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Haiyu Mao
PhD candidate, Graduate School of Engineering,
University of Tokyo

Jianwei Dang
PhD, Graduate School of Engineering,
University of Tokyo

Kazuyuki Motohashi
Professor, Graduate School of Engineering,
University of Tokyo

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IAM
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Research and Education Program
The University of Tokyo

Physically Proximate or Culturally Cohesive?

Geography, Ethnic Ties, and Innovation in China

Haiyu Mao[1]

[1]*PhD candidate, Graduate School of Engineering, University of Tokyo*

Jianwei Dang[2]

[2]*PhD, Graduate School of Engineering, University of Tokyo*

Kazuyuki Motohashi[3]

[3] *Professor, Graduate School of Engineering, University of Tokyo*

Abstract

Recent scholarship suggests that collaboration between a firm's headquarters personnel and indigenous overseas inventors enhances innovation by the latter. We explore how headquarters inventors' physical proximity and intrafirm ethnic networks influence this knowledge spillover. Data from 104 U.S. multinational firms show that collaboration between inventors in the U.S. and on-site collaboration in China increase the number of inventions created by indigenous Chinese inventors. A cohesive intrafirm ethnic Chinese collaboration network strengthens knowledge spillover.

Keywords: *Ethnic Networks; Engineer Mobility; Multinational Corporations; Foreign Direct Investments*

1. Introduction

U.S. multinational corporations (MNCs) are increasingly conducting research and development (R&D) in China to benefit from its scientific and engineering talent (Lewin et al. 2009). Moreover, China is transforming from "the world's factory" into "the world's market." Catering to the needs of the local Chinese market, U.S. MNCs increasingly employ international co-invention to leverage their indigenous Chinese manpower to create innovations in China.

We distinguish "China invention" from "Chinese invention." A China invention is one that is created entirely in China by indigenous Chinese inventors. A Chinese invention is one created solely by inventors who are ethnically Chinese. They may be Chinese expatriates who work at or formerly worked at U.S. firms or indigenous Chinese who have not. We define "collaboration network" as a network consisting of a variety of inventors that are geographically distributed, and heterogeneous in terms of their operating environment and/or culture, but that collaborate to better achieve common goals. After accumulating skills by collaborating with their U.S. counterparts, including western and Chinese expatriate inventors, indigenous Chinese innovators are expected to create innovations without intellectual input from headquarters (Branstetter et al. 2014).

The ability of MNCs to generate knowledge spillovers among indigenous inventors depends on whether they can transfer knowledge from home base to local recipients (Kogut & Zander 1993). Almeida et al. (2002) identify the tacitness of knowledge as its main impediment to cross-border transfer. Szulanski (1996) and Von Hippel (1994) cite the importance of personnel mobility—i.e., assigning inventors overseas—in transferring tacit knowledge. Foley and Kerr (2011) emphasize how ethnic collaboration networks transmit codified and tacit knowledge to generate inventions.

Notwithstanding the consensus endorsing in-country assignments and collaboration of ethnic networks, little empirical evidence indicates whether collaborating with headquarters inventors generates spillovers among a firm's indigenous inventors. Moreover, little is known about how overseas assignments and ethnic collaboration networks interact to sponsor knowledge spillover in host countries. This study closes this gap by researching three questions with reference to R&D in China by U.S. multinationals. First, does collaborating with headquarters inventors generate knowledge spillovers among firms' indigenous Chinese inventors? Second, as headquarters inventors' physical proximity to indigenous inventors is replaced by virtual electronic collaboration, how does a firm's ethnic Chinese collaboration network facilitate cross-border knowledge transfer and spillovers? Third, as headquarters inventors' proximity to indigenous inventors intensifies by assigning personnel to China, do firms with cohesive Chinese collaboration networks generate more knowledge spillovers?

Foley and Kerr (2013) indicate that expatriate inventors at MNCs promote overseas collaboration with indigenous innovators of their own ethnicity. This study advances the literature by examining the role of Chinese expatriate inventors as intermediaries between western and indigenous Chinese inventors. We demonstrate that a cohesive intrafirm network strengthens cross-border collaboration and innovation by firms' indigenous Chinese inventors.

