INNOVATION AND INTER-FIRM TECHNOLOGICAL NETWORKING: EVIDENCE FROM CHINA'S INFORMATION COMMUNICATION TECHNOLOGY INDUSTRY

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With 11 tables
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Summary: This study examines the relationships between inter-firm networking and innovation within industrial clusters in a developing context. Based on a unique dataset that was collected through a large-scale survey with firms in China's information communication technology (ICT) industry, this study systematically scrutinizes the benefits of linkages with foreign and domestic firms for innovativeness of Chinese firms. Our analyses have revealed a number of interesting patterns. First of all, Chinese firms have benefited from collaborating with both domestic and foreign firms, but particularly helpful was to maintain simultaneous technological relationships with both. Secondly, the positive impact of collaborating with domestic firms only held up to a point, above which the impact turned negative. Yet, such nonlinearity did not apply to networking with foreign firms. Thirdly, private-owned enterprises (POEs) were neither more innovative, nor more adaptive in using inter-firm technological networks than state-owned enterprises (SOEs) in China. Finally, firms in industrial satellite Suzhou and Dongguan were less innovative than those in other three major metropolitans of China – Beijing, Shanghai and Shenzhen.

Zusammenfassung: Dieser Beitrag untersucht die Zusammenhänge zwischen Unternehmenskooperation und Innovation auf Grundlage von Befragungsdaten aus der chinesischen ICT-Industrie. Dabei differenziert die Analyse nach dem Kooperationspartner (einheimisch oder ausländisch). Es zeigt sich, dass chinesische Firmen von der Zusammenarbeit mit beiden Arten von Partnern profitieren. Besonders vorteilhaft ist der gleichzeitige Zugang zu beiden. Der Zusammenhang zwischen Kooperation mit einheimischen Partnern und Innovation ist nicht-linear und nicht durchgehend positiv, während die Zusammenarbeit mit ausländischen Partnern durchweg Vorteile bietet. Während sich kaum Unterschiede im Kooperations- und Innovationsverhalten von Privat- und Staatunternehmen zeigen, existieren erhebliche regionale Unterschiede: Firmen in Suzhou und Dongguan sind weniger innovativ als die in den anderen untersuchten Zentren.

Keywords: Inter-firm networking, innovation, China

1 Introduction

This study concerns the relationships between firm innovation and inter-firm technological networking. In the literature of flexible production, inter-firm networks within a regional cluster have been identified as the critical component of fostering technological dynamism and innovation (Storper 1997; Scott 1988; Saxenian 1996; Harrison 1992). While there is rich literature on such issues in advanced countries (Andersson et al. 2002; Antoncic and Prodan 2008; Baum et al. 2000; Freel and Harrison 2006; Gemünden et al. 1992), similar studies in the developing countries are few and far between. In particular, there is little theoretical clarity about the impacts of different types of networks on firm behavior in such contexts. What has been clear is the importance of global linkages for local firm capability building (Ernst and Kim 2002; Gereffi et al. 2005; Hobday 1995a, 1995b; Humphrey and Schmitz 2002, 2004; Sturgeon et al. 2008; Sturgeon 2002). Recent burgeoning literature on global production networks (GPN) (Coe et al. 2008; Coe et al. 2004; Ernst and Kim, 2002; Yeung, 2009) and global value chains (GVC) (Humphrey and Schmitz 2002, 2004; Sturgeon et al. 2008; Sturgeon 2002) have strengthened the argument on the importance of technological transfer within networks. As firms in developing countries locate in the lower technological hierarchy, their incorporation into the global networks should help improve their competitiveness, though not necessarily their innovativeness. The question remains on the effect of domestic linkages as Liefner et al (2006) argued that firms in developing countries may have limited global linkage and they are much more likely to develop networking relationships with other domestic firms(Liefner et al. 2006). Some scholars have docu-

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mented the positive impacts of such domestic (local) linkages on firm innovation in developing countries (Berger and Revilla Diez 2008; Revilla Diez and Berger 2005; Revilla Diez and Kiese 2006; Wang 1999; Wang and Wang 1998; Zhou and Tong 2003; Zhou 2005, 2008a). It would be useful to compare empirically technological networking with both domestic and foreign firms and their impacts on firm innovation in China.

Most of the previous studies are conceptual in nature and frequently based on annotate evidences. Our study will scrutinize the values of different forms of networks in a developing context. One of the key characteristics of such economy is the presence of a wider variety of firms than in a more mature market economy. Some are part of GPN networks, and others are primarily oriented to the domestic market and may be embedded in a more traditional network with other indigenous parties. To analyze the specific nature of the inter-firm relationships, it is necessary to take the differences among firms, and variations in regional contexts into account. We examine the following questions. First, what are the effects of networking with foreign and domestic firms on firm innovation, and whether or not is there a desirable balance between the two? Secondly, are there over-embeddedness effects which argue that too many interactions between businesses may be detrimental to firm innovation (Bathelt et al. 2004; Boschma 2005; Torre and Rallet 2005; Uzzi 1997; Weterings and Boschma 2009)? Thirdly, do the varied levels of internal R&D and firm ownerships affect the relationship between inter-firm networking and firm innovation? Finally, are regional contexts making a difference in the above relationships?

