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Zi-Lin He [a] & Poh-Kam Wong [b]

[a] Department of Organization and Strategy, Tilburg University, Tilburg, The Netherlands

[b] NUS Entrepreneurship Centre, National University of Singapore, Singapore

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Reaching Out and Reaching Within: A Study of the Relationship between Innovation Collaboration and Innovation Performance

ZI-LIN HE* & POH-KAM WONG**

**Department of Organization and Strategy, Tilburg University, Tilburg, The Netherlands, **NUS Entrepreneurship Centre, National University of Singapore, Singapore*

ABSTRACT A large body of research has thoroughly discussed and examined agglomeration advantages for innovation of geographically concentrated firms. However, there is an increasing awareness that this intellectual tradition tends to overemphasize the role of geographic proximity in the transfer of knowledge between firms and to under-theorize the contribution of nonlocal knowledge flows. With a sample of 143 manufacturing firms from Singapore, this research attempts to answer three interrelated questions: (1) Does local networking effort provide firms with added value above and beyond what is available to them by just "being there?" (2) Does local collaboration contribute more to innovation performance than nonlocal collaboration? (3) What is the joint impact of local and nonlocal collaborations on innovation performance? We find that while local and nonlocal collaborations are statistically indistinguishable from each other in terms of their relative importance, they represent complementary spurs to innovation. Despite the unique research setting of Singapore as a city state, we argue that our findings may be generalizable to geographic systems in other parts of the world.

KEY WORDS: innovation collaboration, local and global, innovation performance, Singapore

1. Introduction

Firms often innovate through networking with partners, including customers, suppliers, specialist service providers, universities, and even competitors. Benefits of innovation collaboration generally involve a combination of sharing development costs and risks, accessing complementary skills and capabilities, learning from partners, accelerating time-to-market, etc. (DeBresson & Amesse, 1991; Hagedoorn, 2002). Many scholars have documented a positive and significant correlation between collaborative networks

Correspondence Address: Zi-Lin He, Department of Organization and Strategy, Tilburg University, Tilburg, The Netherlands. Email: z.l.he@uvt.nl

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and innovation performance for firms in different industries, such as biotechnology (Powell *et al.*, 1996) and semiconductor (Stuart, 2000). In a study of firms across different manufacturing industries, Hagedoorn & Schakenraad (1994) report a positive relationship between the frequency of R&D partnerships and rates of innovation.

The last few decades have also witnessed a growing influence of geography in the discussion of learning and innovation, both in academia and among policy makers. Geographic systems of different varieties, such as cluster, industrial district, and regional innovation systems, are conceptualized as venues of enhanced knowledge creation (Maskell & Malmberg, 1999; Lorenzen & Maskell, 2004) due to several agglomeration advantages for innovation of geographically concentrated firms. Empirical studies have found broad support for a positive relationship between locational agglomeration and firm innovativeness, and a general conclusion is that firms in geographic clusters are more innovative than their isolated counterparts (Baptista & Swann 1998; Beaudry & Breschi 2003).

However, there is an increasing awareness that this intellectual tradition tends to overemphasize the role of geographic proximity in the transfer of knowledge between firms and to under-theorize the contribution of nonlocal knowledge flows to innovation. Three interrelated questions have been raised in the debate over the importance of local versus nonlocal collaboration for innovation: (1) Does local networking effort provide firms with added value above and beyond what is available to them by just “being there?” (2) Does local collaboration contribute more to innovation performance than nonlocal collaboration? (3) What is the joint impact of local and nonlocal collaborations on innovation performance? This paper offers a critical review of the local versus nonlocal debate, develops three hypotheses corresponding to these three questions, and tests them with a sample of 143 manufacturing firms from Singapore.

