition of cross-border knowledge and innovation development of firms in developing countries. Taking China as an example, over the past decades, Chinese firms have aggressively dedicated into investing foreign R&D and employing transnational individuals to overcome the innovation gap with peers and realize the sustainable innovation growth. According to the statistical data published by Ministry of Chinese Science and Technology and Ministry of Chinese Education, China's R&D investment stock reached 285.96 billion USD by the end of 2018, second only to the US, and most of that was from Chinese firms. Meanwhile, over 80 % of Chinese people who studied abroad have returned home after an absence of several years, with the number of such 'returnees' increasing by 8 % in 2018 to 519,000 people, providing Chinese firms with the unique resource of 'the talent pool'. Obviously, these attempts provide potential

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unique opportunities for firms in developing countries alike.

Against this background, the topic on cross-border knowledge linkages has received a fair degree of attention from economic geographers (Saxenian 2002; Bathelt et al., 2004; Yeung, 2009). For firms in developing countries, cross-border knowledge pipelines serve as important learning mechanism to obtain external knowledge spillovers (He et al., 2017; Yeung, 2021). Different types of cross-border knowledge pipelines imply heterogeneous learning mechanism, and tend to be interrelated and complementary for each other (Rutten, 2017). Multiple cross-border knowledge pipelines are typically distinguished as two types of the formal organisation-based global linkage and the relatively informal individual-based global linkage in the literature (Lorenzen & Mudambi, 2013; Fitjar & Huber, 2015). But we have limited understanding of how these two different types of cross-border knowledge pipelines affect innovation performance of firms especially in developing countries, and until recently few of research has empirically examined the interplay between different types of cross-border knowledge pipelines (Bathelt, & Li, 2020).

Cross-border knowledge pipelines provide opportunities for firms to innovate but do not necessarily contribute to innovation gains for firms, implying the necessity to analyse the underlying conditions through which cross-border knowledge pipelines impact firm's innovation performance (Bathelt et al., 2018). Cross-border knowledge pipelines are associated with firm's internationalization (Bathelt, & Li, 2020). The internationalization activities of firms in developing countries are deeply embedded in the institutional background and heavily shaped by their ties with domestic governments (Peng, Wang & Jiang, 2008). As Bathelt & Li (2020) demonstrated, 'a firm's internationalization process relies not only on its internal assets and capabilities but also on an external support system including government agencies, business associations, service providers, and experienced experts for transnational knowledge' (p. 11). However, existing studies mainly focus on the firm's absorptive capacity when investigating internationalization activities of firms in developing countries, and relatively ignore the discussion of the potential contingency role of institutional factors partly because of information scarcity (Békés & Muraközy, 2018; Bathelt, et al., 2020).

To fill this research gap, this study employs the unique dataset of 4,658 Chinese firms in the Zhangjiang National Innovation Demonstration Zone (Shortly as Zhangjiang), and attempts to address the following research questions: (1) To what extent are foreign R&D investment and returnees beneficial to firms' innovation? (2) What are interactive effects of foreign R&D investment and returnees on firms'

innovation? (3) What is the heterogeneous moderating role of state ownership in the relationship between two types of cross-border knowledge pipelines and firm innovation?

The paper is organised as follows. Section 2 reviews the literature regarding how cross-border knowledge pipelines improve firms' innovation and presents the theoretical arguments. Section 3 delineates the development of Zhangjiang and introduces the data and methodology employed in Section 4. Section 5 presents an analysis based on the estimation results. Finally, we provide a discussion and conclusions.

2 Theoretical background and hypothesis

2.1 Cross-border knowledge pipelines

According to the previous paper, the concept of "global pipelines" has been used to refer to trans-local linkages across countries (Bathelt et al., 2004; Maskell, Bathelt & Malmberg, 2006; Grillitsch & Trippel, 2014). From the perspective of firm, we argue that cross-border knowledge pipelines can be defined loosely as the global linkages related to the knowledge acquisition strategies of MNEs to leverage and integrate dispersed ideas and technologies across nations. Cross-border knowledge pipelines provide diversified and non-redundant technologies for the recombinant and generation of newly valuable knowledge across national borders, in order to concentrate on the exploration and exploitation of external knowledge (Bathelt & Li, 2020).

Much of recent literature on cross-border knowledge pipelines stresses the differences between the formal organisation-based linkage and the relatively informal individual-based linkage (Moodysson, 2008; Yeung, 2009; Fitjar & Huber, 2015). In this present, we primarily focus on foreign R&D investment and transnational individuals represented by returnees as the two types of cross-border knowledge pipelines, and they often represent different learning modes and interactive mechanisms of knowledge creation.

To be specific, foreign R&D investment as the formal organisation-based global linkage is often the outcome of the firm-level strategic behaviour. They are conducted to achieve specific outcomes, and involve active interventions which are typically not indigenous but designed and maintained for short and single returns (Fitjar & Huber, 2015). Hence, foreign R&D investment as a kind of global linkage deliberately maintained by organisations is likely to serve

Table 1: The differences of two types of Cross-border knowledge pipelines

	Foreign R&D investment	Transnational individuals.
Mode of cooperation	formalized relationships such as cooperative arrangements, alliances, joint ventures, sub-contracting or licencing	any interaction between individuals that goes beyond official/formal collaboration and formal roles
Knowledge creation	Formal, organized and goal-directed, serve for relatively short-time and one-way objectives	more informal, flexible and robust; cutting across organizational boundaries
Type of innovation	codified knowledge; less technological diversity	Tacit knowledge is personal knowledge embedded in individual experience; emergent and more radical

for relatively short-time and one-way objectives. In terms of innovation activities, innovation emerging through foreign R&D investment tends to be characterised by strategic and relatively less technological diversity.