Our data were collected through a large-scale survey with firms in China's information communication technology (ICT) industry in 2006-7. The analyses have revealed a number of interesting patterns. First of all, we found that innovation in Chinese firm benefited from collaborating with both domestic and foreign firms. Particularly helpful was to maintain simultaneous technological relationships with both domestic and foreign firms. This suggests that certain level of balancing is crucial for innovation. Second, there existed a nonlinear relationship between innovation and interactions with domestic firms: the positive impact of collaborating with domestic firms only held up to a point, above which the impact turned negative. Over-embedded in traditional networks may not help firm innovation. However, such nonlinearity does not apply to foreign networks, suggesting that the effects of different networks may lead to different trajectories. Third, we found that internal R&D did *not* enhance the positive impact of inter-firm technology collaboration on firm innovation, although internal R&D itself had shown consistently positive and significant impact on firm innovation. In other words, internal R&D and benefits of external collaboration do not seem to reinforce one another in the context of China. Fourth, our analyses found little differences in behavior based on ownership: private-owned enterprises (POEs) were neither more innovative, nor more adept in using inter-firm technological networks than state-owned enterprises (SOEs) in China, although the latter have been traditionally categorized as less efficient and less motivated to innovate. Finally, our analyses revealed little regional differences in the intensity of inter-firm networks despite major differences in innovation among the regions. These findings verify, but also raise considerable questions with the literature on networking and innovation.

The remainder of the paper is organized as follows. The next section reviews prior research and introduces the framework, followed by a section on data and methodology. Section 4 reports the results of analyses and the final section concludes the paper with a brief discussion on the implications for firms and policy makers.

2 Theoretical background and hypotheses

It has been well recognized in the literature of flexible production and technological innovation that an active inter-firm networks is one of the most crucial factors in fostering innovation and such networking is at the core of successful regional technology clusters (Storper 1997; Scott 1988; Saxenian 1996; Harrison 1992). At a micro level, firms benefit from networking in many aspects (Ahuja et al. 2008). First of all, it allows firms to leverage their internal capabilities and gain access to external resources, thus increase the size of R&D resources that can contribute to innovation. Secondly, technological networking with other firms raises the diversity of knowledge, resources, skills and capabilities that are available to partners, and each party benefits from the complimentarily of their joint efforts. Thirdly, due to the increasing return of knowledge production, access to external resources can improves the efficiency of firm technological efforts. The outcome of technological networking is greater than the combined effect of R&D efforts should

firms work independently. Entering technological cooperation with other firms can also help share the cost of increasingly costly projects and reduce the risk associated with R&D projects (Hagedoorn and Schakenraad 1994; Stuart 2000). For young and small firms, entering into networks with major players in the field may help build the firm's image and make it more attractive for further technological cooperation in addition to attracting customers and suppliers (Hagedoorn and Schakenraad 1994; Stuart 2000). As such, we expect both "additive" and "multiplying" effects of external networking, where the former refers to access to additional resources and the latter refers to the improved efficiency and effectiveness of networking on firm innovation.

Yet, empirical studies do not show consistent results on networking. On the one hand, some studies have shown that technological networking contributes to firm innovation. For example, Gemünden et al. (1992) found positive impact of inter-firm cooperation on firm innovation performance. Baum et al (2000) also found that the number of alliances at the time of firm establishment positively affected the patenting activities of firms in their study of Canadian firms. Ahuja (2000) revealed the positive effects of technological ties on innovation in his study of the US chemical industry. Similar positive effects of networking were also found in other studies (Andersson et al. 2002; Antoncic and Prodan 2008; Freel and Harrison 2006; Lorenzoni and Lipparini 1999; Zaheer and Bell 2005). In the context of developing countries, it has been argued that networking with firms from advanced economies is particularly valuable for technology upgrading, because of the lack of resources and experience as well as the immature domestic institution. In this aspect, the GPN (Coe et al. 2008; Coe et al. 2004; Ernst and Kim 2002) and the GVC theories (Gereffi 1999; Gereffi et al. 2005; Humphrey and Schmitz 2002, 2004; Sturgeon et al. 2008; Sturgeon 2002) have been very influential. They argue that entering into relational networks with lead firms from foreign countries is particularly helpful for transfer knowledge, particularly tacit knowledge, from lead firms to local suppliers.

On the other hand, Stuart (2000) found no effect of the number of alliances on firm patenting activity. Kotabe and Swan (1995) found that firms that engaged in inter-firm cooperation produced innovations that were less novel and had less impact. Such results have led scholars to explore the potential causes for such conflicting results. Prior research has revealed that this could be related to the absorptive capability of the firm (Ahuja 2000; Gulati 1999; Mowery et al. 1996), its prior experience in managing inter-firm cooperative relationships (Sampson 2005), and the capability of partners among others (Stuart 2000).

The key to understand these conflicting results appears to do with heterogeneity of the firms and the diversity of inter-firm network. The three factors we considered thus include nature of inter-firm networks, firm internal characteristics, and (local) context.

Network can be defined as the way in which suppliers and buyers coordinate their relationships, which not only involve technological superiority/inferiority, but also power relations. It is natural to expect the impact of inter-firm networking on firm innovation is affected by partners' capabilities: networking with partners with strong capabilities is particularly beneficial. For example, Stuart (2000) found that large firms and those with leading edge technologies are considered of more valuable partners who are more likely to exert positive impacts on the other partner in inter-firm cooperation. Chinese firms have been engaged in networking with both domestic as well as foreign firms. Typically, foreign firms are more technological advanced than domestic firms. Therefore, one may expect that networking with foreign firms will have stronger impacts than networking with domestic firms on local firm innovation. Yet ties with a more powerful party may also reduce autonomy for the weaker parties and also the later may suffer the lock-in effects if it does not have other networks. In addition, foreign firms and domestic firms, coming from different institutional environments, may have difficulty to communicate and coordinate with each other. In comparison, domestic firms may enjoy closer relationships because of their origin from the similar institutional environments and familiarity with each others. Altenburg et al. (2008) argue that firms maintain simultaneous ties with both national and international parties enjoy more benefits in innovation because it allow firms to maintain multiple channels to interact with consumers. Zhou (2008b) argues that China's most able firms are those who synchronize advantages of collaboration with foreign affiliated companies and understanding of the domestic markets. Such arguments and empirical evidences lead to our first two hypotheses:

Hypothesis 1: Networking with foreign firms will *not* exert stronger positive effects on firm innovation than networking with domestic firms.