2. Agglomeration Advantages for Innovation

Three broad conceptual arguments have been advanced in the literature to suggest advantages of geographic agglomeration for innovation. First, agglomeration gives firms access to a pool of specialized inputs and service providers induced by industrial demand and external economies of scale. Specialized local suppliers make intermediate inputs and services available in a greater variety, at lower prices, and on shorter delivery times, which is crucial for firms to respond swiftly to evolving market conditions and emerging innovation opportunities (Feldman, 1994). In many cases, firms also cluster in proximity to their main customers, thereby perceiving customer needs more clearly and rapidly (Campbell-Kelly *et al.*, 2010). These localized input–output linkages or buyer–supplier relationships are a good source of ideas for innovation (Lundvall, 1988; von Hippel, 1988). In addition, continuous comparison and imitation among local competitors in a densely populated environment provide pressure as well as inspiration for innovation as firms race to get ahead of one another (Porter, 1998).

Second, agglomeration gives rise to local labor market pooling whereby on the one-hand workers are better matched to jobs or firms, and on the other it becomes easier for firms to locate and recruit specialized technical personnel (Audretsch & Stephan, 1996). Moreover, intraregional mobility is much more likely than interregional mobility for scientists, engineers, and entrepreneurs, laying a key foundation of learning and innovation for clusters and firms within them (Casper, 2007). A byproduct of inter-firm mobility in the local labor market is overlapping personal, organizational, and professional networks that characterize many vibrant regional economies and clusters. These social relations are oftentimes primary knowledge sources for co-located firms.

Third, agglomeration accelerates the pace of innovation as knowledge developed within one organization spills over to those nearby. Knowledge spillovers or something “in the air” as Marshall (1920) called it tend to be geographically bounded like “an atmosphere cannot be moved”. Reasons for localized knowledge spillovers are many [see Breschi & Lissoni (2001) and Lorenzen (2005) for a discussion and critique]. The general argument is that geographic proximity promotes innovation because it increases not only the frequency of interaction but also the effectiveness of knowledge exchange between local actors by facilitating face-to-face contact and contributing to the emergence of trust and norms of cooperation (Arikan, 2009). Although knowledge flows across organizational boundaries in all industries, “the intensity and effects of such streams are heightened by spatial proximity” (Whittington *et al.*, 2009, p. 92). Therefore, localized knowledge flows are “a public good, but a local one” (Breschi & Lissoni, 2001, p. 258), bestowing clustered firms with a string of innovative advantages not available to outsiders.

To sum up, clustered firms have easier and cheaper access to certain collective resource pools, including specialized intermediate inputs, a pooled local labor market, and spatially bounded knowledge flows, especially flows of sticky, tacit knowledge. Access to these resource pools is presumably limited to co-located firms. Regarding innovation as an interactive learning process, one would conclude that within a cluster, firms interact more with other local actors and benefit more from local knowledge flows that are shared among and retained by local participants and, as a result, they innovate at a faster rate and have higher innovation performance than their isolated competitors.

In recent years, however, researchers cast doubt on the local, endogenous focus of these mainstream geography studies of innovation. Boschma (2005) argues that geographic proximity is neither a necessary nor a sufficient condition for knowledge spillovers and interactive learning. Lorenzen (2005, p. 401) makes the remark that these studies are “bordering on overstressing their point” as they cannot explain when and why knowledge also flows globally. Several scholars point out there is nothing inherently spatial about networks and it would be wrong to assume that knowledge flows are geographically localized (Bunnell & Coe, 2001; Boschma & Ter Wal, 2007). In the following section, we present a critical review of this debate by asking three interrelated questions, and from there we develop three testable hypotheses.

3. Hypothesis Development

3.1 Is “Being There” Enough?

The first question concerns the relevance of firms’ conscious networking effort within a cluster. The traditional view is that “being there”, namely co-location *per se*, is sufficient for firms to benefit from localized knowledge flows and collective learning processes because being close to each other almost automatically gives rise to more frequent, effective, and often unplanned interaction. Local knowledge flows permeate a cluster unconsciously and promptly like something “in the air”. Localized knowledge spillovers are *unconscious* as they are assumed to be readily available for clustered firms that share certain location-specific absorptive capacity. Local knowledge is thus conceptualized as a semi-public good that is spatially bounded, and access to which requires nothing more than cluster membership. Next, local knowledge exchange is *prompt* or spontaneous because local firms are assumed to be more willing to share knowledge and exchange ideas with other local actors as a result of shared norms, values, and other formal and informal institutions that hold down misunderstanding and opportunism (Gertler, 1995; Lorenzen, 2005).