This study samples U.S. Fortune 500 Companies in a firm fixed model to study how headquarters inventors' physical proximity to indigenous inventors and intrafirm ethnic collaboration networks affect innovation by indigenous Chinese inventors.

2. Theory and Hypotheses

2.1 Physical Proximity and Local Knowledge Spillover

Evolutionary theory suggests MNCs excel at transferring and developing knowledge across borders. This knowledge, according to Kogut and Zander (1993), comprises the required information and know-how. Knowledge is information about *what* something means, and know-how is *how* to do something. Almeida et al. (2002) used "cross-border knowledge building" to describe the process by which MNCs combine transferred knowledge with indigenous partners' knowledge. Previous studies have analyzed several dimensions of a firm's knowledge. Winter (1998) identified four: *tacit or articulable, observable or not observable in use, complex or simple,* and *dependent or independent of a system.* Following winter's taxonomy, Zander and Kogut (1995) identify five dimensions: *codifiability, teachability, complexity, system dependence,* and *product observability.*

These categorizations imply that not all knowledge is codified easily and transferred within a firm. Polanyi's (1967) well-known discussion of tacit knowledge suggests that people know more than they can convey—a suggestion akin to noncodifiable and complex knowledge—and exporting tacit know-how internationally is more challenging than transferring it intrafirm. Academic literature long has studied how intrafirm worker mobility—i.e., assigning personnel to foreign subsidiaries—creates and transfers knowledge across borders (Bartlett & Ghoshal, 1999; Edstrom & Galbraith 1977). Tacit knowledge is "sticky" unless people possessing it are mobile (Szulanski 1996). In their study of transmitting U.S. aerospace technology to Japan, Hall and Johnson (1970) insist that transferring technical know-how requires sending U.S. personnel to Japan. Their insistence confirms Nelson and Winter's (1982) claim that frequent face-to-face formal or informal interactions and learning-by-observing are imperative for transferring tacit knowledge.

Recently, scholars have researched knowledge spillovers among a firm's indigenous inventors in host countries. Hovhannisyan and Keller (2010) examined how short-term assignments of inventors overseas affect innovation abroad. Choudhury's (2010b) study of U.S. multinationals' R&D centers in India found that working with a returnee manager raises the likelihood that indigenous Indian inventors will generate patents.

There are several reasons why physical proximity helps to transfer knowledge to indigenous inventors. It promotes face-to-face interactions that facilitate transfer of tacit know-how and amplifies trust through social relationships. The possibility of knowledge spillovers rises when work-related topics enter the conversation between mobile inventors and local inventors during their spare times. Moreover, it better informs collaborating teams about local customers and technology frontiers (Stuart & Podolny 1996). Therefore, we hypothesize the following.

HYPOTHESIS 1a. *Assigning headquarter inventors to China enhances innovation by indigenous Chinese inventors.*

2.2 Intrafirm Ethnic Collaboration and Knowledge Spillover

Ethnicity is an important channel for transferring codified and tacit knowledge through international networks (Kerr 2008). Understanding the behavior of an ethnic group requires understanding the context in which behaviors occur (Edward 1976). Communication in "high-context" cultures relies on implicit knowledge, non-verbal signals, and behavioral clues. "Low-context" cultures emphasize verbal information and explicit knowledge. In "high-context"

China, implicit knowledge is often hidden behind verbal information, whereas in "low-context" cultures such as Germany verbal communication is more direct and avoids ambiguity. Misunderstandings between people from high-context and low-context cultures hamper knowledge transfer. Therefore, we hypothesize that culturally homogenous teams reduce barriers to communication, facilitate transfer of tacit knowledge, and improve innovation among indigenous inventors.