By contrast, the individual-based global linkages in the form of relatively informal personal ties and mobility, used to be created and held by transnational individuals. This type is more flexible in knowledge transferring, and ‘international personal networks exhibit a more robust positive relationship with innovation than international formal networks’ (Fitjar & Huber, 2015). Additionally, transnational individuals lead to innovation activities through trust-based interactions among heterogeneous individuals (Trippel, Tödtling, & Lengauer, 2009). Such learning effect and knowledge outcomes brought by these creative individuals is emergent and more radical (Mudambi & Swift, 2009).

2.2 Foreign R&D investment, returnees and firms’ innovation performance

Foreign R&D investments for firms in developing countries are associated with their innovation strategies to generate disruptive innovation and keep pace with the industry leaders (Awate, Larsen, & Mudambi, 2015). In the context of developing countries, firm’s foreign R&D investment is driven primarily by the technological exploration rather than technological exploitation. In this respect, foreign R&D investment facilitates to obtain external innovation resources which are scarce and unavailable at domestic, and expand the firm’s knowledge base. Second, in the face of increasingly sophisticated technological changes, foreign R&D investment can help decrease the risk and uncertainty of innovation projects, responding quickly to fierce global competition and the future technical revolutions (Fu et al., 2021). More importantly, in the case of a lack of technical ability, these firms from developing countries could create business linkage with international technological leaders through their foreign R&D investment, providing the opportunities to leverage and learn from different types of international partners (Fan, 2011; Si & Liefner, 2014).

Meanwhile, increasing numbers of studies suggest that the importance of foreign R&D investment for firms in developing countries (Tang, Tang, & Su, 2019). Fan (2011) employed the case studies of the companies Huawei and ZTE and found that the R&D globalisation strategy as an important technological strategy is beneficial to tap into global resources and markets unavailable to firms from developing countries when they possess a certain level of technological capability. Using the patent data from different patent offices, Schaefer & Liefner (2017) analyse Huawei’s ability to reach better R&D performance through offshore R&D, and they find that foreign R&D investment outperform their domestic activities to help them produce advanced knowledge. Based on a questionnaire survey of 738 Chinese firms, Si, Liu & Zhang (2021) suggest that three types of foreign R&D investment in forms of cross-border R&D collaboration, setting up offshoring R&D centres and transnational merger and acquisition (M&A), all of which contribute to improving the firm’s innovation performance. Actually, contrary to these firms from developed countries, the process of accessing and applying external knowledge for firms in developing countries mainly extends from global to local contexts, and the vast domestic markets in developing countries are considered to provide for local firm natural testing grounds to integrate and apply innovation resources by conducting foreign R&D investment.

In regards to another important form of cross-border knowledge pipelines, the benefits of transnational individuals related to firm’s innovation can be attributed to the following aspects: on the one hand, transnational individuals can transfer effectively tacit and complex knowledge critical to firm’s innovation, and are hence typically viewed as ideal carriers of this type of knowledge (Kogut and Zander, 1992). There is increasing recognition of the critical roles of transnational individuals in transferring and acquiring external knowledge, especially for ‘know-how’ and ‘know-who’ types of knowledge, particularly in developing countries where firms are characterised by insufficient knowledge base and less absorptive capacity for technological learning (Filatotcheva, Liu, Lu, & Wright, 2011; Bathelt & Li 2020). On the other hand, transnational individuals possess cross-cultural

background and experience, and thus have advantages in coping with challenges from different organisational and institutional contexts to integrate external knowledge. Innovation activities increasingly depend on interactive learning. Social capital theory emphasises the role of relational capital in acquiring knowledge externally through individualized networks. Transnational individuals represented by returnees can help to access external knowledge based on their relational networks (Liu et al., 2010).

The voluminous body of work on transnational individuals shows the importance of returnees for external knowledge sourcing. For instance, Fu, Woo, & Hou (2016) have stressed that it is the returnees that help Chinese solar panel firms have become global leaders. Wang (2012) also pointed out that returnees have played an important role in the development of the strategic emerging industries such as renewable energy, electrical cars and biotechnology in China. Using the survey data, Liu et al., (2010) found that returnee firms are more innovative than non-returnee firms, and returnees are an important channel for international knowledge spillovers based on unique networks resources and plentiful social interaction.

Hence, we propose the following hypotheses:

H1a: Foreign R&D investment positively affects firm innovation performance.

H1b: Returnees positively affect firm innovation performance.

2.3 The interaction effect of foreign R&D investment and returnees

The interplay especially for the complementary relationship between different types of cross-border knowledge pipelines has been stressed by recent literature (Bathelt & Li, 2020). With rapidly changing and complex technology, people increasingly realised the importance of external knowledge sources in firms' innovation management practices. However, to benefit from external knowledge, one must cope with the potential barriers of cross-border knowledge pipelines involving connecting, sense-making, and integrating of cross-border knowledge (Mathews, 2002; Bathelt, Cantwell, & Mudambi, 2018). In this respect, transnational individuals not only directly affect firms' innovation but also indirectly affect the innovation performance of Chinese firms when they engage in internationalization activities to build cross-border knowledge pipelines (Wu & Coe, 2022).

On the one hand, transnational individuals comprise a vital channel for gaining tacit knowledge of international markets, facilitating the efficiency of foreign R&D investments (Liu & Buck, 2007; Fitjar & Huber, 2015). Introducing

foreign technology is one thing but then being able to use it fully is another (Fu, Woo, & Hou, 2016), that is to say, the ease of mastering foreign technological knowledge is associated with the firm's absorptive capacity which represents the ability of a country to identify, assimilate and exploit knowledge from the environment (Cohen & Levinthal, 1989). A firm can absorb new foreign technology largely depends on its absorptive capacity. Prior studies demonstrated the significant role of individuals in affecting diffusion and absorption of foreign knowledge, for transnational individuals are characterised by their cross-cultural advantages to bridge transnational contexts (Liu, Lu, & Choi, 2014; Si, Zhang, & Teng, 2021). What's more, foreign technologies developed in other countries mismatch with the economic and social conditions of developing countries, which requires transnational individuals to adapt this new foreign technology to suit local conditions. Therefore, only with the successful internalization of the tacit knowledge of the foreign innovation can the foreign innovation be employed to reach its potential. In short, there is synergy between foreign R&D investments and transnational individuals.