A widely used term to delineate the diffused benefits of geographic agglomeration is "*local buzz*" (Bathelt *et al*., 2004). Being exposed to local buzz or local broadcasting, clustered firms receive specific information on business opportunities and innovative ideas rather automatically and continuously. Local actors are surrounded by "a concoction of rumors, impressions, recommendations, trade folklore and strategic information" (Grabher, 2002, p. 209). They continuously contribute to and benefit from the diffusion of information, inspiration, and good ideas by just "being there". Their participation in the buzz does not require particular investment, and agglomeration advantages accrue to local firms without any conscious and purposeful collaboration among them.

This "something-in-the-air" perspective assumes, explicitly or implicitly, that knowledge is evenly distributed in a cluster and all firms within will benefit equally from knowledge spillovers. However, this is hardly the case in reality, and there has been mounting evidence that within a cluster, knowledge is distributed unevenly and firms have heterogeneous capabilities to contribute to or benefit from local knowledge flows (Shaver & Flyer, 2000; Boschma & Ter Wal, 2007; Asheim *et al*., 2009).

In a conceptual paper, Boschma (2005) offers compelling arguments that geographic proximity is neither a necessary nor a sufficient condition for knowledge spillovers and interactive learning. The "being-there" argument oversells learning benefits of co-location; physical proximity does not automatically embed firms in the local web of social relations for knowledge exchange because the development of trust and the emergence of shared interpretative schemes require more than just co-location. Rather, geographic proximity facilitates interactive learning by strengthening the other dimensions of proximity or similarity, be it cognitive, organizational, or social (Boschma, 2005).

Informal, unstructured knowledge spillovers cannot adequately meet firms' knowledge needs. Formal partnerships are an important mechanism to transfer complex knowledge (Mowery *et al*., 1996); firms must go beyond merely "being there" and purposefully create formal collaboration structures to exchange or co-develop knowledge with other local actors. By committing to share the payoffs from joint development and respecting each others' proprietary know-how through contractual safeguards, firms will be more forthcoming with sharing knowledge (Zaheer & George, 2004). Firms may be part of a local cluster, but rarely is the case that they are connected to other local actors to the same extent and in the same way. Formal relational linkages with other local actors expand access to skills and resources above and beyond what is available through undirected, spontaneous "local buzz".

Considerable empirical evidence has accumulated for the argument that the extent to which firms can tap into the local knowledge base depends on more than just geographic proximity. In her seminal research on Silicon Valley, Saxenian (1994) shows that what matters to interactive learning is much more than mere co-location; instead, firms must get themselves embedded in regional networks through establishing partnerships with other actors. In a study of US public firms in the biotechnology industry, Zaheer & George (2004) find that firms do better by not relying merely on spontaneous knowledge spillovers from within the region, but by establishing formal partnerships with other local firms. Using a longitudinal sample of US life science firms in regional clusters, Whittington *et al.* (2009) present evidence that firms' centrality in local networks positively influences their rate of patenting. Similarly, Boschma & Ter Wal (2007) challenge the assumption that all firms in a regional cluster are equally affected by agglomeration benefits when they show that firms with more central positions in the local network of the Barletta footwear district in Italy have stronger innovation performance. As they conclude, "it mattered being locally connected: being co-located was just not enough" (Boschma & Ter Wal, 2007, p. 196).

In summary, geographic proximity may facilitate but never guarantee local networking. Local clustering and local networking are two distinct concepts; local clustering is tied to diffused agglomeration benefits and spontaneous knowledge spillovers, whereas local networking is a strategic means of purposeful and selective knowledge exchange between a firm and another local actor (Visser, 2009). Whether local firms network with each other and how such networking effort pays off should be examined separately, above and beyond the fact that they are geographically co-located. With the above reasoning and available empirical evidence, it is expected that local collaborative relationships make a firm more innovative than its less connected local peers. This leads to the following hypothesis:

Hypothesis 1: Given that firms are located in the same geographic area, local collaboration enhances their innovation performance.