Hypothesis 2: Simultaneous technological collaboration with both domestic and foreign firms

will have stronger impacts on firm innovation than exclusive technological collaboration with either domestic or foreign firms.

Beyond the ties with foreign and domestic parties, there are also questions about returns in proportion to networking efforts. Some scholars argue that there is a threshold above which networking effort may have negative return or limit the firm's innovation potential (Boschma 2005; Weterings and Boschma 2009). Too close relationships between organizations may lead to firms' "over-embeddedness" (Uzzi 1997), that may limit firms' awareness of other opportunities out of the networks. Westerings and Boschma (2009) have empirically demonstrated that face-to-face contacts between firms and their customers have positive impacts on firm innovation only up to a point above which the impact became negative. As such, our third hypothesis becomes:

Hypothesis 3: The positive impact of networking only holds up to a threshold above which the impact becomes negative. We expect this will be the case for ties with both domestic and foreign firms.

In addition, internal characteristics of firms have critical implications on the effectiveness and efficiency of their utilization of external business networks. Such internal issues include their technological orientation, absorptive capability and the coordination mechanism. In particular, absorptive capabilities, which are critical for firms in developing countries to screen, select and transfer technologies from advanced economies, have proven to be pivotal for firm innovation (Cohen and Levinthal 1990). As shown by previous studies, absorptive capabilities are also critical for firms to benefit from external networks (Ahuja 2000; Gulati 1999; Mowery et al. 1996). However, it is entirely possible that firms with strong capabilities may feel less compelled to collaborate with other parties, especially in immature market. In a transitional economy such as China, many firms spinning off from research institutes or state-owned-enterprises have long sheltered from competition and as a result, did not have a strong collaborative culture (Zhou 2005, 2008a). For many, internal R&D and external networking have not been well integrated by Chinese firms with the exception of the most able ones (Zhou 2008a, b). It is thus unclear whether or not Chinese firms can take the full benefits of the synergy between in-house capabilities and external networking. We hypothesize that

Hypothesis 4: Chinese firms with stronger absorptive capabilities or Internal R&D are *not* necessarily more likely to benefit more from inter-firm technological collaborations.

Previous studies on innovation in China have also found that firm ownerships have critical implications for firm innovation (Sun 2002a). In this study, we focus on domestic firms, which include state-owned-enterprises (SOEs) and private-owned enterprises (POEs). SOEs, the major players of the Chinese economy during the period before the reforms, have been known for their lack of self-motivation, discipline and low efficiency in manufacturing and innovation (Sun 2003). A decade has passed since the Chinese government initiated the privatization program in the late 1990s, and only a small number of large SOE remain, which are confined to a few strategic sectors. POEs, in contrast, did not receive much support from the state and were under discrimination for a long time because of the Communist ideology (Huang 2005). As a result, they are relatively small compared with SOEs. POEs should have stronger motivations than SOEs to engage in innovation although they have the least resource. As such, we expect POEs will be more likely to take advantage of the learning opportunities offered through inter-firm networking than SOE. However, there are significant changes in recent years as many SOEs are restructured, have improved their management, and become more innovative due to the different reform measures that have been implemented. Meanwhile, POEs in China have faced more restrictions in entering into competitive fields with SOEs and in obtaining resources from the state sectors. The advantages of POEs in competition become less clear. The above discussion leads to our fifth hypothesis.

Hypothesis 5: private owned enterprises (POEs) will *not* necessarily benefit more from inter-firm technological networks than state-owned-enterprises (SOEs).

Finally, local context defines the environment where the supplier-buyer relationships are embedded. A large body of literature has advocated the impacts of local relational assets, 'institutional thickness' (Amin 1999; Storper 1997), 'untraded interdependencies' (Storper 1997), or 'local buzz' (Bathelt et al. 2004) on firm and regional learning and innovation. We further argue that local context could affect the relationships between inter-firm networking and firm innovation as different industrial specialization and norms of interaction may differ from place to place. As demonstrated by (Zhou et al. 2011), significant differences in industrial structure, technological intensive and R&D norms exist in the five cities that are included in this study (Beijing, Shanghai, Suzhou, Shenzhen and Dongguan). Beijing, Shanghai and to

a less degree Shenzhen are the top-tier metropolitans in China and enjoy unparalleled advantage in science and technology infrastructure, central government's support, and local government mobilizing capability. As a result, firms in such cities have a diverse industrial and ownership structure and are more likely to invest in R&D. Suzhou and Dongguan are the industry satellites of nearby metropolitan regions. Firms in these two areas are heavily dependent on foreign investment and in export assembly with much less investment in internal R&D (Zhou et al 2011). Such a regional difference leads to our final hypothesis:

Hypothesis 6: Location in Suzhou and Dongguan weakens the impact of inter-firm technological networking on firm innovation.