Transnational individuals enable firms to overcome the liability of being outsiders when firms conduct internationalization activities like foreign R&D investments. Transnational individuals may compensate for geographical distances and create institutional proximity to innovation opportunities through their international networks (Saxenian, 2006). Transnational individuals, especially for returnees, may connect diverse knowledge to help Chinese firms engage in foreign R&D investment, further improving the positive effect of foreign R&D investment on innovation. These returnees returned to home countries not only brought back new knowledge in science and technology, but also brought back ideas for advanced commercial production, playing an important role in improving the innovation performance of firms in developing countries (Rauch & Trindade, 2002). Saxenian (2002, 2006) in the 1980s observed that local firms in Israel, Taiwan, and India have greatly benefited from these cross-region collaborations with important customers and partners in Silicon Valley, where transnational technological communities play particularly significant roles. In this regard, transnational individuals play the role to overcome frictions due to different knowledge bases and institutional contexts (Bathelt & Li, 2020). We propose that the moderating role of transnational individuals should be taken into account when examining the effect of knowledge spillovers from foreign R&D investments. Hence, we give the following hypothesis:

H2: Returnees play a positive moderating role in the relationship between foreign R&D investment and firm innovation performance.

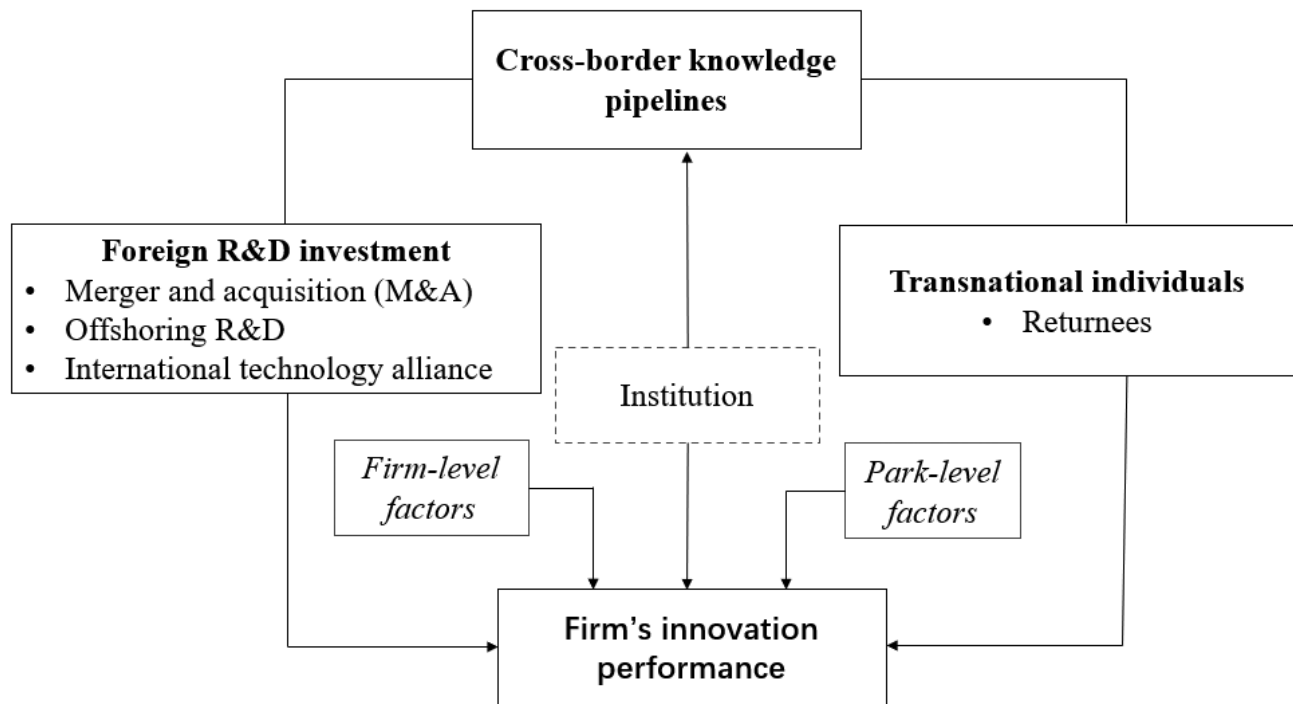


Figure 1: Concept framework – Foreign R&D investment, transnational individuals, and cross-border knowledge pipelines

2.3 The moderating effect of ownership

The process of building cross-border knowledge pipelines is highly associated with firm's internationalization activities. Much of literature have highlighted the importance of institutional factors in explaining the success of internationalization and innovation activities of firms in developing countries (Meyer, 2018). Innovation is viewed as the outcome of knowledge recombination in a new way. The likelihood of accessing less redundant knowledge will be increased when firms operate internationalization activities across countries. Simultaneously, recombinatory costs such as capital expenditures, coordination costs, and integration costs will increase due to the lack of interdependence among countries (Kim, Lampert & Roy, 2020). Institutional advantages facilitate to enhance their recombinant ability and reduce the liability of foreignness they face, which offset deficits in traditional ownership.

Benefiting from cross-border knowledge pipelines requires firm's recombinant capability, while the recombinant capability of firms largely depends on the firm-specific advantages (FSAs). For those firms in developing countries, their FSAs are typically more associated with the endowment of institution advantages rather than these traditional assets in technology and managing experience (Meyer, 2018). More specifically, firm's ownership is considered as the proxy for institutional factor at firm-level that shapes organ-

izational decisions and the structure of organization interaction (Rialp-Criado & Komochkova, 2017). The advantages of FSAs for those in developing countries provide preferential access to resources (Hennart 2012; Narula 2012), notably to financial resources (Morck, Yeung & Zhao, 2008), but also to network relationships with major innovative players. Rialp-Criado and Komochkova (2017) indicate that access to financing is the most severe obstacle to firm's business development, as exemplified by more than 10 % of private Chinese SMEs. In contrast to private firms, state-owned firms often possess more closer political connections with government, indirectly providing a favourable institutional environment for firms' innovation internationalization activities.