3.2 Is Local Collaboration Superior to Nonlocal Collaboration?

An extension of the "being-there" perspective is a focus on local networks as the dominant driver of innovation. Following influential studies of Silicon Valley and the Third Italy, many researchers set their analytical and empirical focus on local, endogenous processes especially local networking to explain regional innovation and growth. Distance costs of knowledge coordination and transfer are the most common justification for this choice of focus (Lorenzen, 2005). Most of these arguments start with the distinction between tacit and codified knowledge. Tacit knowledge is highly situated, which means it is very much embedded within a particular physical and social context (von Hippel, 1994). Transmission of tacit knowledge must be accompanied by intensive interaction and joint observation. For example, research scientists and engineers often communicate with the help of instruments, sketches, machines, and prototypes at hand to convey what they cannot verbalize (Song *et al.*, 2007, p. 56). Consequently, the transfer of tacit knowledge is mostly a matter of face-to-face contact and personal relations that come about more easily when the knowledge sender and receiver are geographically proximate. While distance increases the difficulty of transferring tacit knowledge, the effectiveness of transferring codified knowledge does not decline sharply with geographic distance.

Moreover, when the asset being traded involves tacit knowledge, the exchange is likely to be plagued by various concerns of opportunism. To mitigate opportunism in knowledge exchange, trust has to be developed between partners to lubricate their interaction, yet creating trust requires a period of rich communication and shared experience, which is difficult if actors are located far apart. Local partners often intuitively understand the rules and procedures each follows, and localized social institutions such as reputation effects help reduce transaction costs and misunderstandings, rendering local knowledge coordination and transfer comparatively more efficient (Lorenzen, 2005).

However, an increasing number of scholars start questioning the utility of making a distinction between tacit and codified knowledge in this debate and asking whether the role of local networking has been exaggerated. First of all, there is nothing inherently spatial about networks and it would be wrong to assume that networks are geographically delimited (Bunnell & Coe, 2001; Boschma, 2005). Both tacit and codified knowledge can be exchanged locally and globally. On the one hand, much of the knowledge circulated within a geographic cluster is highly codified (Lorenzen, 2005), though local firms often make better use of it due to access to the cluster's complementary tacit knowledge base (Tallman *et al.*, 2004). On the other hand, tacit knowledge circulates through members of an epistemic community that have overlapping cognitive frameworks (Breschi & Lissoni, 2001). Yet an epistemic community is seldom as wide as including all actors in a local economy, and at the same time it often crosscuts many geographical boundaries.

Next, although face-to-face contact is conducive to transferring tacit knowledge, this does not mean that exchange partners have to be located close to one another. Temporary spatial proximity can be organized through various means such as regular visits, joint workshops, and meetings at conferences or trade fairs (Rallet & Torre, 2000; Breschi & Lissoni, 2001). Modern information and communication technology also creates new opportunities for interactive learning without co-location, making knowledge networks less spatially delimited than ever (Boschma, 2005; Song *et al.*, 2007). Various tools of computer-mediated communication like e-mail and videoconferencing allow a geographically dispersed, culturally diverse group of scientists and engineers to work on the same innovation project. To be sure, these tools cannot completely replace face-to-face contact. They nonetheless make knowledge coordination and transfer much less dependent on co-location. As soon as initial trust and sufficient mutual understanding have been established, transfer of tacit knowledge can be made possible by these distance-insensitive tools, though face-to-face meetings may still be necessary at critical phases of the innovation process (Hildrum, 2009; Weterings & Boschma, 2009).

From a firm's point of view, complementary knowledge inputs for innovation success are not bounded by spatial proximity, but found wherever available. Partner selection in principle should be based on the extent of learning potential and access to complementary capabilities. Although collaboration might be cheaper or easier within a geographic cluster, no region has monopoly on good ideas and hence firms need nonlocal partnerships to access skills and resources not available within their local regions. Moreover, depending on the quality and sophistication of local knowledge sources, geographic clusters may be ranked hierarchically (Cooke, 2006). While many regions in advanced economies are blessed with large knowledge stocks accumulated in a path-dependent process, firms in latecomer industrial clusters especially need nonlocal knowledge in the innovation process as they are often distant from both lead users and technology suppliers (Ernst, 2000; Chen, 2009).