3 Data and methodology

3.1 Research design

This study was based on a unique dataset that was collected through a large scale survey with more than 1000 firms in China's information communication technology (ICT) industry. We chose the ICT industry because China has placed strategic importance on this industry and has registered very impressive growth in this industry. We limited the study area to the three major city-regions in China: Beijing, Shanghai-Suzhou, and Shenzhen-Dongguan, because they concentrated the lion's share of China's ICT industry. The questionnaire contains more than 200 questions on issues related to firm innovation and linkages, among others. The survey was commissioned to a firm affiliated with the Chinese National Statistics Bureau and was completed in late 2006 to early 2007. Based on our preliminary analyses, we are very satisfied with the overall quality of the survey (for more detailed description of the dataset, please see Zhou et al. 2011). Based on the same dataset, we have analyzed issues such as regional patterns of innovation, innovation in foreign firms, and market relationships on firm innovation (Lin et al. 2010; Sun and Du 2010; Wei et al. 2010; Zhou et al. 2011). In this study, we will focus on the relationship between inter-firm technological linkages and innovation in the 714 domestic firms (Tab. 1).

3.2 Variables and models

Firm innovation is measured by two types of activities in patenting and new product development. Specifically, we choose two binary variables: one to indicate whether or not a firm had any (domestic or foreign) patent grant (AnyPatent), and the other to measure whether or not the firm developed any new product (NewProduct) during the three years prior to the survey. We are aware of the various issues relating to using patent data as the measurements of firm innovation since firms in different industries or segments of one industry may have different propensity to apply for patents, and different patents have different value (Basberg 1987). However, patent data are still very valuable for evaluating technological innovation and capabilities and have been commonly used in prior research (Bommer 2001; Cantwell and Iammarino 2001; Porter 2003; Sun 2000). In this

Tab. 1: Distribution of the sampled firms

Region	Hardware total	Computer/communication equipment manufacturing (401 and 404)	Electronic parts (405 and 406)	Semi-conductor (4052 and 4053)	Software
Beijing	100	40	30	30	180
Shanghai	110	30	50	30	120
Suzhou	155	47	78	30	20
Shenzhen	151	55	96	0	70
Dongguan	115	40	75	0	0
Total	631	212	329	90	390
FIE	322	94	168	50	85
DIE	309	108	161	40	305

Notes: We did not conduct surveys with semiconductor sectors in Dongguan due to their marginal presence. In Shenzhen, even though we intended to sample semiconductor companies, its small presence and the high-rejection rate forced us to give up that sector as well.

Tab. 2: Definition of variables for modeling the relationship between innovation and technological linkages

Variables	Definitions	Expected Relationship
Dependent variables		
AnyPatent	Whether or not the firm has any domestic/Foreign patents	
NewProduct	Whether or not the firm developed any new product technologies 2004-06	
Independent variables		
Controls		
Years	Years since establishment	–
Emp	Number of employees	–
RDExp	Percentage of R&D expenditure in total budget	+
POE	Whether or not the firm is a private owned enterprise	+
SU_DG	Whether or not the firm is located in Suzhou or Dongguan	–
Linkage variables		
DTekLink_Total	The sum of importance/frequency a firm attached to all forms of technological linkages with domestic firms	+
DTekLink_Sq	The squared term of DTekLink_Total	–
FTekLink_Total	The sum of importance/frequency a firm attached to all forms of technological linkages with foreign firms	+
FTekLink_Sq	The squared term of FTekLink_Total	
DTekLink_Only	Whether or not a firm had only technological linkages with domestic firms	++
FTekLink_Only	Whether or not a firm had only technological linkages with foreign firms	+
BothtekLinks	Whether or not a firm had technological linkages with both domestic and foreign firms	+++

study we limited the firms to the four subsectors of the ICT industry, so the industrial differences are somewhat controlled. We also limited our studies to China's domestic firms and the potential differences between foreign affiliates and domestic firms are also controlled. For new product development, we adopted the broad definition that these innovations were new to the firms, not necessarily new to the national or international market. Although thresholds for such innovations are relatively low, they still indicate the intent and capability of firms. We chose the binary format of the variables because many firms in China did not report any patent or development of new product among our samples. For example, more than 70% of surveyed firms did not have any patent grant, and more than 40% of firms did not develop any new product during the three years prior to the survey. (Tab. 2)

For technological linkages, the survey asked firms two major questions: How important/frequent are the technological linkages they have with foreign and domestic firms in technology development respectively? Previous studies have shown that Chinese national innovation system was fragmented with uneven interactions among the different actors, between firms, or between firms and universities, and other agencies (Sun 2002a, b). We want to see if the situation has improved after a few decades of reforms. Six types of technological linkages were identified; technology alliance, technology cooperation, technology licensing, technology advising, information exchange, and personnel exchange. As such, we have twelve questions together for technological linkages with foreign and domestic firms. As table 3 demonstrates, the majority of firms in China did not report any technological linkages with foreign or domestic firms. For example, more than 70% of the surveyed firms did not report any technological linkages such as technological alliance, technological cooperation with foreign firms (Tab. 3). Networking with domestic firms was more active and still more than 50% firms did not have any such linkages. Such a finding offered further evidence to demonstrate that Chinese firms still are less inclined to network (Zhou 2005).

