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Barriers to innovation and innovation performance: The mediating role of external knowledge search in emerging economies

Abstract

Using survey data from companies located in the Wuxi (Taihu) international science park in China, we aim to analyze to what extent science park residents experience barriers to innovation and to what extent opening up the innovation process allows them to overcome constraints and increase innovation performance. Findings indicate that surveyed firms that mostly undertake incremental innovation perceive many constraints and that the depth of external knowledge search—that is, the intensity of the relationship with external sources of knowledge—significantly influences innovation performance, mediating the relationships between innovation barriers and innovation performance. Our results allow us to explain how open innovation practices can be used to mitigate existing barriers, and therefore permeate the knowledge filter, and to theorize on the importance of institutional factors for open innovation theory in emerging economies.

Keywords: Open innovation; Science parks; Barriers to innovation; China; Innovation performance.

Tweetable headline: Is quality not quantity that matters! The intensity of relationships with external knowledge sources helps to mitigate innovation constraints, facilitate the flow of knowledge and enhance innovation performance in emerging market firms.

We surveyed high-tech SMEs located in the Wuxi (Taihu) international science park in China to find out to what extent external firm barriers to innovation have an impact on the innovation performance of science park residents, and how open innovation strategies affect this relationship. Here the main implications:

- 1) Research: Institutional factors need to be considered when studying open innovation, particularly in an emerging country context. Results emphasize the importance of deeper external knowledge sources as one mechanism to mitigate institutional barriers.
- 2) Management: Human resource constraints are an important barrier for SMEs and managers should stimulate learning through reward systems and training that increase absorptive and innovative capacity ability.
- 3) Policy: Local officials responsible for the management of science parks in China should put more efforts in providing financial support by creating specialized venture capital and a better knowledge of risk analysis from the financial system.

JEL codes: O36; O32; L26.

1. Introduction

Innovating organizations are likely to face many challenges and impediments throughout the innovation process (D'Este et al. 2012; Madrid-Guijarro et al. 2009; Sandberg and Aarikka-Stenroos 2014). While some authors consider innovation barriers advantageous as they screen out the most impractical innovation projects (Hölzl and Janger 2012), extant studies reveal that barriers normally either prevent or hamper innovative activity (D'Este et al. 2012; Hadjimanolis 2003; Larsen and Lewis 2007). To overcome these obstacles, several scholars have recommended that pursuing assistance from external actors is a critical part of the organization's innovation strategy; as a result, the way that organizations innovate is becoming more open (Chesbrough 2003; Chesbrough et al. 2006). In this innovation-focused framework, governments, research institutions, and organizations are taking action to foster innovation (Figlioli and Porto 2012). Some of these initiatives comprise producing environments that foster interaction amongst different stakeholders at the local level. Science parks, for example, have risen to prominence as settings with advantageous conditions for innovation (Bellavista and Sanz 2009), with past research demonstrating that organizations gain from complementary knowledge when they co-locate in an industrial cluster to take advantage of knowledge collaboration and spillover (Audretsch and Belitski 2019; Belitski and Desai 2016). The large majority of science parks are policy-driven, government-sponsored initiatives and agglomerations (Huang et al. 2012), and are intended to foster the emergence and development of on-site technology and knowledge-based organizations, allowing resident organizations to have access to resources and settings at lower transaction costs (Williamson 1991). This is particularly pertinent in the case of emerging economies like China, where science parks operate as government agencies but have relatively high autonomy and take a pivotal responsibility in driving innovation (Huang et al. 2012).

However, in spite of science parks' extensive diffusion and the favorable conditions

for science park residents, there is still no settlement on the usefulness of science parks (Albahari et al. 2018). Therefore, we ask: *To what extent do external firm barriers to innovation have an impact on the innovation performance of science park residents, and how do open innovation strategies affect this relationship?*

Building on the knowledge spillover theory of entrepreneurship (KSTE) (Audretsch and Keilbach 2008; Audretsch et al. 2006; Audretsch and Belitski 2013; Belitski and Desai 2016), and using the knowledge filter concept to express spillover barriers (Acs et al. 2004), we intend to analyze to what extent high-tech firms located in science parks in an emerging economy face barriers to innovation and to what extent they overcome these challenges—in particular, by opening up their innovation process through external knowledge breadth or depth (Laursen and Salter 2006). This follows recent calls for a better understanding of how open innovation practices enhance knowledge spillovers in emerging economies (Kafourous and Forsans 2012; Spithoven et al. 2013) and the need to study the efficiency of science parks in China (Tian 2013).

Our empirical study is based on a survey of 137 firms operating in the Wuxi international science park, one of the 53 state-level parks created by the Ministry of Science and Technology of China. Results indicate that science park residents perceive barriers to innovation in terms of qualified personnel, inter-firm cooperation, and financial constraints, but those barriers do not significantly limit their innovation performance. While most of the firms innovate, their innovation is mostly incremental in nature. Findings indicate that firms facing barriers to innovation increasingly turn to external knowledge searches, namely drawing deeply from external sources of knowledge, with a positive influence on innovation performance. Results also denote that external knowledge depth¹ mediates the relationship between barriers to innovation and innovation performance.

¹ We followed Laursen and Salter (2006), who define external knowledge depth as the degree to which companies draw on different search channels as sources of knowledge that are intensively integrated into the firm's innovation processes.

The contributions of this study are threefold. Firstly, the study shows that science parks in emerging economies allow resident firms to innovate despite perceived barriers, and therefore play an important role in innovation ecosystems, empirically testing past theoretical arguments (Albahari et al. 2018). Therefore, our study adds to the literature on science parks by adding to the knowledge on the efficiency of science parks as an instrument of innovation and the scholarly discussion of whether innovation needs to be spatially limited or if science parks could eventually be a limit to innovation. This is particularly important when advanced information and communication technologies (ICTs) make cooperation across locations and borders possible (Boschma 2005), and when foreign market knowledge acquisition through international activity has been proven to be important for improving innovative capabilities (Torres de Oliveira et al. 2019; Williams et al. 2016).

Secondly, from an open innovation viewpoint, this research highlights the importance of external sources of knowledge to increase innovation performance, and the importance of deep openness to mitigate barriers to innovation. Therefore, we add to the debate by not only focusing on the barriers to open innovation strategies themselves (e.g., Savitskaya et al. 2010; V. van de Vrande et al. 2009) but also on how open innovation can be used as a strategy in itself to diminish barriers to innovation performance. In addition, we contribute to the knowledge-sourcing literature by explaining that knowledge-sourcing is also based on institutional and strategic reasoning. Indeed, this results extends the findings of previous studies which identify absorptive capacity (De Nicolai et al., 2016), technological, cognitive, and cultural proximity (Boschma, 2005; Balland et al. 2015) as well as geographic perspective (Roper et al. 2017) as relevant factors influencing external knowledge search.