Recent empirical investigations have demonstrated the need to examine local and nonlocal collaborations side by side and uncover how they influence innovation performance in each other's presence. Using network analysis, Gilding (2008) shows that the Melbourne biotechnology cluster in Australia is characterized by both dense local connections and growing international linkages especially with partners in the USA and UK, including those from world biotechnology hubs such as Boston, San Diego, San Francisco, and Cambridge. Doloreux & Mattson (2008) study 172 knowledge-intensive firms in the region of Ottawa, Canada, and identify a U-shaped geographic pattern of innovation collaboration, which means both local and global partners are most common, but collaboration at the provincial and national scales is clearly not as significant. Although these studies direct our attention to the co-existence of local and distant collaborations, this approach does not directly address the theoretical question about their relative importance for innovation performance. It must be noted that the higher incidence of local collaboration often found in the literature does not testify their superiority over nonlocal collaboration. For instance, Kristensen & Vinding (2001) find that although Danish manufacturing firms have more domestic partnerships than foreign firms, a much larger proportion of domestic partnerships are regarded as of minor importance for innovation success, while a small number of distant partners play a greater role in providing critical knowledge inputs.

Several other studies have offered interesting insights by statistically analyzing how local and nonlocal collaborations are related to firms' innovation performance. With a sample of 358 biotechnology firms in Canada, Gertler & Levitte (2005) document the importance of global networks for innovation performance as measured by granted and pending patents, along with the value of local networks for raising capital to support innovation. By studying network portfolios of 33 firms in the footwear district of Barletta in southern Italy, Boschma & Ter Wal (2007) show that both local and nonlocal collaborations increase the share of sales from new products. Comparing regional and extra-regional knowledge flows in the Dutch computing service and life science industries, Weterings & Ponds (2009) find that extra-regional knowledge flows are more valuable for solving technological and organizational problems.

We opt to hypothesize that nonlocal collaboration does not enhance innovation performance of firms more than local collaboration because partnerships at the local and nonlocal scales provide distinct benefits and both are important for innovation. Knowledge inputs from other local actors provide the firm with tacit, spatially sticky knowledge that may be difficult to be decoded by outside firms. Although local knowledge search is more limited in scope, it is nevertheless less costly to locate and recognize useful local knowledge. Nonlocal partnerships, in contrast, connect firms to distant and dissimilar contexts. While greater distance leads to larger distance costs of knowledge coordination and transfer, it also increases the likelihood that knowledge transfer takes place across cultural, institutional, and technological boundaries, which will take firms to unique, diverse and nonredundant knowledge (Zaheer & George, 2004). Considering all the above, there is no compelling *a priori* reason to expect that nonlocal collaboration is superior to local collaboration with respect to innovation performance, or vice versa. Hence, we hypothesize the following:

Hypothesis 2: Nonlocal collaboration does not enhance firms' innovation performance more than local collaboration, and vice versa.

3.3 Are Local and Nonlocal Collaborations Complements or Substitutes?

An interesting question concerns the joint impact of local and nonlocal collaborations on innovation performance. There are three possibilities, namely independent, substitute, and complementary. If the first possibility holds, the effects of local and nonlocal collaborations on innovation are independent and additive, i.e., there is no interaction effect. If they are substitutes for each other, benefits that accrue to local collaboration obviate the need to establish and maintain distant partnerships, and vice versa. This implies a negative interaction effect between local and nonlocal collaborations on innovation performance. In the last scenario where local and nonlocal collaborations represent complementary spurs to innovation, knowledge gained through local collaboration will enhance firms' ability to benefit from their distant partnerships or tapping into distinctive knowledge situated in different geographic contexts will help firms benefit more from local knowledge flows. This implies a positive interaction effect between local and nonlocal collaborations on innovation performance.