Tab. 3: Technological linkages with foreign and domestic firms

	% of domestic firms reporting technology linkages with foreign firms					
Importance/frequency of the linkages	Tech Alliance	Tech Cooperation	Tech Licensing	Tech Advice	Staff Exchange	Info Exchange
	%	%	%	%	%	%
Not exist	83.52	79.48	86.64	78.34	77.04	75.53
Not important/frequent	3.43	3.26	6.68	5.21	4.40	3.75
OK	3.10	3.26	4.40	11.73	11.24	12.40
Important/frequent	7.99	10.26	1.63	3.91	6.51	7.01
Very important/frequent	1.96	3.75	0.65	0.81	0.81	1.31
Total	100	100	100	100	100	100

	% of domestic firms reporting technology linkages with domestic firms					
	Tech Alliance	Tech Cooperation	Tech Licensing	Tech Advice	Staff Exchange	Info Exchange
Not exist	67.92	59.77	75.73	59.05	54.56	52.61
Not important/frequent	4.23	4.07	10.91	8.81	6.84	6.68
OK	7.82	8.31	9.61	24.47	25.24	24.10
Important/frequent	15.31	20.36	3.26	6.85	11.07	14.01
Very important/frequent	4.56	7.49	0.49	0.82	2.28	2.61
Total	100.00	100.00	100.00	100.00	100.00	100.00

Due to the fact the all these technological linkages are strongly correlated with each other (Tab. 4), we added scores of all these links together for foreign and domestic firms accordingly. As a result, we obtained two combined variables to measure firms' technological linkages with foreign and domestic firms (FTekLink_Total and DTekLink_Total). These two combined variables are highly correlated with the variety of original measurements of technological linkages (Tab. 4). Based on the two combined variables, we further extracted three more linkages variables in binary formats: DTekLink_Only, FTekLink_Only, and BothTekLinks. DTekLink_Only indicates that the firm had only technological linkages with domestic firms while they had no technological linkages with foreign firms, and BothTekLinks indicates whether or not a firm maintained simultaneous technological linkages with both domestic and foreign firms. The results show that 44.04% and 47.87% of firms maintained technological linkages with foreign and domestic firms respectively. Foreign technological linkages are correlated with linkages with domestic firms: the majority of the firms with technological linkages reported to have technological linkages with both domestic and foreign firms (34.19% of all firms), while only 13.27% of the firms reported to have technological linkages with domestic firms only and 9.37% of firms reported to have technological linkages with foreign firms only.

To examine the relationships between technological linkages and firm innovation, we used logistical regressions since the dependent variables were in binary formats. We expected that the various technological linkages had positive impacts on firm innovation. We also expected the linkages with foreign firms (FTekLink_Only) would have stronger impacts than linkages with domestic firms (DTekLink_Only) (Hypothesis 1), while simultaneous linkages with domestic and foreign firms (BothTekLinks) would have stronger impacts than either DTekLink_only or FTekLink_Only (Hypothesis 2). To test hypothesis 3 (the nonlinear relationship between innovation and inter-firm networking), we included the squared terms of linkages with foreign firms (FTekLink_Total) and domestic firms (DTekLink_Total). In order to test hypotheses 4 and 5, we included the interactions between internal R&D expenditure and ownerships on the one hand and variables measuring linkages on the other hands. Finally, to test the regional impact in hypothesis 6, we included the interactions between the linkage variables and the variable measuring whether or not a firm was located in Suzhou or Dongguan (SU_DG).

In all the models, we included a few control variables, including years of establishment (Years), number of employees (Emp), share of R&D spending in total budget (RDExp), whether or not the firm

Tab. 4: Correlations among technological linkages with foreign and domestic firms

Correlations	Correlations among technological linkages with foreign firms						
	Tech Alliance	Tech Cooperation	Tech Licensing	Tech Advice	Staff Exchange	Information Exchange	FTekLink_ total
Tech Alliance	1.00	0.75	0.59	0.69	0.69	0.70	0.84
Tech Cooperation		1.00	0.64	0.78	0.79	0.77	0.90
Tech Licensing			1.00	0.75	0.68	0.66	0.79
Tech Advice				1.00	0.86	0.84	0.92
Staff Exchange					1.00	0.89	0.93
Information Exchange						1.00	0.92
FTekLink_total							1.00

Correlations	Correlations among technological linkages with domestic firms						
	Tech Alliance	Tech Cooperation	Tech Licensing	Tech Advice	Staff Exchange	Information Exchange	DTekLink_ total
Tech Alliance	1	0.69	0.37	0.58	0.64	0.59	0.81
Tech Cooperation		1.00	0.46	0.63	0.69	0.68	0.87
Tech Licensing			1.00	0.59	0.46	0.40	0.63
Tech Advice				1.00	0.73	0.68	0.85
Staff Exchange					1.00	0.82	0.89
Information Exchange						1.00	0.86
DTekLink_total							1.00

Notes: All coefficient coefficients are significant of 0.05

was private owned enterprises (POEs), and the location: whether or not the firm was located in Suzhou or Dongguan (SU_DG).

4 Results of analyses

We will present the results of bi-variate analyses first before reporting the results of the multi-variate logistic regression analyses. The top panel in table 5 demonstrates that 35.26% of firms with technological linkages with domestic firms only reported to have patents. In comparison, 42.42% of firms with technological linkages with foreign firms only and 46.15% of firms with linkages with both domestic and foreign firms reported to have patents The same pattern can be observed for new product development. Among firms with no technological linkages with either domestic or foreign firms, only 54.2% of reported to have developed new products. In comparison, between 70.68% (firm with technology linkages with domestic firms only) and 84.85% (with technology linkages with foreign firms only) reported to have developed new products. Such results lent preliminary support to our second hypothesis which expects that simultaneous networking with foreign and domestic firms offer stronger impact than exclusive networking with either domestic or foreign firms. However, the results failed to validate the first hypothesis which expects that networking with foreign firms do not have stronger impacts than collaborating with domestic firms