Finally, we add to the KSTE (Audretsch & Keilbach 2007; Audretsch et al. 2006) by explaining how high-tech emerging-economy firms located in a science park are permeating the knowledge filter (Braunerhjelm et al. 2010) by engaging in deeper open innovation

strategies, thus circumventing existing institutional barriers. As such, we uncover the importance of institutional factors when studying open innovation. Moreover, we highlight the importance of deeper open innovation as one mechanism to penetrate the knowledge filter in addition to other mechanisms identified in previous studies like entrepreneurship (Acs et al., 2004; Carlsson et al., 2009) and absorptive capacity (Qian and Jung, 2017).

2. Theoretical framework and hypotheses

2.1. Barriers to innovation and innovation performance

Knowledge and innovation are vital to firm competitiveness, and, increasingly, companies are abandoning the idea that knowledge generation is mostly an internal process and are starting to source knowledge externally (Colombo et al. 2011) within local ecosystems (Audretsch and Belitski 2017), collaborating with competitors, suppliers, and research institutes and universities (Scandura 2016). This strategy has augmented the significance of external sources of knowledge to a central strategic problem (Howells 2006).

Diverse knowledge-based intensive research institutions, namely universities, private research institutions, and business services, have been recognized as means for knowledge spillovers, stimulating organizations to advance their inner innovative resources and capabilities (Thomä and Bizer 2013). According to the KSTE (Carlsson et al. 2009; Audretsch and Keilbach 2008; Audretsch and Lehmann 2005), designs and knowledge created in one firm context (such as an organization or university research laboratory) but which are left uncommercialized as the outcome of the ambiguity inherent in knowledge, assist as a basis of knowledge-generating entrepreneurial prospects.

However, barriers can preclude current knowledge from being transformed into economic knowledge (Braunerhjelm et al. 2010). These barriers have been denoted as “knowledge filters.” The manifestation of a knowledge filter fosters the difference between

the beneficial knowledge created by knowledge-creating organizations and the genuine knowledge that organizations eventually commercialize (Audretsch et al. 2020; Audretsch and Keilbach 2007). Most authors categorize barriers into internal and external obstacles (Hadjimanolis 2003; Madrid-Guijarro et al. 2009; Piatier 1984). Internal obstacles are those that arise inside the company (e.g., mindset, competencies, resources, organizational structure), while external barriers or institutional factors (e.g., the education system, availability of specialized human resources, the financial system) are those that result from the external environment and are largely uncontrollable by single firms (Sandberg and Aarikka-Stenroos 2014).

The KSTE erects on the foundation that the spillover of knowledge—particularly its tacit element—is spatially bounded (Howells 2002). The theory states that entrepreneurship is higher in the presence of larger investments in knowledge. Prospects for entrepreneurial activities are higher when the aptitude to access knowledge spillovers from geographically neighboring sources is superior. This can be the case when the entrepreneur is situated in nearby proximity to research-intensive institutions, universities, large high-technology organizations, or other that produce knowledge (Audretsch and Lehmann 2005), such as in science parks (Audretsch and Belitski 2019). Science parks usually offer science park residents favorable conditions for innovation (Vásquez-Urriago et al. 2016) in the form of physical infrastructure, support services, and relationship networks with other firms and with other research intensive centers such as universities, among others.

From the late 1980s that the Chinese Government has been encouraging the emergence and expansion of national science parks (Hu 2007; Cheng et al. 2014), which are regarded as very important components of China's National Innovation System. Although science parks have been vigorously encouraged by overseas firms, China's political and legal system, culture, and economic development strongly influence the purpose, function, and

behavior of Chinese science parks compared with their foreign equivalents (Macdonald and Deng 2004). Authors have found that their solid prejudice toward production and export-oriented high-technology manufacturers and their heavyweight dependence on overseas investment sets China's science parks apart from those found in developed economies (Sutherland 2005). Moreover, science parks in China have a hierarchical structure, with national-level parks enjoying more preferential policies than local- and municipal-level parks (Cheng et al. 2014) that have been established in recent years as a result of political decentralization (Zhang and Wu 2006).

In spite of their widespread diffusion and the favorable conditions for science park residents, we still lack consensus on the efficacy of science parks (Albahari et al. 2018). Considering the ambiguity of the results of previous studies (e.g., Fukugawa 2006; Siegel et al. 2003; Yang et al. 2009; Hansson et al. 2005; Colombo and Delmastro 2002) and the characteristics of the Chinese business system (Redding and Witt 2009)—that is, the government's strong role, lack of clear definition of property rights, financial intermediaries mostly oriented toward state-controlled firms, top-down supervisor–subordinate relationships, and a weak education system—we assume that, despite the favorable environment, science park residents may still face constraints to innovations.

2.2. External knowledge search and innovation performance

Open innovation is a paradigm that states that when organizations look to develop their technology or innovations, they can and should use external ideas instead of depending only on internal areas (Chesbrough 2006). Indeed, many organizations are increasingly considering knowledge and ideas from external sources of the organizational boundaries to stimulate innovation and improve the firm's innovation performance (Badawy 2011; Gambardella and Panico 2014; Love et al. 2014; Grigoriou and Rothaermel 2017; Van de

Vrande 2013; Verreyne et al. 2020). According to Laursen and Salter (2006), external knowledge can be measured by external search breadth and depth. External search breadth is defined as the number of different sources of knowledge that a firm relies upon for their innovation activities, and external search depth is outlined as the extent to which organizations extrapolate from external sources (Laursen and Salter 2006).

The combined use of external and internal knowledge to stimulate a firm's innovation is an important cornerstone of the open innovation concept (Chesbrough 2006), and recent studies indicate that the concurrent engagement in co-creation with external partners and internal innovation delivers extra improvements in new product or service commercialization (Audretsch and Belitski 2019). However, the management of knowledge spillovers and knowledge collaboration remains one of the main challenges facing firms (Audretsch et al. 2020; Belitski et al. 2019). Studies suggest that firms might diverge in their capacity both to engage in knowledge-sourcing actions and exploit the local knowledge infrastructure (Roper et al. 2017; Audretsch and Belitski 2019). Indeed, scholars indicate that different factors such as absorptive capacity (Denicolai et al., 2016), geography (Roper et al., 2017), technological, cognitive, and cultural proximity (Boschme,2005; Balland et al., 2015) influence external knowledge source. Moreover, constraints in effectively applying resources are important as they have an impact on innovative performance and a firm's search approach in both breadth and depth (Garriga et al. 2013).