We argue that local and nonlocal collaborations exert complementary forces. First of all, qualitative differences between local and nonlocal collaborations allow firms to bring together heterogeneous yet complementary strands of knowledge to generate innovation that is difficult for local and distant competitors to replicate. Firms innovate, at least in part, through recombining existing knowledge rather than inventing new knowledge that did not exist before. According to Usher (1929, p. 11), innovation can be seen as "constructive assimilation of pre-existing elements into new syntheses, new patterns, or new configurations". Weitzman (1998) likens innovation to developing new plant species by cross-pollinating existing plant varieties, and argues that knowledge can build on itself in a combinatorial process. Following this fundamental insight, we submit that by combining idiosyncratic local knowledge with novel ideas drawn from distant sources, not only do firms expand their innovative potential, but also bring forth innovative outputs that cannot be quickly imitated by competitors due to added social complexity and causal ambiguity as a result of knowledge recombination (Dierickx & Cool, 1989).

The second argument for complementarity is that a mix of local and nonlocal partnerships is vital for overcoming spatial lock-in and preventing local network failure. Although local partnerships are often characterized by interpersonal relations and overlapping affiliations that lessen costs of knowledge coordination and transfer, excessive collaboration among local members will turn "ties that bind into ties that blind" (Grabher, 1993, p. 24), and unchecked local processes of imitation, selection, and homogenization will turn "hot spots" of dynamic industrial clusters into "blind spots" (Pouder & St John, 1996). A one-sided local focus will make a firm's network configuration too closed and too rigid, meaning a reduced awareness of ideas and developments outside the local region and a lack of flexibility in responding to new threats or opportunities. Firms will also find themselves caught in a cycle of accessing the same knowledge as a result of interacting repeatedly with the same set of local partners (Zaheer & George, 2004). Nonlocal partnerships play a key role in avoiding these problems of spatial lock-in at both the firm and the regional level (Bathelt *et al.*, 2004; Boschma & Ter Wal, 2007). The infusion of different impulses and ideas into local networks via collaboration with distant partners will prevent the knowledge base of local industries from becoming ossified (Whittington *et al.*, 2009, p. 95). Local connections may even become more beneficial when they are matched by distant partnerships that both promote diversity of ideas for recombination and mitigate the tendency of local inbreeding that suppresses long-term innovation potential (Bathelt *et al.*, 2004; Boschma, 2005).

Next, if we conceptualize collaboration with distant partners as more exploratory and collaboration with local partners as more exploitative (Drejer & Vinding, 2007), it is plausible that firms with combinations of local and nonlocal collaborations are likely to have the best innovation performance, as many studies find that exploration and exploitation work in tandem to enhance innovation (e.g., He & Wong, 2004; Smith & Tushman, 2005). Related are the complementary roles of weak ties and strong ties. While far-flung collaborative relationships resemble weak ties in terms of having less social contact or less intimate interaction, local partnerships are akin to strong ties that are characterized by emotional intimacy, reciprocal assistance, and informal deal-making (Zaheer & George, 2004; Whittington *et al.*, 2009). According to Uzzi (1997), a mix of weak and strong ties accelerates innovation and improves competitiveness because they perform different functions.

This complementarity hypothesis is thoroughly discussed by Bathelt *et al.* (2004), yet so far it has been seldom tested systematically. For instance, with a sample of 33 firms, Boschma & Ter Wal (2007) find that firms well connected in both local and extra-local networks of technical knowledge have the best innovation performance, suggesting a positive interaction effect between local and nonlocal collaborations. However, their small sample size makes it impossible to rigorously test this hypothesis. In Chen's (2009) case study of Taiwanese machine tool firms, both local and foreign connections are found to be crucial for technology upgrading and new product development, but for different issues or in different phases of the innovation process. This qualitative finding implies that local and nonlocal collaborations reinforce each other to drive innovation success, and quantitative data have to be collected to test this hypothesis. In the present research, we attempt to provide solid empirical evidence that supports or rejects the complementarity hypothesis:

Hypothesis 3: There is a positive interaction effect between local and nonlocal collaborations on firms' innovation performance.