HYPOTHESIS 1b. *Assigning Chinese expatriate inventors to China enhances innovation by indigenous Chinese inventors.*

2.3 Intrafirm Ethnic Collaboration and Physical Proximity

Extensive literature suggests that assigning inventors abroad facilitates cross-border knowledge transfer; however, information and communications technology (ICT) increasingly replaces in-country interaction (Gibson & Cohen 2003). Virtual teams can promote cultural synergies, creativity, and a competitive advantage for MNCs (Zakaria et al. 2004). However, much of China-based R&D involves projects intended for applications outside China (Branstetter et al. 2014). Indigenous Chinese members of virtual teams are expected to undertake more repetitive and codified tasks, whereas their U.S. counterparts provide intellectual and creative input. After collaborating with colleagues in the U.S., the indigenous Chinese are expected to create innovations for Chinese markets independently. Hence, we hypothesize the following.

HYPOTHESIS 2. *Virtual Collaboration between headquarters inventors in the U.S. and indigenous Chinese inventors can increase innovation among the latter.*

Interpersonal trust enhances transfer of tacit knowledge among virtual teams (Jarvenpaa & Leidner 1998), and that knowledge forms the basis for indigenous recipients to create knowledge. However, learning between individuals requires trust that cannot be easily facilitated by ICT (Von Zedtwitz et al., 2004). As defined by Mayer et al. (1995, p. 712), interpersonal trust is "the willingness of a party to be vulnerable to the actions of another party based on the expectations that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party." If geographically dispersed multicultural teams fail to build trust early, when speculative information and free-form discussion dominate collaboration, future collaboration may never get off the ground (Gassmann 2001). How can virtual teams generate knowledge spillover among indigenous Chinese inventors, and how can they build reciprocal trust? One answer is that virtual teams must cultivate "swift trust" because they lack time to develop trust gradually, and their members are prone to trust persons they are familiar with (Jarvenpaa et al. 1998). Therefore, expatriates are inherent intermediaries between knowledge recipients of their own ethnicity and knowledge senders from other cultures (Kapur 2001). They could comprise the core of collaborative intrafirm networks (Funk 2014) that transfer tacit knowledge and engender knowledge spillovers. A cohesive network between Chinese expatriates and local Chinese facilitate the trust building between headquarter western inventors and local inventors, because both of the two parties have mutual trust toward Chinese expatriates, and both parties are more likely to develop interpersonal trust toward each other because of having a common intermediary. As a result, the possibility of tacit knowledge transfer and knowledge spillover will rise because of the mutual trust developed between headquarter and local Chinese inventors. Hence, we offer the following hypothesis.

HYPOTHESIS 3a. *A cohesive collaboration network of expatriate and indigenous Chinese can strengthen cross-border collaboration and innovation among the latter.*

Teaching tacit know-how requires frequent small-group interaction and often involves a private language or code (Kogut & Zander 1992; Katz & Kahn 1966). Therefore, we posit that a cohesive ethnic Chinese collaboration network, one that includes assigning expatriate Chinese inventors to China, can facilitate transfer of tacit knowledge to indigenous Chinese inventors, increasing their innovative output.

HYPOTHESIS 3b. *A cohesive intrafirm network can strengthen the benefits of assigning Chinese expatriate inventors to China and foster innovation among a firm's indigenous Chinese inventors.*

3. Data and Method

3.1. Data for Ethnic Chinese Innovators

We use U.S. patent data to examine whether expatriate Chinese innovators promote patents by U.S. multinationals in China. Furthermore, we investigate whether assigning expatriate Chinese innovators to Chinese subsidiaries fosters China inventions as defined earlier. Patent data are common indicators of innovation (Griliches 1990; Hall et al. 2001; Nagaoka et al. 2010). Previous studies used patent data to examine expatriate ethnic innovators and MNCs' innovation abroad (Choudhury 2010a; Choudhury 2010b; 2010c; Foley & Kerr 2013). Patent data contain informative details about the innovation, inventor and owner (assignee), allowing us to identify ethnicity by matching inventors' names with a database and to identify specific inventors by examining changes in their addresses. We sampled U.S. Fortune 500 companies because most are multinational and conduct R&D in China. Their activities should produce patents attributable to indigenous Chinese inventors.