Past research on both developed and emerging economies has shown that there is a significant positive relationship between dissimilar constraints to innovation and external knowledge search. With a large-scale panel data from a Swiss Innovation Survey, Keupp and Gassmann (2009) investigated in what way constraints to innovation impact on the depth and breadth of knowledge search. The researchers combined innovation barriers into information- and capabilities-related constraints and risk-related obstacles. Their results show that both

innovation barrier groups positively and significantly impact the breadth and depth of knowledge search. Using the same survey, Garriga and colleagues (2013) established that obstacles related to organizational resources affect external search breadth and depth positively in the case of incremental innovation but not radical innovation.

In an emerging-economy setting, and with a Chinese manufacturing firm-level survey, Fu and colleagues (2014) show that Chinese firms that suffer from different innovation barriers (finance/risk, knowledge/skills, and institute/market barriers) are more likely to engage in external knowledge searches, both from a breadth and depth perspective. Yet, the strength of those relationships varies across firm size, technology intensity, and ownership type. The same authors argue that external knowledge search should be expected in firms in emerging economies since they tend to face substantial resource, capability, and institutional constraints, which impact their innovation performance. When considering the science park environment, we might also expect that these barriers will also be drivers for collaboration (Belitski 2019). Building on those results, we suggest the following:

H1. Barriers to innovation positively affect the external knowledge search of science park residents.

To grow and innovate, organizations need to agglutinate different sources of outside knowledge to take advantage from investment in research and development (R&D) and vice versa (Audretsch and Belitski 2020). In fact, the specific element of knowledge is at the core of open innovation (Dahlander and Gann 2010; Lopez-Vega et al. 2016; Mina et al. 2014; van de Vrande and de Man 2011). For example, Laursen and Salter (2006) found that depth and breadth searching across a multitude of search channels can provide organizations with new ideas and resources that they can use to improve their innovation performance and opportunities. Access to broad knowledge facilitates understanding of new information

(Chiang and Hung 2010) and potential changes, and helps to increase the organization's knowledge pool (Ferrerias-Méndez et al. 2015). External knowledge can help companies to find new market opportunities (Wang et al. 2015) and the possibility of finding technical solutions to meet customer needs (Hargadon and Sutton 1997).

More intense links with different external sources of knowledge provide firms with access to different forms of knowledge and abundant opportunities to learn (Love et al. 2014). Moreover, external knowledge searches through the intensive use of different channels allow firms to deepen their knowledge and relationships with other partners and enable a common approach when working together (Cruz-González et al. 2015). However, we also know that when the strategy on OI exceeds a threshold the firms' performance decline (Zhang et al. 2018). Indeed, an overreliance on OI investment might present challenges to firms' as managing the span of attention (Simon 1947), not-invented-here syndrome (Katz and Allen 1982; Gentile-Ludecke et al. 2020), and might attract opportunistic behavior from partners (Zhou et al. 2018), which is particularly relevant in countries with weak institutional frameworks as China.

However, we argue that a knowledge-rich environment, such as a science park, can strengthen an organization's ability to innovate (Audretsch and Belitski 2019) as it facilitates the flow of ideas and entrepreneurial activity (Audretsch and Keilbach 2007) and can moderate the opportunistic behavior mentioned before. If organizations are entrenched in the right networks and relationships, they can create relational rent from their associations within the science park residents or benefit from positive externalities. Indeed, science park residents disperse knowledge that can be captured and used by others but also profit from knowledge spillovers transmitted by neighboring firms (Díez-Vial and Fernández-Olmos 2015). Past research show the effect of a firm's closeness to organizations with related knowledge (Belitski and Desai 2016). These firms can benefit from access to specific

resources and assets, learning economies following collaboration with suppliers and customers, and reduced transaction costs due to their close proximity (Almeida and Kogut 1999; Ketels and Memedovic 2008; Sarkees et al. 2010). Proximity, in fact, helps to identify useful external knowledge, reduces search and exploration costs, and helps to reduce the risk of opportunistic behavior because of increased interaction (Boschma, 2005)—particularly unofficial networking activities, which are frequent on science parks (Díez-Vial and Fernández-Olmos 2015). Therefore, we propose:

H2. External knowledge search positively influences science park residents' innovation performance.

2.3. The mediating effect of external knowledge search

Government have considered science parks as innovation and used local development strategy instruments to foster the growth and creation of local knowledge-based entrepreneurship (Amoroso & Soriano, 2019). Debating on the effectiveness of science parks, studies have recognized their heterogeneity and evolution, as well as the importance of considering the interactions and networks amongst the different stakeholders involved with the science park (Wright et al. 2019). Knowledge spillovers are a cornerstone illustrative factor in the gathering of innovative firms; however, not all knowledge that spills over is picked up and developed by entrepreneurs into economically useful knowledge because of the knowledge filter (Acs et al., 2004). The knowledge filter facilitates or detracts from the ease with which entrepreneurship, knowledge transformation and commercialization occur. If the filter is tight or highly restrictive (e.g. where the regulatory environment is excessive or capital availability is highly constrained), it is difficult for knowledge to be converted into something that is economically useful (Acs et al. 2004). In the same logic, we propose that companies that have developed relationships with other firms in search of external

knowledge are more able to exploit the knowledge externalities and penetrate the knowledge filter. In fact, the question of how a firm's use of external sources of knowledge, both depth and breadth, mediates the relationship between constraints and innovation performance remains unexamined.

Firms that experience barriers to innovation are likely to capitalize on external opportunities to boost their innovation efficiency. Indeed, science parks offer infrastructure that ties together ideas, business initiatives, scientists, and technology, and facilitates access to different resources for innovation as well as enabling knowledge creation. Science parks provide an environment for cooperation and information exchange that eases the knowledge search process. Therefore, we posit that:

H3. The relationship between barriers to innovation and innovation performance is mediated by external knowledge search.

Our conceptual framework can be found on Figure 1.

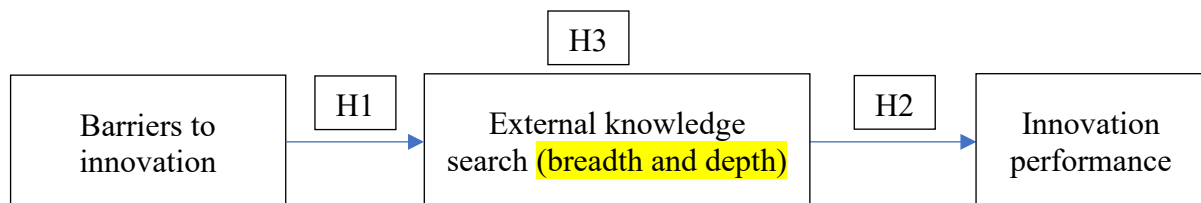


Fig. 1. Conceptual framework.