From the perspective of knowledge application, institution advantages are reflected in providing large market to apply overseas knowledge. The innovation systems of developing countries are immature due to the limited absorptive capacity and weak institutions (Françoso & Vonortas, 2022). Most of innovation resources are concentrated in public sector like universities and public research organizations. Actually, innovation is not solely the R&D processes, but also is the commercialization processes (Kim & Pennings, 2009). Such policies and unique technological resources because of closer-ties with government allow firms to obtain more opportunities not only in accessing more various and more superior overseas R&D sources, but also more importantly in the aspect of market to transform R&D resources.

State-owned firms with higher government-associated relationship enjoy preferential access to friendly regulation, financial sources, and important information related to the foreign business environment, and hence theoretically possess more abundant resource and more significant incentives to help firm build cross-border knowledge pipelines, like investing foreign R&D and employing returnees (Chang et al., 2006). Therefore, we argue that state-owned firms are more likely to achieve higher innovation performance by building cross-border knowledge pipelines. Building upon these arguments, we hypothesise the following:

H3a: State ownership positively moderates the effect of foreign R&D investment on a firm's innovation performance.

H3b: State ownership positively moderates the effect of returnees on a firm's innovation performance.

3 Methods and data

3.1 Data

The empirical analysis employed a dataset of 4,685 Chinese firms which registered in Zhangjiang National Innovation Demonstration Zone. Zhangjiang was established in 1992 and consist of a group of 22 high-tech parks in Shanghai at the end of 2015 (Figure 2). In 2011, Zhangjiang was formally granted by the central government as a national experiment and demonstration zone for indigenous innovation. Over the last two decades, Zhangjiang has taken aggressive actions in encouraging MNEs to explore and exploit global R&D resources, and attracted high-quality talent from the whole world, aiming to build a regional innovation ecosystem in connection with global innovation networks (Zeng et al., 2011).

As an important demonstration area to serve the 'indigenous innovation' strategy of the Chinese government, Zhangjiang have great advantages in accessing extensive global innovation sources and take especially aggressive action in exploiting cross-border R&D resources and transnational individuals (Zeng et al., 2011). By 2011, Zhangjiang attracted 58 persons in the central "thousands of talents" programme, accounting for 67% of the total in Shanghai and 7% of the national total (ZJHP, 2012), and the percentage of R&D in GDP increased by 3.11% (Zhang, 2015).

The unique dataset in this study is collected by the Administrative Committee of Zhangjiang in Shanghai. As the only management office authorized by government, the Administrative Committee of Zhangjiang is responsible to

investigate the development of Zhangjiang every year, and this dataset is based on the 2015 Zhangjiang Annual Sampling investigation. The advantage of this dataset lies in covering detail firm-level information, including firm's basic characteristic and innovation outcome, as well as firm's internationalization behaviours such as exporting, foreign R&D investment, the employment of transnational individuals. Table 2 offers an overview of the basic characteristic of firms in Zhangjiang.

Table 2: Basic information of Chinese firms at Zhangjiang 2015

Firm characteristics	Type	Number of firms	Proportion/%
Cross-border knowledge pipelines	Foreign R&D investment	50	1.1
	Transnational individuals	924	19.7
The number of patent applicants	<10	589	12.6
	10~50	64	1.4
	50~100	10	0.2
	>100	11	0.2
Ownership	State-owned	655	14.0
	Private	4030	86
Industry	High-tech	2296	49
	Non high-tech	2389	51

3.2 Variables

3.2.1 Dependent variables

This study used the invention patent and new product as the dependent variable to proxy for the firm's innovation performance. It is generally accepted that patents and new products are employed as suitable indicators of innovation (Crescenzi & Rodríguez-Pose, 2017). In line with previous research (Sun & Du, 2010), we captured firms' patents using the natural logarithm of the total invention application patents per employees, and measured firms' product innovation with the natural logarithm of new products per employee.

3.2.2 Independent variables

To test the above hypotheses, different types of cross-border knowledge pipelines were captured, namely *foreign R&D investment* and transnational individuals represented by *returnees*. The key variables of this study contain *foreign R&D investment* and transnational individuals represented by *returnees*. To be specific, *foreign R&D investment* is con-