Our data come from several sources. The first is the 2013 Chinese patent database by the China State Intellectual Patent Office (SIPO). The second is the Disambiguation and Co-authorship Network of the U.S. Patent Inventor Database (Fleming et al. 2014), which contains bibliographic information for U.S. patents granted during 1975–2010. The third is the 2008 listing of Fortune 500 firms from the FORTUNE Datastore. The fourth is the Chinese Ethnic Surname Database by the Institute of Genetic and Developmental Biology of the Chinese Academy of Sciences. It includes 387 pinyin[1] covering 97% of Chinese surnames (Yuan 2009). The fifth is Compustat financial database 2010.

We started with the SIPO patent database to construct our firm-level dataset. First, we extracted all patents granted by SIPO that have a U.S. priority and a related Chinese patent with a U.S. priority application from January 1999 through December 2007—i.e., all Chinese-originating patents first granted in the U.S. and then in China. We used post-1999 samples because almost no Chinese patents list indigenous Chinese inventors until 1999 and we stopped after 2007 to prevent the 2008 financial crisis from affecting our analysis.

[1] Pinyin is an official phonetic system for transcribing Mandarin pronunciations of Chinese characters into the Latin alphabet

Second, we use the 2008 list of Fortune 500 firms to match patent applicants. We compiled 104 Fortune 500 firms that sought at least one Chinese patent from 1999 to 2007.

Third, we matched names of the 104 Fortune 500 firms with the U.S. Patent Inventor Database and extracted all U.S. patents sought by these firms during 1999–2007. Further, using Compustat, we obtained the firms' financial information (e.g., sales).

Finally, we used the Chinese Ethnic Surname Database to estimate inventors' ethnicity. Some Korean and Chinese surnames share pinyin; thus, we compiled a dataset of first and last Korean names for all U.S. patents created in Korea. We dropped from our sample patents granted to inventors with Chinese surnames and Korean first names. We used changes in addresses to assess inventors' mobility. If an inventor declared a U.S. address for his first patent and a Chinese address subsequently, we defined him as having experience with a U.S. firm.

Our procedures created a firm-level panel dataset of 104 Fortune 500 firms spanning 1999–2007 for analysis. Many Fortune 500 companies use both overseas assignment and ICT in transnational R&D projects; however, they weight project phases differently (Von Zedtwitz et al. 2004). For example, initially, IBM assigns headquarters inventors abroad to introduce its corporate culture and to collaborate with indigenous inventors. Later, cross-border collaboration occurs via video conferences and email. Figure 1 indicates trends in inventions by type of collaboration with indigenous Chinese inventors. In the early years, nearly half of all inventions originated through in-country collaboration between headquarters inventors assigned to China and indigenous Chinese inventors. However, as firms accumulate experience in China, in-country collaboration diminishes and ICT-supported collaboration increases. This finding supports Von Zedtwitz et al.'s (2004) arguments.

Figure 1

3.2. Method

We use an ordinary least squares model that includes firm fixed effects to test our hypotheses. We include fixed effects to control for firm differences and add a year-specific fixed effect to control for increased participation of ethnic Chinese inventors.

Dependent Variables

Log (# Patents on Inventions by Indigenous Chinese). This dependent variable denotes innovative output by sampled firms' indigenous Chinese inventors. It is the log of the number of firm's patents created exclusively by indigenous Chinese inventors. "Indigenous Chinese inventors" refers to Chinese who never worked in the U.S. previously.

Number of patent citations for China inventions measures the technological impact of inventions created by firms' indigenous Chinese inventors. All patent awards herald innovation (Hall et al. 2000; Nagaoka et al. 2010); however, we use the number of citations (net of self-citations) to indicate the technological impact of China inventions (Trajtenberg 1990), as previously defined, during five years after the patent filing date—the window within which patents receive the most citations (Hall et al. 2001).

Independent Variables

Log (# local co-invention by U.S. expatriate and indigenous Chinese). To test Hypothesis 1a, the independent variable is the log of the number of a firm's patents awarded to Chinese inventions. As previously defined, those are created in China by Chinese expatriates and/or indigenous Chinese inventors. Addresses from patent filings identified whether Chinese inventors were expatriates or indigenous.