3. Methodology and data

3.1. Sample and data collection

We conducted a survey at the Wuxi international science park. The park is an important part of the Wuxi National High and New Tech Development Zone, founded in 1992 with the aim of being a center of scientific innovation and industrial transformation in specific industries:

equipment and machinery manufacturing, cloud computing and the Internet of Things, microelectronics, and new materials. In 2013, Forbes ranked Wuxi as the fifth-best business city in Mainland China; Wuxi also leads the ranking out of 90 smart cities in China (China Daily 2016). Currently, 1050 companies and 59 R&D centers reside in the park.

Similar to other national-level science parks, in order to reside in the Wuxi park, firms must meet certain qualifications: they must create or employ technology in new or high-technology products, they should devote as a minimum 3% of their yearly gross revenue to R&D, at least 30% of the employees are required to possess college degrees, and companies have to be recertified annually. Qualified firms receive a range of tax and regulation benefits (including a three-year deferral of corporate tax along with a reduced tax rate after that) an exemption for the first RMB 300,000 produced from technology abroad, and an exemption from import licenses for technology material or parts used in export production (Zhang and Sonobe 2011).

The choice of the Wuxi science park has specific motivations. Being a recent park in one of the most developed provinces of China, Jiangsu, we believe that it meets the best possible conditions for the emergence and development of innovation through new ventures, as well as for the creation of disruptive systems. Furthermore, having gained access through a group of officials who approved the study and introduced it to the companies operating in the park, we were able to avoid the constraints of high bureaucratic processes and control, which are known to be common in China (Torres de Oliveira and Figueira 2018, 2019).

The survey was conducted over two months, between November and December 2016. The questionnaires were delivered personally to senior managers of 180 randomly selected firms. The number of companies to be sampled was agreed upon with the group of officials who supported the study. The survey was written in English and translated to Chinese; to ensure language accuracy and validity, we conducted back-translation (Brislin 1970),

contracting two different Chinese professionals. Out of the 180 distributed questionnaires, we received 137 questionnaires, which were subsequently analyzed in this study. Table 1 summarizes some characteristics of the sample firms.

Table 1

Characteristics of the respondents and company percentage ($n=137$).

<i>Sector of activity</i>	<i>%</i>
Information and communication technology	47.5
Industrial product and services	26.3
Other service	26.2
<i>Size</i>	
1–250 employees	97
> 250 employees	3
<i>Ownership</i>	
<i>Chinese firms</i>	89.0
- State-controlled Enterprises	5.1
- Listed companies	1.5
- Companies with many investors	64.2
- Family business	18.2
<i>Foreign-owned firms</i>	11.0
- Joint venture	7.3
- 100% foreign-owned	3.6
<i>Degree of internationalization—Sales</i>	
- Asia	12.4
- World	16.2
<i>Customers</i>	
- Business to business	49.6
- Business to consumers	38.7
- Public sector	11.7

Source: Own analysis based on survey data

Almost fifty percent of the firms under study work in the ICT sector. With an average activity of almost six years, many companies in the sample are start-ups or firms in the first development stage. Two-thirds of the Chinese firms that constitute the large majority (89%) of the surveyed sample have a number of investors, with only 18.2% being family-owned. Only a marginal number of firms have a state-controlled ownership structure.

3.2. Measures

3.2.1. Dependent variable

In our study, the dependent variable is innovation performance, measured as the summated number of the forms of innovation introduced in the period 2012–2014, similar to Apanasovich and colleagues (2016), Forés and Camisón (2016), or Verreyne and colleagues (2019). In the survey, companies were asked whether they introduced any of the following innovation types: product, service, process, organizational (three categories), and/or marketing (two categories). These types of innovation were coded following the Organisation for Economic Co-operation and Development (OECD) manual on innovation data collection and interpretation (OECD 2005). We generated a dummy for each innovation outcome and then used the sum of the eight dummies to formulate our innovation variable.

3.2.2. Independent variables

The independent variables in the study included business system barriers and sources of external knowledge. To capture the barriers to innovation, we used variables derived from the literature (Fu et al. 2014; Laursen and Salter 2014; Roper et al. 2017; Audretsch and Belitski 2019). We asked respondents to indicate if the aspects identified constrained their innovation activities and were considered important in taking the decision not to invest. The barrier variable was measured using 21 items adapted from Fu and colleagues (2014) using a five-point Likert scale (1=unimportant, 5=very important). These authors validated a multidimensional measure of barriers to innovation with three dimensions: financial barriers, skill relationship barriers, and market and institutional barriers.

External knowledge search was operationalized using two constructs: external knowledge breadth and external knowledge depth (Laursen and Salter 2006). In the questionnaire, the participants were asked about the level of importance of information sources they have used for innovation activities, including: suppliers; customers; competitors;

consultants; universities; government or public research institutes; conferences; scientific journals; professional and industrial associations; and professional, industry or service standards (ranging from 1=not at all important to 5=crucial). External knowledge breadth of innovation was then measured using the sum of the number of external knowledge sources that were integrated into the innovation process of the firms operating in the science park; that is, the sources that the participants reported as being at least slightly important. On the other hand, the external knowledge depth of innovation focused on the sources that were deeply integrated into the firm's innovation process and the extent to which companies drew on different search channels; that is, the sources that the participants reported as being crucial. We then took the sum of these sources to create our external knowledge depth of innovation variable.

3.2.3. Control variables

In the study, we included the age of the firm, ownership, and industries as control variables. While young/newly established and family firms have a higher chance of innovating because they are more likely to engage in risk-taking activities (Coad et al. 2016), the mature, state-owned and listed firms have advantages in mobilizing resources to meet the demand for innovation activities (H. Gao et al. 2018). In our study, firm age was measured by years in business (log). The ownership variables were classified into state-owned, public (listed/multiple investors), family business, and foreign direct investment firms. These categories were then recoded as dummy variables. We also added industries as control variables because there are different innovation strategies between industries, where manufacturing firms are more likely to invest in a wider range of innovations than service firms (Ettlie and Rosenthal 2011). In this study, firm industries were classified into three

binary variables: ICT, manufacturing, and service. Table 2 provides a summary of our variables.

Table 2

List of variables.