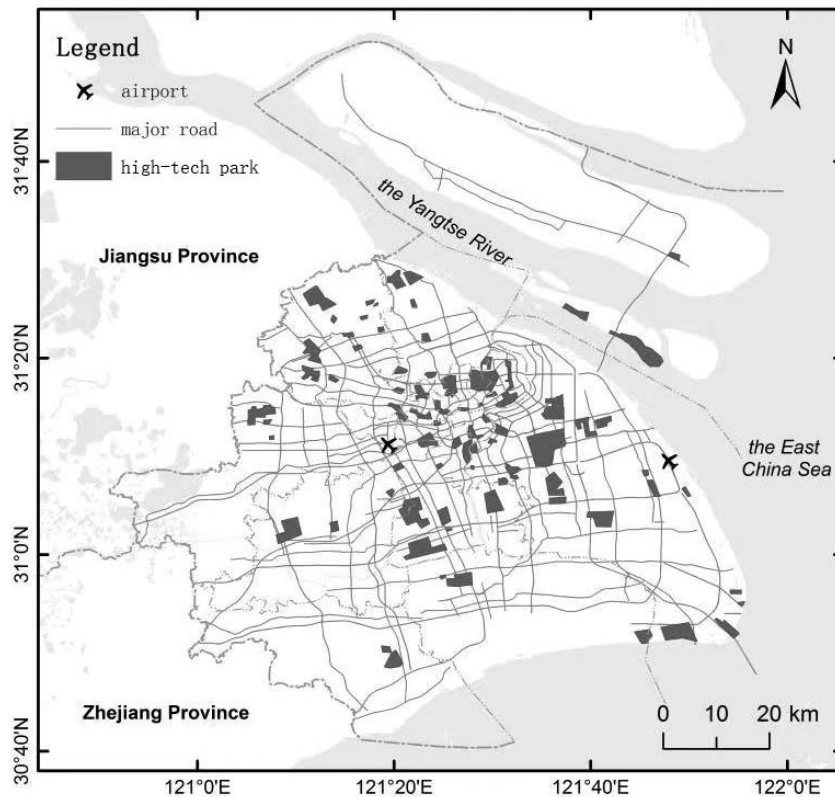


Figure 2: The landscape of Zhangjiang Park

structured as a dummy variable. It is set as the value of '1' when a firm operates any form of foreign R&D investment, such as transnational merger and acquisition (M&A), offshoring R&D, international technology alliance, and '0' otherwise. Returnees are those who have gone abroad to study and obtain a degree among employees. They can be high-end experts with leading technology, senior executives of firms, or professional and technical personnel with special skills. Following previous research, *returnee* is measured by the ratio of returnees to the total number of employees.

3.2.3 Control variables

Generally, firm's innovation performance is not only associated with the firm's characteristics, but also the particularities of their context (Bruna & Fernández-Sastre, 2021). In this study, we focus on these factors from the firm level and the park level, which potentially influence the innovation performance of firms. According to a large body of empirical research on firms' innovation, we identified a series of available variables to take into account, such as firms' high-tech certification, size, age, ownership, industry, domestic R&D investment, and export, as well as the influencing factors at the park level including the size of park (*Parksize*) and the actual production effect (*Parkgdp*).

More specifically, firms with high-tech certification refer to these mainland China firms registered for more than one year and possess their own independent intellectual property rights in key high-tech industries. Therefore, high-tech firms are stronger willing to innovate and more innovative. We proxy for *high-tech* by introducing dummy variables as '1' if a firm is a high-tech firm ('0' otherwise). Additionally, since a firm's ownership structure is highly associated with the innovation performance especially in the context of developing countries, we take *ownership* as a dummy variable that stated-owned firms take the value '1', and '0' otherwise. In general, stated-owned firms have relatively easy access to financial support and preferential policies that facilitate firms' innovation capacity (Andrésa & Zhang, 2020). Hence, we assume that state-owned firms are more innovative. Firm size is also considered highly related to innovation behaviour. Larger firms typically have more advantages in financial and intangible assets to afford innovation risks and failures, thus theoretically they are more innovative (Rialp-Criado & Komochkova, 2017). At the same time, older firms have richer experiences and tend to possess the social capital for engaging in innovation activities. *Age* is captured by a firm's year in the form of natural logarithm since the firm founded. Many studies have emphasized the differences between innovation process in low- and medium- technology (LMT) and high-

tech (HT) industries (Santamaría, Nieto & Barge-Gil, 2009). In general, the innovative behavior of LMT firms involves internally experimenting with and adapting technologies and learning that are not necessarily rooted in formal R&D components, in contrast to LMT firms, R&D-intensive HT firms possess more advantages to face the challenge of innovation. According to the OECD's (2011) classification of industries, firms were divided into two groups: LMT and HT industries. It is widely acknowledged that innovation activities largely depend on R&D investment. In this sense, R&D investment contributes to increasing innovation intensity and improving firms' absorptive capabilities to apply external technologies. *Domestic R&D investment* is measured by R&D investment at domestic, taking the logarithm. Export is also highly associated with firm's innovation performance. It is widely recognised that the effect of learning-by-exporting allows firms to acquire timely information about markets, products, and consumer preferences for firms' innovations, and obtain knowledge especially tacit knowledge, which is crucial to innovation (Liu et al., 2010; Cassiman & Golovko, 2011).

Additionally, from the perspective of the park level, we concentrating on the potential influence of local knowledge spillover by considering two variables *ParkSize* and *ParkGdp*, namely the size of a park and the park's GDP. Innovation depends on interaction among actors that geographical proximity facilitates. The size of a park is captured by the number of onsite firms. The park's GDP reflects the development stage and the maturity level of a park, which is measured by the total product value of the park in which the firm is located. To reduce or eliminate bias, most of variables are at natural logarithms.

3.3 Methods

Given the character of the dependent variables, we used the tobit regression to analysis for our estimation model. Keeping line with prior literature, it is preferable for employing the tobit regression to test our hypotheses since the dependent variable is censored (Tobin, 1958; Yi, Hong, Hsu, & Wang, 2017; Teng et al., 2020). Specifically, the equation of regression models as follows:

$$\text{Innovation performance}_i = \alpha + \beta \text{ForeignR\&D}_i + \lambda \text{Transindividual}_i + \delta X_i + \varepsilon, (1)$$

The variable *Innovation performance*_{*i*} indicates innovation performance of the firm *i* in Eq. (1). *X_i* is a vector of the interaction terms (Returnee × Foreign R&D, Ownership × Foreign R&D, Ownership × Returnee).

Table 3 provides detailed information on the descriptive statistics of the indicators and correlation matrix of

all variables. We conducted a test on the potential issue of collinearity among independent variables. According to the empirical findings presented in Table 3, there is no multicollinearity in our model since the highest Variance Inflation Factor (VIF) among explanatory variables is only 2.79, far below the critical point of 10 (Belsley et al., 1980). Regression analyses further identify interrelationships among judgement variables.