In addition, the middle and bottom panels in table 5 report the relationships between the overall strength of linkages with foreign and domestic firms and firm innovation. Here conflicting results are revealed. For linkages with foreign firms, it seemed that more intensive linkages led to more innovations. For example, the group with FTekLink_total scores above 11 seemed to be most innovative while the group with no technological linkages with foreign firms (FTekLink_total = zero) was least innovative. In comparison, for linkages with domestic firms, the relationship seemed to be *nonlinear*: the middle group with DTekLink_total scores between 1 and 10 demonstrated the highest degree of innovativeness. Such results offered partial support to our expectation of the nonlinear relationship between inter-firm technological linkages and firm innovation as explained in the third hypothesis. It is likely that we can divide domestic firms into two types. One consists of the traditional firms which had linkage exclusively with

Tab. 5: Innovation and inter-firm technological linkages: preliminary analyses

	Total	AnyPatent		NewProduct	
		No	Yes	No	Yes
NoTekLinks	100%	78.50%	21.50%	45.80%	54.20%
DTekLink_only	100%	64.74%	35.26%	29.32%	70.68%
FTekLink_only	100%	57.58%	42.42%	15.15%	84.85%
BothLinks	100%	53.85%	46.15%	16.18%	83.82%

	Total	AnyPatent		NewProduct	
		No	Yes	No	Yes
FTekLink_total=0	100%	64.74%	35.26%	29.32%	70.68%
1<=FTekLink_total<=10	100%	56.00%	44.00%	18.18%	81.82%
11<=FTekLink_total	100%	50.91%	49.09%	13.56%	86.44%
Chi-square		4.168***		7.948***	

	Total	AnyPatent		NewProduct	
		No	Yes	No	Yes
DTekLink_total=0	100%	75.70%	24.30%	42.3%	57.70%
1<=DTekLink_total<=10	100%	58.47%	41.53%	20.43%	79.57%
11<=DTekLink_total	100%	62.59%	37.41%	27.97%	72.03%
Chi-square		16.93***		26.08***	
Overall	100%	68.1%	31.90%	32.40%	67.60%

Notes: * significant at the level of 0.10, ** significant at the level of 0.05 and * significant at the level of 0.01**

other traditional firms. This type has very limited innovation. The other type of firms develops linkages with more dynamic domestic firms and often with foreign firms, and enjoys better results in innovation.

The results on analyzing the relationship between innovation and the individual control variables (Tab. 6) reveal that innovative firms were more established, bigger, and more R&D intensive than non-innovative firms. For example, the average years of operations, number of employees, and R&D spending in total budget were 8.4 years, 188.9 employees, and 31.1% for firms with patents, in comparison to 7.2 years, 124.9 employees, and 26.64% for firms with no patents. Firms in Beijing and Shanghai seemed to be more innovative while firms from Suzhou and Dongguan were much less innovative. For instance, 42.1% of firms in Beijing and 32.8% in Shanghai reported to have patents while the corresponding rates for Suzhou and Dongguan were 13.1% and 25.0% respectively. However, SOEs seemed to be more innovative than POEs. As indicated in Table 6, 36.5% of SOEs reported to have patents while only 32.12% POEs did so. Similarly, 81.5% of SOEs reported to have developed new products during the three years prior to the survey, while only 66.3% POEs did so. This may first appeared to be surprising, since it is against the stereotype of SOEs. But it is not surprising as we explained before.

Table 7 reports the results of the regression analyses with different specifications of the variables measuring inter-firm technological networking. Both DTekLink_only and FTekLink_only showed positive and significant impacts on the dependent variables (Table 7) and BothLinks exerted stronger impacts than exclusive linkages with either domestic firms or foreign firms. Linkages with foreign firms, once again, showed stronger impact on innovation than linkages with domestic firms, contrary to our first hypothesis. Similar results are observed when we choose NewProduct as the dependent variable.

In table 8, we used different measurements of inter-firm technological linkages where we added up scores of different inter-firm interactions and similar results were found. However, the squared terms of linkages with domestic firms (DTekLinks_Sq) and foreign firms (FTekLink_Sq) showed different impacts on firm innovation, whereas the former demonstrated negative impact and the latter showed positive impact. The negative impact of the DTekLinks_Sq, which indicated the nonlinear relationship between domestic linkages and firm innovation, was consistent with what we expected

Tab. 6: Comparison of innovative and non-innovative firms

	All firms average	Firms with no patents	Firms with patents	Firms with no new products	Firms with new products
Years	7.71	7.23	**8.39****	6.94	**8.08*****
Employees	152.15	124.87	**188.91****	140.83	**157.58**
R&D Spending (%)	28.13	26.64	**31.05****	19.92	**31.95*****

		Firms with no patents	Firms with patents	Firms with no new products	Firms with new products
Beijing	100%	57.87%	42.13%	21.85%	78.15%
Shanghai	100%	67.19%	32.81%	34.07%	65.93%
Suzhou	100%	86.89%	13.11%	52.46%	47.54%
Shenzhen	100%	73.55%	26.45%	37.42%	62.58%
Dongguan	100%	75.00%	25.00%	44.00%	56.00%
Total	100%	67.50%	32.50%	32.41%	67.59%
Chi-squares		23.583***		26.791***	

		Firms with no patents	Firms with patents	Firms with no new products	Firms with new products
POE	100%	67.88%	32.12%	33.75%	66.25%
SOE	100%	63.46%	**36.54%**	18.52%	**81.48%**
Total	100%	67.50%	32.50%	32.41%	67.59%
Chi-squares		0.422		5.216***	

Notes: * significant at the level of 0.10, ** significant at the level of 0.05 and * significant at the level of 0.01**