Variable	Description	Scale
Innovation performance	Summated number of the types of innovation introduced by the companies in the period 2012–2014 Types of innovation: product, service, process, organizational (three categories), marketing (two categories)	count (from 0 to 8)
External knowledge breadth	A number of external sources provided information for new innovation projects or for the completion of existing ones. (10 major external sources: suppliers, customers, competitors, consultants, universities, government, fairs, scientific journals, industrial associations, technical standards)	count
External knowledge depth	Number of the abovementioned external sources that were considered by the firm as crucial (highest usage, score of 5)	count
Barriers to innovation	Perceived importance of three innovation barrier dimensions. 1. Financial barriers: perceived importance of the following factors as barriers to innovation (five items): excessive perceived economic risk, direct innovation costs too high, cost of finance, lack of finance from sources outside the company, lack of funds within the company 2. Skill and relationship barriers: perceived importance of the following factors as barriers to innovation (10 items): lack of qualified personnel, lack of incentives for training investment, lack of rewards for innovation, lack of freedom to develop own ideas, low level of idea sharing within the firm, strong control and orientation of work from the boss, low level of cooperation inside the company, lack of information on technology, lack of market information, difficulty in finding partners to innovate together. 3. Market and institutional barriers: perceived importance of the following factors as barriers to innovation (six items): low level of confidence in local institutions, low level of protection of intellectual property, influence from governments (central, provincial, and local) active involvement of the government in R&D activity, a market dominated by established enterprises, low-level relationship with research institutions.	factor score
<i>Control variables</i>		
ownership	4 Dummies	1=State-owned company; 2= Listed/multiple investors company; 3=Family business; 4=Foreign directed investment company
Firm age	Year of foundation	count (log)
Industry	3 Dummies	1=yes

3.3. Bias testing

We achieved a response rate of 76%. This high response rate helped us to avoid the problems of non-response bias (Babbie 2007). In addition, interviewing senior managers who have comprehensive knowledge about the operation and management of their business allowed us to control for respondent bias (Slater and Narver 2000).

Regarding the potential concern of common method bias from the use of a field survey technique (Chang et al. 2010), we used procedural remedies ex-ante and mixed the order of the questions on the questionnaire. Moreover, we did an exploratory examination and applied the Harman one-factor extraction check. The factor analysis of the variables exposed that nine factors had eigenvalues greater than one. No single factor explicated more than 50 percent of the variance, thus supporting that a common method bias was not a problem in our study (Podsakoff et al. 2003).

3.4. Analysis method

We combined different statistical software to conduct our study. First, we used the Statistical Package for Social Sciences (SPSS) version 25 to run our factor analysis and estimate the factor scores. We then utilized the Hayes Process Macro program version 2.6 with ordinary least squares regression to test our hypotheses; the use of this program allowed us to test both the direct and indirect relationships simultaneously.

4. Results

4.1. Factor analysis

We first checked the adequacy of the data. The Kaiser-Myer-Olkin statistic was greater than 0.6, indicating sampling adequacy. The Skewness and Kurtosis values were less than 3.29,

implying that our data were normally distributed. The outliers were ensured by examining the Mahalanobis distance (Kline 2011).

We then ran confirmation factor analyses for the three dimensions of business system barriers. The individual confirmatory factor analysis (CFA) (Abrami et al. 2014) models were developed using the validated items in Fu and colleagues (2014). The higher-order CFA model of business system barriers was then formulated by combining these three first-order factors. These models were also modified to ensure the goodness of fit. The values of the obtained fit indices show that the models fit the data well (Hair et al. 2010; see Table 3).

Table 3

Goodness of fit for the CFA models.

CFA models	χ^2	p	CFI	TLI	NFI	RMSEA
Financial barriers	4.095	0.393	1.000	0.999	0.987	0.013
Skill and relation barriers	43.363	0.107	0.987	0.983	0.950	0.048
Market and institution barriers	2.267	0.322	0.999	0.995	0.995	0.031
Barriers to innovation	238.102	0.000	0.961	0.947	0.895	0.062

The reliability and validity were tested using Cronbach's alpha, the composite reliabilities (CR), the average variance explained (AVE), and the correlations among constructs. In our models, the CR values ranged from 0.88 to 0.91, which were greater than the cut-off point of 0.70 (Hair et al. 2010). The Cronbach's alpha values were all greater than 0.8, indicating the reliability of the scales (Kline 2011). The AVE values were higher than the cut-off value of 0.5, whereas the correlations between these constructs were less than the mean squared root of AVE, thus suggesting convergent and discriminant validity (Hair et al. 2010; see Table 4).

Table 4

Correlation between constructs and the reliability and validity.

Measurement	Cronbach's Alpha	CR	AVE	1	2	3
1. Financial barriers	0.83	0.88	0.62	0.787		

2. Skill and relation barriers	0.92	0.93	0.58	0.656	0.762	
3. Market and institution barriers	0.86	0.90	0.59	0.534	0.728	0.768
4. Barriers to innovation	0.94	0.91	0.76			

Note: Squared root of AVE in bold. No correlation between first-order and higher-order constructs.

4.2. Descriptive analysis

4.2.1. Innovation barriers

Table 5 presents the degree to which companies considered the importance of business system barriers.

Table 5

Barriers to innovation ($n=137$).

Factors	Items	Percentage
Finance barriers	Excessive perceived economic risk	73.7
	Direct cost for innovation too high	75.9
	Cost of finance	73.0
	Lack of finance from sources outside your company	72.3
	Lack of funds within your company or group	60.6
Skill and relation barriers	Lack of qualified personnel	76.6
	Lack of incentives for training investment	67.9
	Lack of freedom to develop own ideas	65.0
	Lack of rewards for innovation	67.2
	Low level of ideas sharing within the firm	65.0
	Strong control and orientation of work from the boss	62.0
	Low level of cooperation inside the company	51.8
	Lack of information on technology	67.2
	Lack of market information	65.7
	Difficulty in finding partners to innovate together	70.8
Market and institution barriers	Low level of confidence in local institutions	61.3
	Low level of protection of intellectual property	63.5
	Influence from governments—central, provincial, and local	68.6
	Active involvement of the government in the R&D activity	65.0
	Low level of relationship with research institutions	56.9
Market dominated by well-established companies	66.4	

Source: Own elaboration based on survey data

Overall, the surveyed companies seem to perceive a large number of constraints generated by the characteristics of the Chinese business system. More than 70% of the firms

identified the financial system as the most problematic constraint to innovation. Four out of the six barriers that 70% of the firms indicated as very important were related to the financial sector. The other two important barriers were related to the lack of qualified personnel (76.6%), which is the barrier with the highest proportion of importance, and difficulty in finding a partner to innovate with (70.8%). The least important constraint was considered to be the lack of cooperation inside the company.

4.2.2. Innovation performance

In our sample, more than two-thirds of firms introduced at least one of the abovementioned types of innovation. Approximately one-third of the firms that reported an innovation developed new services (37.2%) or new products (36.5%). Two-thirds of the firms indicated that the innovation had an adaptive character, being only new to the company. For one-third of the firms, the innovation was radical in nature, and a large proportion of those companies (64%) applied for patents. Almost half of the surveyed firms carried out process innovation, while 51.8% and 40.14% reported organizational and marketing innovations respectively. Hence, results indicate that for the majority of surveyed firms, the perceived constraints limited the innovation activity to a mere incremental innovation.