Log (# local co-inventions by U.S. non-Chinese & indigenous Chinese). To test Hypothesis 1a, we introduce an ethnicity variable that differs from the previous variable. It is the log of the number of patents awarded for inventions co-created in China by a firm's non-Chinese and indigenous Chinese inventors.

Log (# Cross-border co-inventions). Our second hypothesis predicts that cross-border collaboration between headquarters inventors in the U.S. and indigenous Chinese inventors generates knowledge spillover among the latter. This independent variable denotes the extent to which a firm sought to patent inventions co-created by U.S. and indigenous Chinese inventors.

Ethnic Chinese collaboration networks - Cohesion. To measure the cohesion of collaboration networks we divided the number of a firm's patents awarded to inventions co-created by Chinese expatriates and indigenous Chinese by the total of the firm's patents. Values span 0 to 1; a higher value indicates greater network cohesion.

Experience with cross-border co-invention is a dummy measuring whether a team of indigenous Chinese inventors who secured patents includes members who previously had collaborated with U.S. headquarters inventors of any nationality through virtual teams.

Experience of cross-border co-invention with Chinese expatriates is a dummy measuring whether a team of Chinese who secured patents includes members who previously had collaborated with Chinese expatriate inventors through virtual teams.

Experience of local co-invention with U.S. experienced inventors is a dummy. It indicates whether a team of indigenous Chinese who secured patents includes members who previously had collaborated with headquarters inventors of any nationality assigned to China.

Experience of local co-invention with U.S. experienced expatriate Chinese inventors.
This dummy indicates whether indigenous Chinese inventors had previously collaborated with headquarters expatriate Chinese inventors assigned to China.

Control Variables

We controlled for the innovative capability of sampled firms by introducing control variables. *Log (# Firm U.S.-invented patents)* measures the number of patents awarded to U.S. inventions the firm sought in a given year.

Log (# Firm Sales) measures the U.S. firm's sales revenues to control for a firm size effect. We add firm fixed effects and year fixed effects to control for firm differences and time variance. Table 1 presents the correlation matrix and descriptive statistics.

Table 1 here

4. Results

Tables 2 and 3 present models of quantity of output by indigenous Chinese inventors and the technological impact of their patents, respectively. Hypothesis 1a predicts that assigning headquarters expatriate Chinese inventors to China will boost innovation output by indigenous Chinese inventors. Models 2–6 in Table 2 test this hypothesis by introducing the two independent variables: number of patents for inventions by Chinese expatriates in China and indigenous Chinese inventors, and number of patents for inventions by non-Chinese headquarters inventors in China and indigenous Chinese inventors. Coefficients for the two independent variables are significant and positive in Models 2–6. Hypothesis 1a is supported.

Hypothesis 2 posits that cross-border collaboration with headquarters inventors enhances innovation by indigenous Chinese inventors. Models 1 and 3–6 test this hypothesis. The coefficient for Log (# Cross-border co-inventions) is significant and positive in all models. Hypothesis 2 is supported.

Hypotheses 3a and 3b address the interdependent effects of a firm's ethnic Chinese collaboration network and headquarters inventors' physical proximity to indigenous Chinese inventors on innovation by the latter. Hypothesis 3a predicts that when headquarters inventors' physical proximity to local Chinese inventors decreases, a cohesive intrafirm Chinese collaboration network strengthens knowledge spillover. Hypothesis 3b predicts that when headquarters inventors' work in China, a cohesive intrafirm Chinese network strengthens knowledge spillover.

Table 2 here

In Table 2, Models 4–6 test these hypotheses by measuring relations between a firm's ethnic Chinese network and types of co-invention. In Model 4, the coefficient for interaction between network cohesion and number of cross-border co-inventions is significant and positive. Innovation by indigenous Chinese increases among firms with cohesive ethnic Chinese collaboration networks. Hypothesis 3a is supported.

In Model 5, interaction between network cohesion and the number of co-inventions involving non-Chinese and indigenous Chinese inventors is positive but not significant. At firms with cohesive Chinese collaboration networks, assigning non-Chinese inventors to China does not enhance innovation by indigenous Chinese inventors.