Tab. 7: Logistic regression: innovation and inter-firm technological linkages I

Dependent variables	AnyPatent		NewProduct	
Independent variables	**B**	**Exp(B)**	**B**	**Exp(B)**
Years	0.04	1.04**	0.03	1.03
Emp	0.00	1.00***	0.00	1.00
RDExp	0.01	1.01	0.03	1.03***
POE	0.16	1.17	-0.65	0.52
SZ_DG	-1.01	0.36***	-0.47	0.62*
DTekLink_only	0.82	2.26***	0.55	1.73***
FTekLink_only	1.00	2.72***	1.45	4.28***
BothLinks	1.45	4.28***	1.58	4.87***
#Obs	569.00		577.00	
-2 LOG Likelihood	655.38		629.36	
Nagelkerke R Sq	0.15		0.21	
% Correct	0.71		0.72	

Notes: * significant at the level of 0.10, ** significant at the level of 0.05 and * significant at the level of 0.01**

(Hypothesis 3), since over-embeddedness may limit firms' innovation potential. Nevertheless, the "over-embeddedness" argument did not seem to apply to linkages with foreign firms. This may indicate the special value of building and maintaining linkages with foreign firms for Chinese domestic firms.

Tables 7 and 8 also reveal a few findings related to the control variables. In the models where AnyPatent

Tab. 8: Logistic regression: innovation and inter-firm linkages II

Dependent variables	AnyPatent		NewProduct	
Independent variables	**B**	**Exp(B)**	**B**	**Exp(B)**
Years	0.04	1.04**	0.04	1.04*
Emp	0.00	1.00***	0.00	1.00
RDExp	0.01	1.01*	0.03	1.03***
POE	0.19	1.21	-0.62	0.54
SZ_DG	-0.98	0.37***	-0.46	0.63
DTekLink_Total	0.19	1.21***	0.21	1.23***
DTekLinks_Sq	-0.01	0.99***	-0.01	0.99***
FTekLink_Total	0.11	1.12*	0.15	1.16*
FTekLink_Sq	0.00	1.00***	0.00	1.00
#Obs	569.00		577.00	
-2 LOG Likelihood	656.28		624.33	
Nagelkerke R Sq	0.15		0.22	
% Correct	0.69		0.68	

Notes: * significant at the level of 0.10, ** significant at the level of 0.05 and * significant at the level of 0.01**

was the dependent variable, all the control variables showed significant impacts except the ownership variable (POE). The results showed that firms with more years in operation, more employees, and more R&D spending were more likely to register patents, while firms in Suzhou and Dongguan were less likely to own patents than firms in Beijing, Shanghai or Shenzhen. The above results were consistent when we chose the new product development as the dependent variable, although in most cases such relationships turned to statistically insignificant.

Table 9 reports the potential impact of internal R&D on the relationship between inter-firm interactions and firm innovation. As expected, internal R&D did *not* necessarily enhance the positive impact of inter-firm technological linkages on firm innovation. In *none* of the models, the interaction term between R&D spending and the various linkages variables showed significant impacts.

Table 10 reports the results of analyses on the impact of ownership on the relationship between inter-firm networking and firm innovation. The interaction terms between POE and the linkage variables did not show consistent impacts on innovation. Among all the interactions, only *BothLinksBYPOE* showed positive and significant impact on new product development: private ownership and linkages with both domestic and foreign firms reinforce their impacts on firm new product development. However, no other interaction variables show significant impacts on *AnyPatent* or *NewProduct*. Such results raised further doubt about the validity of the claim that private-owned firms are in better position to take advantage of technological linkages than state-owned enterprises in China.

In the final set of analyses (Tab. 11), we examined the impact of regional settings on the impact of inter-firm networking on firm innovation. The interaction terms between SU_DG and the linkage variables showed neither consistent nor significant impacts on firm innovation. It seemed that regional variation among these five cities does not show strong impact on the relationship between network and innovation, although firms in Suzhou and Dongguan did seem to be less innovative than those in the first-tier cities in China such as Beijing, Shanghai and Shenzhen.

5 Conclusions and discussion

This study focuses on the relationships between inter-firm technological networking and firm innovation and addressed one major question: whether or not inter-firm technological networking helps firm innovation. Our analyses confirmed the positive impacts of inter-firm technological networking on firm innovation that have been revealed by many prior studies (Ahuja 2000; Baum et al. 2000; Gemünden et al. 1992). Our unique contribution to

Tab. 9: Logistic regression: innovation and inter-firm linkages III

Dependent variables	AnyPatent		NewProduct	
Independent variables	**B**	**Exp(B)**	**B**	**Exp(B)**
Years	0.04	1.04**	0.03	1.03
Emp	0.00	1.00***	0.00	1.00
RDExp	0.00	1.00	0.03	1.03***
POE	0.14	1.15	-0.62	0.54
SZ_DG	-1.02	0.36***	-0.45	0.64
DTekLink_only	0.64	1.90*	0.97	2.64***
DTekLinkOnlyByRDExp	0.01	1.01	-0.02	0.98
FTekLink_only	0.59	1.80	2.11	8.29***
FTekLinkOnlyByRDExp	0.01	1.02	-0.03	0.97
BothLinks	1.33	3.78***	1.53	4.62***
BothLinksByRDExp	0.00	1.00	0.00	1.00
#Obs	569.00		577.00	
-2 LOG Likelihood	654.68		626.12	
Nagelkerke R Sq	0.15		0.21	
% Correct	0.71		0.73	

Notes: * significant at the level of 0.10, ** significant at the level of 0.05 and * significant at the level of 0.01**