Table 6

Degree of innovation of the surveyed companies (%).

<i>Companies with at least one type of innovation</i>	77.4
<i>Companies that did not innovate</i>	22.6
<i>Product innovation</i>	
New goods	38.0
New services	37.2
Radical product innovation	36.5
Incremental product innovation	63.5
Product innovation new to market	75.5
Product innovation new to firm	24.5
<i>Process innovation</i>	

New processes	44.5
Organizational innovation	
<i>Total organizational innovation</i>	51.82
New/improved management systems	27.7
Major changes in internal work organization	38.7
New relationship with enterprises/public institutions	31.4
Marketing innovation	
<i>Total marketing innovation</i>	40.14
Changes in the design and packages of product/services	17.5
Changes in sales and distribution processes	36.5

Source: Own analysis based on survey data

4.2.3. External knowledge search

Table 7 shows the level of openness of innovation in the surveyed firms. The results indicate that among external knowledge sources, clients or customers are placed at the top, with 34.4% of firms using clients as their most important source for innovation activities. This is in line with the highest mean value of levels of importance of this source (3.87 out of 5). Suppliers and competitors are the next most important sources for searching innovation, while less importance is given to institutional information (government or public research institutes, scientific journals, professional associations) and consultants.

Table 7

Information sources for the innovation activity (1= unimportant, 5= very important).

Information sources	% of firms that regard this source as very important (=5)	Mean of importance
Suppliers of equipment, materials, services	24.4	3.57
Clients or customers	34.4	3.87
Competitors	24.4	3.43
Consultants	18.9	3.22
Universities	20.0	3.39
Government or public research institutes	18.9	3.07
Conferences, trade fairs	20.0	3.07
Scientific journals	16.7	3.11
Professional and industrial associations	16.7	3.38

Professional, industry or service standards	20.0	3.36
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Sources: Own elaboration based on survey data

4.2.4. Correlation matrix

Table 8 presents the descriptive statistics of the variables with the correlation coefficients.

The correlation matrix shows that there is a significant association among the variables used in the analysis. Innovation performance significantly correlates with both external knowledge breadth and depth but not barriers to innovation. External knowledge depth positively correlates with barriers to innovation, while this significant correlation does not hold for external knowledge breadth. Table 8 also shows a significant negative correlation between external knowledge breadth and foreign-owned firms, which is interesting in itself.

Table 8

Descriptive statistics and correlations.

	Mean	Std. Deviation	1	2	3	4	5	6	7	8	9
1 innovation_performance	2.6788	2.1418									
2 barrier	3.5860	0.6989	-.044								
3 ex_know_depth	1.5766	2.9072	.251**	.278**							
4 ex_know_breadth	9.2044	1.0923	.255**	.044	.296**						
5 age	3.1818	3.2687	.062	.011	-.010	.099					
6 owner_soe	0.0511	0.2210	-.012	.011	.091	.017	-.055				
7 owner_family	0.1825	0.3877	-.124	.040	.023	-.002	-.087	-.110			
8 owner_FDI	0.1095	0.3134	.064	.024	-.159	-.238**	.039	-.081	-.166		
9 sector_manu	0.3577	0.4811	-.088	.042	.004	.000	-.139	-.035	.042	-.067	
10 sector_service	0.1460	0.3544	-.112	-.102	-.132	-.059	.126	.092	.179*	.120	-.309**

Note: Pearson correlation. ** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

Source: Own calculation based on survey data.

4.3. Hypotheses testing

In our regression models, the barriers to innovation have a negative but non-significant impact on the innovation performance of science park residents (Model 1, Table 9; Model 4, Table 10). Regarding the relationship between barriers to innovation and external knowledge search, results show that barriers to innovation positively influence external knowledge depth, and this relationship is significant at the 1% level (Model 2, Table 9). Experiencing one increase in the barrier will require firms to use 0.8621 more important sources of external knowledge to innovate. However, this positive relationship does not hold for external knowledge breadth (Model 5, Table 10); thus, H1 is only partially supported. The regression results also confirm a positive relationship between external knowledge search and innovation performance, meaning that an increase of one in the number of external knowledge search sources will result in a 0.2598 and 0.5616 increase in the number of innovations introduced respectively. Hence, H2 was accepted (Model 3, Table 9; Model 6, Table 10).

Table 9

Ordinary Least Squares regression on the relationship between barriers, depth, and innovation performance.

	Innovation Performance	Depth	Innovation Performance
	(Model 1)	(Model 2)	(Model 3)
barrier	-0.132 (0.1901)	0.8621*** (0.2393)	-0.356 (0.1895)
ex_know_depth			0.2598*** (0.0677)
age	0.0363 (0.0589)	0.0082 (0.0742)	0.0342 (0.0559)
owner_soe	-0.0662 (0.8577)	1.2548 (1.0798)	-0.3922 (0.8182)
owner_family	-0.4658 (0.5192)	0.3032 (0.6536)	-0.5445 (0.4930)
owner_FDI	0.361 (0.6120)	-1.2399 (0.7705)	0.6831 (0.5867)

sector_manu	-0.5962 (0.4177)	-0.2564 (0.5259)	-0.5296 (0.3968)
sector_service	-0.9968 (0.5832)	-0.8771 (0.7343)	-0.769 (0.5566)
R2	0.054	0.1428	0.1556
F	1.021	2.952**	2.834**

Note: Base: public firms, ICT sector. ***significant at 0.1% level; **significant at 5% level; * significant at 1% level, standard errors in parenthesis.

Table 10

Ordinary Least Squares regression on the relationship between barriers, breadth, and innovation performance.

	Innovation Performance (Model 4)	Breadth (Model 5)	Innovation Performance (Model 6)
barrier	-0.132 (0.1901)	0.0682 (0.0964)	-0.1703 (0.1833)
ex_know_breadth			0.5616** (0.1704)
age	0.0363 (0.0589)	0.0357 (0.0299)	0.0163 (0.0570)
owner_soe	-0.0662 (0.8577)	0.0277 (0.4349)	-0.0818 (0.8255)
owner_family	-0.4658 (0.5192)	-0.959 (0.2633)	-0.4119 (0.4999)
owner_FDI	0.361 (0.6120)	-0.8346 (0.3104)	-0.8298 (0.6060)
sector_manu	-0.5962 (0.4177)	-0.0435 (0.2118)	-0.5718 (0.4021)
sector_service	-0.9968 (0.5832)	-0.0897 (0.2958)	-0.9464 (0.5616)
R2	0.054	0.0723	0.1312
F	1.021	1.38	2.322*

Note: Base: public firms, ICT sector. ***significant at 0.1% level; **significant at 5% level; * significant at 1% level, standard errors in parenthesis.