However, in Model 6 interaction between cohesion and the number of co-inventions created in China by expatriate and indigenous Chinese is significant and positive. At firms with cohesive Chinese collaboration networks, assigning Chinese expatriates to China fosters inventions by indigenous Chinese. Hypothesis 3b is supported.

Table 3 is used to test Hypothesis 1b. Models 1–4 in Table 3 introduce independent variables denoting indigenous inventors' previous experience with cross-border co-invention and local co-invention. Coefficients for experience in cross-border collaboration are not significant in all models. This finding captures two considerations. First, inventions created via cross-border collaboration are mainly destined for global markets. Second, indigenous Chinese inventors generally perform repetitive and routine tasks. The finding intimates that indigenous inventors assimilate the U.S. firm's culture of innovation and generate more patents. However, creating high-impact innovations in China requires indigenous inventors to combine the U.S. firm's culture of innovation with local knowledge, a process they did not learn during cross-border collaboration. Therefore, cross-border collaboration might not prepare indigenous Chinese to generate inventions with high technological and economic value.

However, Hypothesis 1b predicts that assigning Chinese expatriates to China helps indigenous inventors to generate high-quality patents eventually. Models 3 and 4 support this hypothesis. In Model 3, the coefficient for experience collaborating in China is significant and positive. In Model 4, after adding all variables, the coefficient for collaborative experience with expatriate Chinese in China is significant and positive. Hypothesis 1b is supported.

Table 3 here

5. Discussion and Conclusion

This study has expanded upon Kogut and Zander's (1993) theory that MNCs enjoy competitive advantage by transferring information and know-how to create cross-border knowledge. This study has demonstrated that R&D at Fortune 500 firms with cohesive networks of ethnic Chinese generates knowledge spillovers among indigenous Chinese inventors.

Our empirical results include the following. First, cross-border collaboration between expatriate and indigenous Chinese raises the latter's innovative performance. Second, China-based co-invention between headquarters and indigenous Chinese inventors increases innovation by the latter. Third, a cohesive collaboration network between expatriate and indigenous Chinese accrues more benefits of cross-border invention to indigenous Chinese inventors. Fourth, assigning Chinese expatriate inventors to China enhances innovation among indigenous Chinese inventors.

The intended contribution of this study is to investigate the role of MNCs' Chinese expatriate inventors in facilitating cross-border knowledge transfer and knowledge spillover in host countries. U.S. MNCs' transnational R&D in China often involves multicultural teams that include Chinese inventors from a high-context culture, and western inventors from a low-context culture. People from high-context cultures relies extensive informal information and a tendency towards close personal relationships. Low-context cultures tend to allow only a minimum of informal information (Gassmann 2001). Therefore, people from different cultures often have difficulty building trust between each other, especially when members are geographically dispersed. Because Chinese expatriates working in the U.S. generally understand both cultures and can be trained to handle intercultural conflicts, MNCs headquarters ethnic Chinese inventors are an ideal "human bridge" within multicultural teams. Our results suggest that for firms with a cohesive collaboration network between Chinese expatriates and firms' local Chinese, the positive impact of collaboration with headquarters inventors on innovative performance of local Chinese inventors can be strengthened.

This study expands the literature of personnel development and international knowledge spillover. Our results indicate that assigning Chinese expatriates to China yields more effective innovation than collaborating with headquarters inventors in the U.S. Although ICT facilitates international innovation, tacit knowledge is more effectively conveyed face to face.

Our study bears implications for enhancing R&D in China. If firms regard Chinese R&D as supplementary, more cross-border collaboration leverages Chinese manpower. If firms wish to maintain autonomous R&D centers in China, assigning Chinese expatriates there leverages indigenous Chinese talent to create localized innovations. In either case, MNCs should train Chinese expatriates to lead R&D projects in China. They are inherent mediators of cultural conflicts and trust-builders on virtual teams. Overall, firms should promote collaboration between expatriate and indigenous Chinese inventors, using strategic personnel assignments and virtual teams to multiply the creativity of indigenous Chinese inventors.