Table 3: Descriptive statistics of variables

Variable	Mean	Std. Dev.	Min	Max	VIF	1/VIF
patent	0.0117	0.0572	0	1.3863		
size	6.5605	2.8225	0.0010	16.6740	2.0900	0.4779
year	2.1107	0.6488	0	4.7622	1.4200	0.7032
Industry	0.4902	0.5000	0	1	1.1200	0.8923
Hightech	0.2414	0.4280	0	1	2.5700	0.3898
ownership	0.1419	0.3490	0	1	1.2200	0.8190
export	0.4099	1.5405	0	12.2549	1.2100	0.8275
domesticRD	2.3425	2.9691	0	13.3645	2.7900	0.3591
parksize	9.1501	0.9502	5.7869	10.0501	1.6600	0.6015
parkgdp	6.4614	0.9228	3.7377	7.1585	1.8000	0.5546
foreignRD	0.0107	0.1028	0	1	1.0900	0.9164
Returnee	0.0235	0.0976	0	1.5000	1.0200	0.9851

4 Results and findings

4.1 Effects of foreign R&D investment and returnees

Table 4 reports the empirical results of the impact of different types of cross-border knowledge pipelines on firms' innovation. The result of Model 2 in Table 4 shows that both foreign R&D investment and returnees have statistically significant and positive relationships with firms' patenting activity ($\beta = 0.0587$, $p < .01$; $\beta = 0.2657$, $p < .001$, respectively), implying that foreign R&D investment facilitates to enhance firms' innovation performance. This type of cross-border knowledge pipeline in forms of foreign R&D investment could prove to be effective and important for firms' patenting activity. Foreign R&D investment can provide firms with diversified and complementary knowledge from dispersed geographical locations. Actually, foreign R&D investment have often been severed as a major driver of technological upgrading in less developed countries especially at the initial stage of development (Yang, 2015). The transnational technical communities consist by returnees create potential windows of opportunity for firms in developing countries by providing privileged linkages to world-class innovation resources (Saxenian, 2002). Jons (2009) argued that this type

Table 4: Foreign R&D investment, returnees, and firms' patenting activity

InPatent	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Size	0.0015 (0.0030)	0.0012 (0.0030)	0.0020 (0.0029)	0.0018 (0.0029)	0.0022 (0.0029)	0.0015 (0.0030)	0.0023 (0.0029)
Year	-0.0496*** (0.0110)	-0.0494*** (0.0110)	-0.0453*** (0.0109)	-0.0452*** (0.0109)	-0.0450*** (0.0108)	-0.0499*** (0.0110)	-0.0464*** (0.0109)
Industry	-0.0198* (0.0104)	-0.0197* (0.0104)	-0.0202** (0.0103)	-0.0202** (0.0103)	-0.0199* (0.0102)	-0.0204* (0.0104)	-0.0203** (0.0103)
Hightech	0.0726*** (0.0145)	0.0754*** (0.0146)	0.0764*** (0.0144)	0.0784*** (0.0144)	0.0769*** (0.0144)	0.0735*** (0.0146)	0.0752*** (0.0144)
Ownership	-0.0109 (0.0137)	-0.0121 (0.0137)	-0.0107 (0.0135)	-0.0116 (0.0135)	-0.0103 (0.0134)	-0.0066 (0.0139)	-0.0044 (0.0141)
Export	0.0022 (0.0024)	0.0012 (0.0025)	0.0020 (0.0024)	0.0012 (0.0024)	0.0018 (0.0024)	0.0015 (0.0025)	0.0019 (0.0024)
DomesticRD	0.0409*** (0.0030)	0.0402*** (0.0030)	0.0404*** (0.0030)	0.0399*** (0.0030)	0.0396*** (0.0030)	0.0404*** (0.0030)	0.0405*** (0.0030)
Parksize	-0.0071 (0.0058)	-0.0071 (0.0058)	-0.0066 (0.0057)	-0.0067 (0.0057)	-0.0058 (0.0057)	-0.0069 (0.0058)	-0.0067 (0.0057)
Parkgdp	-0.0139* (0.0071)	-0.0144** (0.0071)	-0.0159** (0.0071)	-0.0162** (0.0070)	-0.0165** (0.0070)	-0.0142** (0.0071)	-0.0158** (0.0071)
ForeignRD		0.0587* (0.0305)		0.0448 (0.0302)	0.0084 (0.0332)	0.1193*** (0.0405)	
Returnee			0.2657*** (0.0422)	0.2608*** (0.0423)	0.2389*** (0.0437)		0.2786*** (0.0427)
ForeignRDReturnee					0.5521*** (0.2104)		
OwnershipForeignRD						-0.1295** (0.0581)	
OwnershipReturnee							-0.4449 (0.3102)
_cons	-0.1304** (0.0579)	-0.1236** (0.0579)	-0.1396** (0.0573)	-0.1341** (0.0573)	-0.1411** (0.0572)	-0.1283** (0.0579)	-0.1393** (0.0573)
var(e.InPatent)	0.0363*** (0.0022)	0.0361*** (0.0022)	0.0352*** (0.0022)	0.0351*** (0.0022)	0.0348*** (0.0021)	0.0360*** (0.0022)	0.0351*** (0.0022)
N	4684	4684	4684	4684	4684	4684	4684
r2	0.4844	0.4862	0.5009	0.5020	0.5053	0.4886	0.5023

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

of brain circulation contributed significantly to the reintegration of Germany into the international scientific community after the Second World War. In terms of patenting, H1a and H1b is therefore supported, which is consistent with the finding in most prior research (Hsu et al., 2015; Schaefer & Liefner, 2017; Si et al., 2021).

Besides, Model 2 and Model 3 in Table 5 report the impact of different types of cross-border knowledge pipeline on firm's product innovation. We find that foreign R&D investment exerts no significant influence on the production of innovation, while returnees exerts negative influence on the production of innovation ($\beta = -5.3780$, $p < .005$). The establishment and management of global pipelines involve differences in the cultural and institutional contexts in which the firms operate, not least because of considerable uncertainties and high investments (Maskell, Bathelt &

Malmberg, 2006). In contrast to patenting, the relationship between cross-border knowledge pipelines and product innovation especially for returnees are sensitive to the cognitive distance caused by cultural and institutional contexts. It shows that returnees as transnational individuals have more advantages in technological innovation rather than the innovation of business model or market innovation.