Using the analysis from the Process Macro program, the results exhibit a mediation effect of external knowledge depth on the relationship between business system barriers and innovation performance. The Sobel test further confirmed the significance of this mediation relationship (see Table 11). The indirect effect of barriers on innovation performance was

0.224 that when a firm experienced 1 unit higher of barriers, it was likely to introduce 0.224 unit higher of innovation by engaging in external knowledge depth. In other words, 22.4% variance of impact of barriers on innovation performance was explained through variance of external knowledge depth. However, the mediation effect of external knowledge breadth is not confirmed. Therefore, H3 is only partially accepted.

Table 11

Results of the Hayes Process Macro test on mediation effect

	Coefficient	Standard error	t-statistic	P-value
<i>Mediation effect of depth</i>				
Total effect of barriers on innovation performance	-0.132	0.1901	-0.6947	0.4885
Direct effect of barriers on innovation performance	-0.356	0.1895	-1.8783	0.0627
Indirect effect of barriers on innovation performance	0.224	0.1012		
Sobel test = 2.5808; p-value= 0.0099				
<i>Mediation effect of external knowledge breadth</i>				
Total effect of barriers on innovation performance	-0.132	0.1901	-0.6947	0.4885
Direct effect of barriers on innovation performance	-0.1703	0.1833	-0.9293	0.3546
Indirect effect of barriers on innovation performance	0.0383	0.0615		

Sobel test = 0.6631; p-value= 0.5073

4.4. Robustness tests

To check the robustness of our results, we substituted the innovation performance continuous variable with an R&D investment variable measured by the ratio of R&D over sales turnover. The results exhibited the same pattern with our main findings, indicating that our results are robust.

How firms search for external knowledge for innovation might differ among firms; for instance, state-owned firms have privileges in accessing information—especially those related to the government (Jones and Zou 2017)—which biases the estimation of the impact of external knowledge breadth and depth on innovation, raising concerns about endogeneity. Thus, we performed a Durbin Wu-Hausman test to detect whether endogeneity was present in our study (Davidson and MacKinnon 1993; Hausman 1978). The non-significance of this test implies that endogeneity seems not to be a major issue in our study.

5. Discussion and implications

This study investigates to what extent barriers to innovation have an impact on the innovation performance of science park residents and how external knowledge search affects their innovation performance. Drawing on a sample of 137 high-tech firms located in the Wuxi science park in China, results found that more than three-quarters of the surveyed firms—almost entirely small-sized firms—reported at least one type of innovation in the period 2012–2014, while 22% of the surveyed firms did not innovate. Three-quarters of the surveyed firms undertook incremental innovation, while one-quarter of the surveyed firms had undertaken radical innovation.

Results indicate that entrepreneurs located in the Wuxi science park, despite recognizing the existence of barriers to innovation, are able to pass through the filter that hampers knowledge spillover, confirming that the agglomeration of knowledge activities (which characterizes science parks) increases the ability to access knowledge spillovers. Our study provides insights into the major types of barriers that companies face. Financial-related barriers are the most important barriers to innovation for almost two-thirds of the science park residents. This confirms what Fu and colleagues (2014) identified when conducting a national firm-level analyzes of Chinese firms. The authors found that existing financial

channels and markets are not sufficient for most domestic firms' and companies' (especially small and medium-sized firms') search for external sources of knowledge to make up for funding shortages by sharing innovation costs. In addition, a lack of qualified employees and difficulty in finding a cooperative partner are perceived as being very important constraints to innovation by 76.6% and 70.8% of the surveyed firms. Indeed, the deficiency of adequate knowledge and resources has been considered as one of the main hurdles to Chinese indigenous innovation (Gao et al. 2007).

One interesting result of our study is that science park residents that experience constraints to innovation rely on external knowledge depth (deep linkages to customers, suppliers, and competitors) but not on external knowledge breadth. That means that the higher the knowledge filter, the more companies look for intensity of cooperation with external partners. External search depth indicates a process by which an organization can advance a profounder understanding of its partners' know-how throughout exhaustive collaboration with them. The recurrent use of partners' knowledge leads to additional dependable relationships based on mutual trust and commitment. Therefore, communication improves (Ferrerias-Méndez et al. 2015), and the improved communication further advances the firm's ability to comprehend and obtain experience and expertise from its partners, thus reducing barriers to innovation. The lack of significance in the association between innovation barriers and external knowledge breadth indicates that acquiring a variety of knowledge from different sources may represent a cost. Integrating the different knowledge into a firm's innovation activities requires a high degree of absorptive capacity and limits collaboration (Audretsch and Belitski 2019); as such external knowledge breadth does not contribute to reducing barriers to innovation.

According to our analysis, external knowledge depth mediates the relationship between barriers to innovation and innovation performance, while external knowledge

breadth does not show any mediation effect. The findings support the idea that the relevance and intensity of relationships, rather than their number, enable the flow of knowledge, allowing firms to permeate the knowledge filter and facilitate innovation-relevant synergies. In order to successfully obtain and use complex external knowledge, organizations have to withstand profound relations with external partners (Powell et al. 1996). Establishing deeper relationships with a limited number of external sources increases mutual understanding and trust and, in turn, lowers the barrier to relevant knowledge (Segarra-Ciprés and Bou-Llugar 2018), improving innovation performance. This result may, in part, be due to the type of innovation that science park residents undertake. Findings indicate that the majority of science park residents undertake incremental innovation. This type of innovation implies that firms mostly fine-grain and reinforce their existing knowledge base, and, for that, they need explicit and detailed external information rather than a broader grasp of external information. Indeed, the depth of openness is further closely associated to exploitative learning as it expedites the transfer of in-depth knowledge that enables organizations to prompt solutions by corresponding novel knowledge with marketplace opportunities (Chiang and Hung 2010).

The types of barriers faced by the firms could be a justification for the non-relevance of external knowledge breadth. Firms frequently experience a process of trial and error to learn how to obtain knowledge from an external source but this effort involves time and other valuable resources (Ferrerias-Méndez et al. 2015). Moreover, the presence of valuable external sources does not automatically suggest that the movement of external novel ideas and knowledge into organizations is a spontaneous or stress-free process (Vanhaverbeke and Cloudt 2014). Managing external sources of innovation involves information asymmetries, and, in order to gain access to external knowledge, it is necessary to negotiate agreements. This requires firms to have qualified resources that have the right degree of specialization

(Gentile-Lüdecke et al. 2020) to identify the knowledge sources, to understand the knowledge, and to bring it to the organization.