Figure 1: Trends of Innovations by Inventor Identity

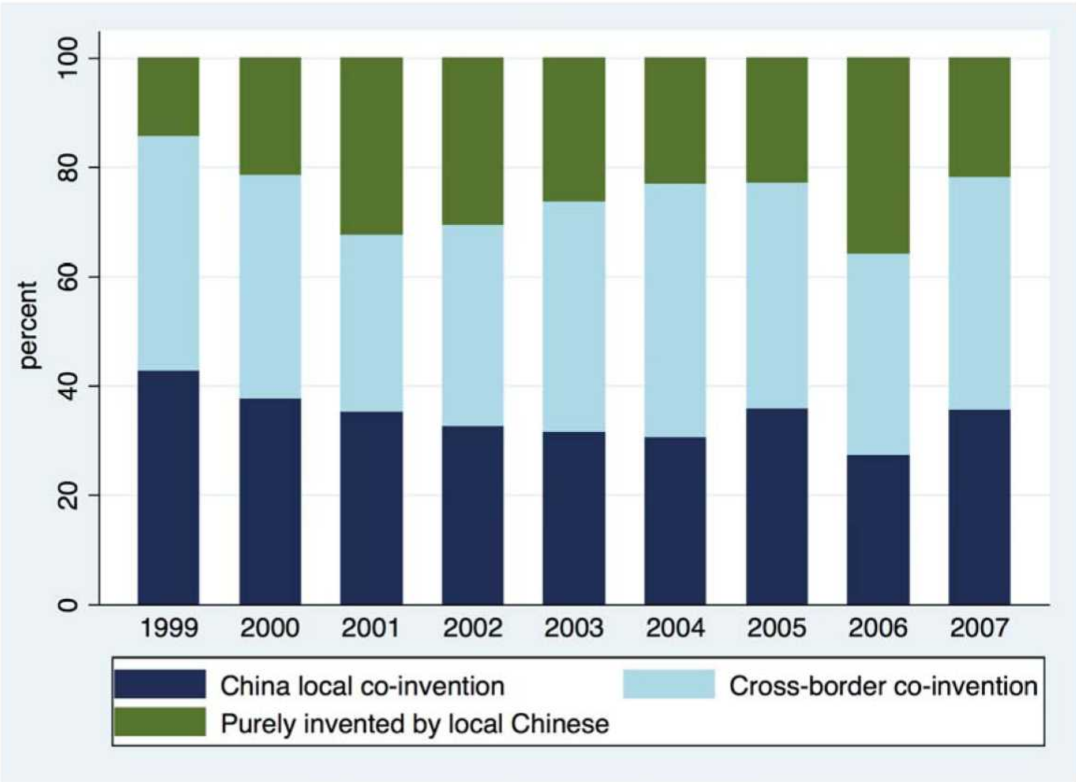

Table 1

Descriptive Statistics and Correlation Matrix

Variable	Mean	S.D.	1	2	3	4	5	1	2	3	4	5
1. Log (# Patents on Inventions by Indigenous Chines	0.08	0.42										
2. Log (# local co-invention by U.S. expatriate & indigenous Chinese	0.06	0.39	0.80									
3. Log (# local co-invention by U.S. non-Chinese & indigenous Chinese	0.01	0.16	0.64	0.81								
4. Log (# Cross-border co-inventions)	0.10	0.50	0.84	0.78	0.62							
5. Cohesion	0.0003	0.003	0.39	0.44	0.40	0.44						
6. Log (# Firm U.S. Invented Patents)	0.36	0.29	0.17	0.37	0.11	0.18	0.12					
1. Number of patent citations for China inventions												
2. Experience of cross-border co-invention	0.09	0.29						-0.08				
3. Experience of cross-border co-invention with expatriate Chinese	0.07	0.26						-0.06	0.89	0.13		
4. Experience of local co-invention with U.S. experienced inventors	0.50	0.50						0.07	0.13	-0.09		
5. Experience of local co-invention with U.S. experienced expatriate Chinese inventors	0.42	0.49						0.13	-0.06	-0.09	0.85	
6. Log (# Firm Sales)	9.15	1.42	0.19	0.20	0.09	0.10	0.03	0.05	-0.10	-0.09	-0.15	-0.11