Tab. 10: Logistic regression: innovation and inter-firm linkages IV

Dependent variables	AnyPatent		NewProduct	
Independent variables	**B**	**Exp(B)**	**B**	**Exp(B)**
Years	0.04	1.04**	0.03	1.03
Emp	0.00	1.00***	0.00	1.00
RDExp	0.01	1.01	0.03	1.03***
POE	-0.08	0.92	-0.95	0.39
SZ_DG	-0.99	0.37***	-0.45	0.64
DTekLink_only	0.48	1.61	0.82	2.27
DTekLinkOnlyByPOE	0.37	1.45	-0.30	0.74
FTekLink_only	21.84	3.06E+09	1.98E+01	3.97E+08
FTekLinkOnlyByPOE	-21.02	0.00	-18.39	0.00
BothLinks	0.67	1.95	-0.18	0.84
BothLinksByPOE	0.85	2.34	1.91	6.75**
#Obs	569.00		577.00	
-2 LOG Likelihood	650.48		624.35	
Nagelkerke R Sq	0.16		0.22	
% Correct	0.72		0.72	

Notes: * significant at the level of 0.10, ** significant at the level of 0.05 and * significant at the level of 0.01**

the literature was to empirically measure and analyze the impacts of the types of inter-firm networks, characteristics of the firms and local contexts on the impact of firm innovation. Our analyses revealed that both foreign and domestic technological linkages contributed to firm innovation, but linkages with foreign firms offered more benefits to local firm innovation than linkages with domestic firms, and it was simultaneous technological linkages with domestic and foreign firms that made the strongest

Tab. 11: Logistic regression: innovation and inter-firm linkages V

Dependent variables	AnyPatent		NewProduct	
Independent variables	B	Exp(B)	B	Exp(B)
Years	0.04	1.04**	1,3	1.03
Emp	0.00	1.00***	0.00	1.00
RDExp	0.01	1.01*	0.03	1.03***
POE	0.14	1.15	-0.72	0.49*
SZ_DG	-0.59	0.55	-0.66	0.52
DTekLink_only	0.77	2.16***	0.39	1.48*
DTekLinkOnlyBySuDG	0.61	1.84	1.17	3.24**
FTekLink_only	1.17	3.21***	1.21	3.34**
FTekLinkOnlyBySuDG	-20.83	0.00	20.65	9.32E+08
BothLinks	1.63	5.11***	1.87	6.48***
BothLinksBySuDG	-1.32	0.27	-0.69	0.50
#Obs	569.00		577.00	
-2 LOG Likelihood	646.78		620.83	
Nagelkerke R Sq	0.17		0.22	
% Correct	0.71		0.74	

Notes: * significant at the level of 0.10, ** significant at the level of 0.05 and * significant at the level of 0.01**

contribution to firm innovation in China. We found that despite the evidence of positive impacts of networking on firm innovation, considerable portion of Chinese firms still did not report any linkages with domestic or foreign firms. Clearly, many still need to go beyond in-house R&D and recognize the value of inter-firm networking.

Our analyses also offered partial support to the argument that over-embeddedness into external networks is be detrimental to firm innovation: the positive impact of networking with domestic firms holds only up to a point, above which the impact turns negative. Nevertheless, such an argument did not seem to be valid in the case of networking with foreign firms: more frequent networking activities with foreign firms seemed to offer stronger positive impact on firm innovation. Such results demonstrated that it is particularly important for firms in China to build "global pipelines" (Altenburg et al. 2008; Bathelt et al. 2004), since foreign firms are more technologically advanced than those domestic firms, although it is easier to communicate with domestic firms. Firms in developing countries should also avoid being over-embedded into networks with domestic firms(Torre and Rallet 2005; Uzzi 1997). But this is not to say that domestic linkage has no value as the best performing firms maintain linkages with foreign and domestic firms.

We further found that the relationships between inter-firm technological interactions and firms innovations were affected by firm internal characteristics and local settings. The findings are not conclusive in these aspects. First of all, we found that internal R&D did *not* seem to enhance the positive impact of inter-firm technological linkages on firm innovation, although internal R&D and technological linkages themselves exert consistent, significant and positive impacts on firm innovation directly. Such results, are in contrast to prior emphasis on internal absorptive capabilities for firms to take advantages of networking (Ahuja 2000; Mowery et al. 1996). The result suggests the weak capabilities of Chinese firms to integrate internal R&D capabilities and external networking. It may also reflect the fact that many Chinese firms have not developed the culture of networking with other firms. We expect that over time Chinese firms will learn such skills and improve the effectiveness of integrating internal and external resources.

In addition, our analyses showed that private owned firms in China are neither more innovative nor are more adept in utilizing inter-firm technological innovations than SOEs. Prior research has emphasized that SOEs in China are less motivated to innovate than PVE. Our results showed that private ownership *per se* did not make a difference in innovative because firstly SOEs have improved their man-

agement and become more innovative; and secondly POEs in China have not fully developed the capabilities to integrate internal and external resources. Such results should be encouraging for Chinese policy makers, who have tried to improve the innovativeness of SOEs.

Finally, our study revealed that firms in Suzhou and Dongguan were less innovative than those in Beijing, Shanghai, and Shenzhen. But that a location in Suzhou and Dongguan did not necessarily weaken the positive impacts of technological linkages with foreign or domestic firms. This suggests that the positive impact of linkages on firm innovation do not change among different types of industry hub.

Overall, our analyses suggest both internal R&D and external inter-firm networking are helpful for firm innovation. For firms in developing countries, building and maintaining linkages with foreign firms offer more value since foreign firms are more advanced technologically in general. Firms in developing countries should also avoid being over-embedded into networks with domestic firms. However, only a small percentage of firms in China have realized the importance of external networks and engaged in active networking with other firms. This is a legacy of the centrally planned period. Our analyses suggest that firms in China should further develop their integrative capabilities in order to take full advantage of the potential synergic effects between internal R&D and external networks.

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