Moreover, a wider search of partners—that is, a greater breadth in search strategies—generates high coordination costs that, in resource-constrained firms, may even decrease the firm’s innovative ability (D’Ambrosio et al. 2017). Finally, external knowledge search is considered to be more important for firms that pursue radical innovation and that perform broad searches of the environment in order to recognize future opportunities. Indeed, by employing several external sources, organizations hedge the risks connected with missing out on a relevant source (Nicholls-Nixon and Woo 2003). Our findings indicate that only a marginal number of the surveyed science park residents undertake radical innovation.

5.1 Theoretical implications

From a theoretical perspective, our research has three implications. Firstly, adding to the extended literature on science parks, our study indicates that science parks in emerging economies allow entrepreneurs to innovate, despite perceived barriers, thus playing a relevant role in innovation ecosystems (Amoroso and Soriano 2019). Therefore, we reconcile the extant literature on emerging economy science parks in the sense that we empirically support past theoretical arguments (Albahari et al. 2018) that science parks are particularly important in emerging economies due to their weak institutional frameworks. Furthermore, understanding the importance of external sources of knowledge in mitigating innovation barriers and how this has positive implications for innovation performance, our study adds to the knowledge on the underlining relevance of spatial specificities (Rammer et al. 2020; Audretsch and Feldman 1996). Our results allow us to explain that knowledge sourcing is not only dependent on a geographic perspective (Roper et al. 2017) but also based on institutional, absorptive capacity (Denicolai et al. 2016), technological, cognitive and cultural

proximity (Boschme, 2005; Balland et al. 2015), and strategic reasonings (Torres de Oliveira, 2020) as firms make strategic choices between breadth and depth open innovation strategies.

Secondly, and from an open innovation perspective, this research highlights the importance of external sources of knowledge to mitigate barriers to innovation and increase innovation performance. In doing so, we focus the debate not only on the barriers to open innovation strategies (e.g., Savitskaya et al. 2010; van de Vrande et al. 2009) but on how open innovation as a strategy can mitigate barriers toward innovation performance. To the best of our knowledge, this is the first attempt to show how an open innovation framework is not only important to the innovation process itself but is also important in mitigating existing institutional barriers, which are particularly important for emerging economies (Peng et al. 2008; Urbano and Alvarez 2014).

Third, we advance the literature on KSTE (Acs et al. 2009; Audretsch and Lehmann 2005). Our results indicate that in order for entrepreneurs to exploit the technological opportunities generated by knowledge spillovers they need to understand those technologies. Intensive interaction with external partners can help to acquire specific expertise that allows firms to convert knowledge into economically relevant knowledge (Braunerhjelm et al., 2010), helping to permeate the knowledge filter. This is particularly important in the context of emerging markets where institutional barriers may act as a barrier to entrepreneurship. Bringing the institutional level to the open innovation debate is also important as past literature has focused on the individual (e.g., Salter et al. 2015), firm (e.g., West et al. 2014), and network or industry levels (e.g., Bianchi et al. 2011), making the institutional level a kind of “black box.” With our results, we show that these institutional factors matter and that firms adopt different strategies when, namely, they perceive the risks involved with low institutionalized economies where predatory and opportunistic behavior is observed. Firms in emerging economies are expected to be more cautious about identifying and establishing

partnerships with local partners when compared with developed economies as they face higher asymmetries or incomplete levels of information on the partner's capabilities, resources, or even predatory behavior (Mahmood and Mitchell 2004). Therefore, open innovation does not happen in the same way in developed and emerging economies; the institutional level of analysis helps to explain the fact that firms in emerging economies prefer to adopt an open innovation strategy, following a depth instead of breadth strategy as this mitigates their risks.

5.2 Policy and managerial implications

Our results also have important implications for the Chinese Central Government, as this research shows that science park residents still face constraints that hamper firm innovation capabilities. If science parks are to play a relevant role in fostering creativity in a global knowledge economy, they have to do more and become active facilitators in creating a network in the knowledge economy. For local officials responsible for the management of science parks in China, our results suggest that initiatives designed to promote greater innovation need to distinguish between the type of barriers that the firms are facing and the impact of these on innovation. Considering the results of this research, more efforts are expected in terms of financial support by, for example, creating specialized venture capital and a better knowledge of risk analysis from the financial system. Efforts should also be made to set up specific activities to foster inter-firm collaboration and increase human resource qualifications because moving from an incremental to radical innovation requires high-level creative ideas and talents. Well-developed capital as well as innovation intermediaries (Oriaifo et al. 2020), such as technical assistance centers, trade associations, and universities, should play the role of boundary spanners to help overcome constraints to innovation.

Finally, this study has important managerial implications. Looking at the skill-related constraints, senior managers should stimulate learning through reward systems and training that increase absorptive and innovative capacity. Understanding why there is a limited level of inter-firm cooperation within China can help managers to try and overcome such voids by creating strategies that ground such interactions, such as informal working groups. Moreover, managers need to be aware that a search strategy focusing narrowly on in-depth linkages with customers, suppliers, and competitors cannot be expected to provide radically new innovation and that the alignment of open search strategies and innovative activities could enhance innovation performance.

6. Limitations and suggestions for future research

This study has several limitations. First, it follows a cross-sectional analysis and therefore has causality limitations. Future research might usefully analyze qualitative and longitudinal datasets to uncover causality and longer-term effects of the institutional factors indicated here. Furthermore, using a single technological park constrained the sample to a province and a city, which may entail singularities. Moreover, we are aware that different typologies of science parks exist (Ng et al., 2019) and that the selection of firms into science parks may have an important impact on the success of the park in fostering firms knowledge sourcing. Because of that, we believe future research should expand the scope by examining open innovation in different science parks in different provinces, accounting for this heterogeneity. Moreover, considering different typologies of science parks may allow to understand if foreign investment, for example, plays an important role within technological parks, as Hu (2007) suggests.

Our sample is largely based on small and medium enterprises and even if this is to expect on

science parks, future research can examine deviations from this pattern². Moreover, focusing on managerial implications, future work should further investigate how organizations engage in open innovation within a science park, and how this is different from organizations outside of the science park environment. Future research should also try to find meaningful differences among our constructs and the different types of innovation.³ Another avenue of research should further investigate specific barriers to innovation—that is, financial systems, skill development, and inter-firm cooperation—that seem to be strongly hindering the innovation process. Another stream of research could focus on what formal and/or informal mechanisms are in place that allow firms within science parks to be comfortable in sharing knowledge but not with firms outside the boundaries of the park. Finally, international activities are important to enhance innovative capabilities, and future research could investigate if there are differences among off-site and on-site firms in international activities and if being spatially limited in a science park constitutes a limitation regarding the international source of collaboration.

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² We thank one of the reviewers for pointing out this limitation.

³ We thank one of the reviewers for pointing out this future research avenue.

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