Table 2

Models of Quantity of Innovation Output (1999-2007)

Dependent Variable:	***Log (# Patents on Inventions by Indigenous Chinese)***					
	(1)	(2)	(3)	(4)	(5)	(6)
Log (# local co-invention by U.S. expatriate & indigenous Chinese		0.664*** (0.0541)	0.459*** (0.0556)	0.356*** (0.0579)	0.441*** (0.0571)	0.336*** (0.0609)
Log (# local co-invention by U.S. non-Chinese & indigenous Chinese		0.427*** (0.0734)	0.417*** (0.0694)	0.381*** (0.0685)	0.361*** (0.0813)	0.390*** (0.0688)
Log (# Cross-border co-inventions)	0.359*** (0.0247)		0.231*** (0.0249)	0.216*** (0.0246)	0.235*** (0.0251)	0.244*** (0.0247)
Cohesion			1.534 (2.010)	−10.24*** (2.961)	0.654 (2.116)	−1.696 (2.103)
Cohesion × Log (# Cross-border co-inventions)				11.80*** (2.212)		
Cohesion × Log (# local co-invention by U.S. expatriate & indigenous Chinese)					5.135 (3.880)	
Cohesion × Log (# local co-invention by U.S. non-Chinese & indigenous Chinese)						8.086*** (1.755)
Control Variables						
Log (# U.S. Invented Patents)	0.00956 (0.0114)	0.00298 (0.0109)	0.00264 (0.0103)	0.00525 (0.0102)	0.00320 (0.0103)	0.00423 (0.0102)
Log (# Firm Sales)	0.00457 (0.00980)	0.00640 (0.00934)	0.00351 (0.00884)	0.00136 (0.00869)	0.00300 (0.00885)	0.00164 (0.00873)
Parent Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−0.0314 (0.0965)	−0.0297 (0.0920)	−0.0143 (0.0870)	−0.00146 (0.0855)	−0.0112 (0.0870)	−0.000921 (0.0859)
N	860	860	860	860	860	860
R^2	0.222	0.294	0.370	0.393	0.371	0.387

Notes. "Cross-border co-created patents" are patents awarded to inventions created by indigenous Chinese who never worked in the U.S. and headquarters inventors in the U.S. "Cohesion" assesses the robustness of a firm's Chinese collaboration network. It is the ratio of the number of patents awarded to teams of Chinese expatriates and indigenous Chinese without U.S. experience, divided by the number of total patents. *** *indicates significant at 1%.*

Table 3

Models of Technological Impact (1999-2005)

Dependent Variable:	*Number of patent citations for China inventions*			
	(1)	(2)	(3)	(4)
Experience of cross-border co-invention	−1.680 (1.126)	−3.641 (2.428)	−3.625 (2.408)	−3.780 (2.397)
Experience of cross-border co-invention with expatriate Chinese		2.438 (2.675)	2.408 (2.653)	3.454 (2.698)
Experience of local co-invention with U.S. experienced inventors			1.897** (0.816)	−0.130 (1.352)
Experience of local co-invention with U.S. experienced expatriate Chinese inventors				2.387* (1.273)
Control Variables *Log (# Firm Sales)*	−1.492 (5.748)	−1.539 (5.750)	−2.839 (5.729)	−2.704 (5.701)
Parent Firm Dummy	Yes	Yes	Yes	Yes
Year Dummy	Yes	Yes	Yes	Yes
Constant	22.01 (48.55)	22.46 (48.57)	33.86 (48.41)	32.63 (48.18)
N	283	283	283	283
R^2	0.218	0.220	0.236	0.247

Notes. The dependent variable sums 5 years of citations for patented inventions created by indigenous Chinese without U.S. work experience. The four independent variables measure whether these Chinese inventors had previously collaborated with headquarters inventors of any ethnicity in the U.S., with Chinese expatriates in the U.S., with non-Chinese inventors in China, or with Chinese expatriates in China. *** *indicates significant at 1%.*

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