4.2 The interaction of foreign R&D investment and returnees

To examine the interaction of foreign R&D investment and returnees, we empirically examine the moderating effect of returnees on the relationship between foreign R&D invest-

ment and firms' innovation performance. According to the empirical results shown in model 5 of Table 4 and Table 5, we find that returnees have a positive and statistically significant moderating effect on the relationship between foreign R&D investment and firms' patenting activity ($\beta = 0.5521$, $p < .001$). Returnees help overcome the liabilities of foreignness, liabilities of outsiders, and liabilities of origin for latecomer firms, facilitating to improve the effective of foreign R&D investment related to patenting (Solheim & Fitjar, 2016). In essence, innovation activities are highly associated with a culturally embedded process. Yang and Liao (2010) identified three interrelated dimensions of 'embeddedness, including societal embeddedness, network embeddedness, and territorial embeddedness'. Returnees can be understood as the concept of communities of practice to some extent, which "contributes to the solution of practical problems and bridges the gap between theoretical and practical knowledge" (Moodysson, 2008).

4.3 Moderating role of state ownership

Model 6 and Model 7 in Table 4–5 separately present the results concerning on the moderating effects of firm's ownership. We find that state ownership is not equally positive for the effect of different cross-border knowledge pipelines on firms' innovation performance. According to the empirical result in Model 6, there is a negative and statistically significant moderating effect of state ownership on the relationship between foreign R&D investment and firms' patenting activity ($\beta = -0.1295$, $p < .001$), while state ownership exerts no significantly moderating effect on the relationship between cross-border knowledge pipelines and firms' product innovation, no matter for foreign R&D investment or returnees. Hence, H3a and H3b is not supported. This implies that state ownership hinders the positive effects of foreign R&D investment on firms' innovation performance to some extent, which is line with the finding in recent some literature like Pereira et al., (2021).

Although state ownership has many advantages to help improve the effective of cross-border knowledge pipelines, absorptive capacity act as a more important moderator for the relationship between foreign R&D investment and firm's innovation. We argue that it is likely to be associated with the business model of state-owned firms in China, which always serves as the agent of government decision-making rather than seeking commercial benefits, and the process of learning the tacit knowledge required in using the foreign technology fully is made easier by strong absorptive capability represented by returnees.

5 Conclusion, implications, and future research

It has been increasingly admitted that cross-border linkages provide more valuable external knowledge than subnational connection for firms' innovation (Fitjar & Rodríguez-Pose, 2011; Fu, Woo, & Hou, 2016; Scalera, Perri, & Hannigan, 2018). Cross-border knowledge pipelines have been the primary driver of firm's innovation in many developing countries because of their immature innovation systems (Wang, 2015; Liefner, et al., 2021). Despite the importance of international knowledge sources, there are unignorable risk and tensions to coordinate and integrate the newly gained heterogeneous knowledge due to the asymmetric knowledge base, and distances of organisational structures as well as cultures within inter/intra-firms (Kim, Lampert & Roy, 2020; Fu et al., 2021). However, we argue that the most interesting question is not whether firm's innovation development benefit from cross-border knowledge pipelines, but how different types of cross-border knowledge pipelines influence firms' innovation.

Inspired by a series work of Bathelt (2018, 2020) on cross-border knowledge pipelines, this study provides an analysis on how the different types of cross-border knowledge pipelines determine firms' innovation, with a focus on foreign R&D investment and returnees. Employing the unique firm-level dataset in Zhangjiang, this study extends the debate on the potential influence of cross-border knowledge pipelines in the context of developing countries. The empirical analyse shows that both foreign R&D investment and returnees, as indicators of two distinct types of cross-border knowledge pipelines, can foster firms' patenting rather than product innovation. Moreover, the interaction of foreign R&D investment and returnees exhibits a significantly positive effect on firms' patenting activity, implying that there is substitution effect from combing foreign R&D investment and returnees. However, for state-ownership firms, we find that there is a subtractive effect for the relationship between foreign R&D investment and firms' patenting, inferring that cross-border knowledge pipelines are more likely to support for private firms' innovation.

In this study, we provide new evidence and insights to understand the role of cross-border knowledge pipelines and its relationship with firms' innovation in the context of developing countries. First, our evidence demonstrates that roles of different cross-border knowledge pipelines on firms' innovation. Departing from the original definition of cross-border knowledge pipelines within specific clusters, there have been a number of studies that focus on the role of

Table 5: Foreign R&D investment, returnees, and firms' product innovation

InNewproduct	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Size	−0.2524*** (0.0631)	−0.2544*** (0.0631)	−0.2622*** (0.0633)	−0.2654*** (0.0633)	−0.2648*** (0.0634)	−0.2544*** (0.0632)	−0.2576*** (0.0634)
Year	0.6045*** (0.2147)	0.6057*** (0.2146)	0.5743*** (0.2146)	0.5753*** (0.2143)	0.5754*** (0.2143)	0.6057*** (0.2146)	0.5580*** (0.2150)
Industry	−2.4628*** (0.2136)	−2.4618*** (0.2135)	−2.4443*** (0.2132)	−2.4422*** (0.2130)	−2.4416*** (0.2130)	−2.4619*** (0.2137)	−2.4362*** (0.2132)
Hightech	2.3602*** (0.2751)	2.3742*** (0.2765)	2.3015*** (0.2750)	2.3216*** (0.2763)	2.3163*** (0.2764)	2.3741*** (0.2769)	2.2929*** (0.2749)
Ownership	−0.0612 (0.2538)	−0.0672 (0.2539)	−0.0685 (0.2532)	−0.0780 (0.2534)	−0.0754 (0.2535)	−0.0670 (0.2577)	0.0181 (0.2641)
Export	0.2528*** (0.0427)	0.2482*** (0.0436)	0.2534*** (0.0426)	0.2464*** (0.0435)	0.2475*** (0.0435)	0.2482*** (0.0436)	0.2533*** (0.0426)
DomesticRD	0.9428*** (0.0638)	0.9394*** (0.0641)	0.9520*** (0.0640)	0.9471*** (0.0642)	0.9479*** (0.0643)	0.9394*** (0.0642)	0.9519*** (0.0640)
Parksize	−0.0434 (0.1043)	−0.0437 (0.1043)	−0.0437 (0.1043)	−0.0443 (0.1042)	−0.0420 (0.1043)	−0.0437 (0.1043)	−0.0437 (0.1042)
Parkgdp	−0.6843*** (0.1349)	−0.6857*** (0.1349)	−0.6722*** (0.1349)	−0.6742*** (0.1348)	−0.6754*** (0.1348)	−0.6857*** (0.1349)	−0.6671*** (0.1349)
ForeignRD		0.2960 (0.5761)		0.4493 (0.5814)	0.3445 (0.6209)	0.2988 (0.8131)	
Returnee			−5.3780** (2.2060)	−5.5185** (2.2211)	−5.9250** (2.4254)		−4.6389** (2.1965)
ForeignRDReturnee					3.0157 (6.1213)		
OwnershipForeignRD						−0.0055 (1.1065)	
OwnershipReturnee							−9.2543 (8.5158)
_cons	−2.3842** (1.0874)	−2.3515** (1.0884)	−2.2320** (1.0858)	−2.1770** (1.0868)	−2.1927** (1.0875)	−2.3518** (1.0899)	−2.2674** (1.0863)
var(e.InNewproduct)	11.2229*** (0.7869)	11.2100*** (0.7863)	11.1564*** (0.7819)	11.1350*** (0.7807)	11.1356*** (0.7807)	11.2101*** (0.7865)	11.1455*** (0.7811)
N	4684	4684	4684	4684	4684	4684	4684
r2	0.2680	0.2681	0.2694	0.2695	0.2696	0.2681	0.2697

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

international knowledge linkages by contrast to local interaction and considering how they contribute to the dynamics of clusters (Aarstad, Kvitastein & Jakobsen, 2016), this study based upon the micro-level data to highlight the influence of cross-border knowledge pipelines on firms' innovation. In terms of the types of cross-border knowledge pipelines, we go further in the difference and interplay between different cross-border knowledge pipelines based on foreign R&D investment and returnees. We find that these two types of different cross-border knowledge pipelines are complementary, reflecting the synergy between different types of cross-border knowledge pipelines.

Additionally, from the perspective of firms' heterogeneity, we examine the moderating role of state ownership differs in foreign R&D investment and transnational individuals to improve firm's innovation performance. Although

an agreement has been reached that global knowledge pipelines play important roles in firm's innovation, there has been little discussion about whether firm ownership may alter the relationship between global knowledge pipelines and innovation. Drawing from the analysis of results concerning the moderating impacts of state ownership, we find that state-ownership negatively moderates the relationship between cross-border knowledge pipelines and the firm's patenting, which can be interpreted as the difference in business model of state-owned firms in China, serving as the agent of government decision-making, rather than seeking commercial benefit maximisation (Nepelski & Prato, 2015). In developing economies, the state has played a significant role in promoting the building and management of cross-border knowledge pipelines, but the way in which the cross-border knowledge pipelines facilitates the

firm's innovation performance may be different, depending on the FSAs especially associated with the role of institutional factors. Our study demonstrates that it is far-reaching to operate theoretical debating and pay more attention on the specific government influence on various cross-border knowledge pipelines.

This study combines the types of cross-border knowledge pipelines and firms' innovation model to uncover heterogeneous effect of different cross-border knowledge pipelines. Innovation requires two processes, including search (the discovery of new knowledge) and transfer (the movement of the knowledge to the point of use) (Cano-Kollmann et al., 2016). The findings in this paper provide empirical evidence to support cross-border knowledge pipelines exerts more significantly positive influence on firms' patenting activity rather than product innovation.

This research we argue, therefore, has important implications for managerial and policy makers especially in developing countries. As we all known, there are nearly opposite opinions regarding the issue on the foreign technology sourcing (Tang & Hussler, 2011). Developed economies are reluctant to allow advanced technologies outflow to developing economies as their potential competitors. On the other hand, developing economies fear the over-dependence on foreign technologies and aspiration on independent innovation, which tend to hinder their aggressiveness on the acquisition of foreign technologies. Since the start of opening up and reform in the 1980s, China has been implementing an open national innovation approach by aggressively importing foreign technologies, it was in the hope of knowledge spillovers from foreign technology until the Medium to Long-term Plan focused on 'indigenous innovation' was launched in 2006. With "the dual circulation" idea put forward at the year of 2021, more recently, it marked a significant shift and the new paradigm for Chinese innovation strategies to access foreign knowledge. Our empirical results confirm the success of Chinese government's efforts on building a more sustainable and long-term innovative development strategy through constructing different cross-border knowledge pipelines.

However, while the two primary forms of cross-border knowledge pipelines become the "last supper" for mutually beneficial cooperation between China and the rest of world, will there be new alternatives or options to provide cross-border knowledge flows? In other words, whether are there new approaches to build cross-border knowledge pipelines? There are risks associated not only with de-globalization but also with a continuation of globalization that excludes China. Given the current political and economic environment as well as the COVID-19, these traditional channels to build cross-border knowledge pipelines are facing more uncertainties and risks than ever before,

whether it is through foreign R&D investment or through transnational individuals. Obviously, the discussion of cross-border pipelines worth giving more thinking in the future. We hence argue that it deserves more research work on cross-border knowledge pipelines in future, to deepen the debate on international knowledge flow. Due to the limitations of data availability, we only make empirical examinations with cross-sectional data in the year of 2015. If possible, it would be more meaningful to use panel datasets to go a step further by investigating the different influences of cross-border knowledge pipelines particularly after the periods of the COVID-19.

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