4. Data and Methods

4.1 Research Setting

During 2000–2004, we conducted a series of surveys in Singapore, Malaysia, and Thailand to investigate innovation collaboration and innovation performance of firms in various sectors. In the 2001 survey that targeted manufacturing firms in Singapore, we included several questions on geographical distribution of their collaboration partners that made it possible to test the above hypotheses.

As a city state of about 4.5 million people concentrated in an area about 3.5 times the size of Washington, DC, Singapore can be seen as a geographic cluster.[1] The country's territory is small enough that spatial proximity exists throughout the entire island (Phillips & Yeung, 2003). Since its independence in 1965, Singapore developed from a former British trading colony into a modern international business hub specializing in high value-added manufacturing and services (Low, 1998). As a newly industrialized economy, the country has accumulated considerable technological capability over four decades of rapid economic development. Singapore is a highly open economy with one of the freest trade and investment regime. In the meantime, the state also plays an active, developmental role in attracting foreign direct investment, offering incentives for foreign companies to locate their

[1] Given that geographic agglomeration of firms is observed in this small island nation, our empirical examination focuses on how firms' innovation performance is related to collaborative relationships across different spatial scales which, as correctly pointed out by an anonymous reviewer, are much narrower than the many benefits of an industrial cluster.

Southeast Asia headquarters in Singapore, and encouraging international expansion of Singaporean companies (Perry *et al.*, 1997; Yeung *et al.*, 2001).

Several prominent historical, political, and geographic realities of Singapore define the unique context in which this study was conducted (see Olds & Yeung, 2004). Historically, its colonial past helped create a sense of openness and cosmopolitan mentality. The British rule also laid important legal, linguistic, and transport foundations for integration into the global economy. Politically, the Singapore authorities are widely seen as a very clean, highly efficient, but oftentimes paternalistic with a single dominant ruling party, People's Action Party. In contrast to its open and free economy, many aspects of political and social life in this island nation are carefully regulated,[2] so government policies and initiatives for economic development are seldom complicated by citizen involvement procedures. Geographically, Singapore is a small, fully urbanized territorial unit. It does not have a hinterland within national boundaries and, therefore, is not constrained by the tension between urban and rural development or between regional and national interests. These unique conditions must be kept in mind when interpreting our statistical findings.

4.2 Sample Selection

The sampling frame covered all firms with five or more employees in the four largest manufacturing sectors in Singapore: electronics, chemicals, precision and process engineering, and transport engineering. A total of 1872 questionnaires were sent to CEOs or R&D directors of firms randomly drawn from the population list. Missing data as well as doubtful or contradictory responses were clarified by telephone follow-ups, or removed from the sample where clarification was not possible. At the end of the survey, we received 371 valid responses, representing a response rate of 19.8%. Response rates differed only slightly between sectors, ranging from 21.6% for chemicals to 19.0% for electronics. Foreign firms were more likely to respond, with a response rate of 23.1% compared with 18.3% for local firms, and this difference is significant at the 5% level. To further test nonresponse bias, we compared 274 early returned questionnaires with 97 late returned questionnaires in terms of respondent position, firm size, age and nationality, and industry affiliation. The early and late respondents did not differ at the 5% level with regard to any of these demographic variables. Therefore, nonresponse bias was unlikely to be serious except for the nationality of firms.

To control for the fact that some of the sample firms may be engaged in few innovation activities and thus it is not meaningful to speak of a spatial pattern of innovation collaboration, we defined a minimum threshold of innovating firms. Firms were regarded as innovating if they had introduced to the market at least one of these two in the last 3 years: (1) a new or substantially improved product and (2) a new or substantially improved

[2] Thorough and careful regulation in Singapore is figuratively described by the Dutch architect Koolhaas (1995, p. 1011) as follows, "it is managed by a regime that has excluded accident and randomness: even its nature is entirely remade. It is pure intention: if there is chaos, it is authored chaos; if it is ugly, it is designed ugliness; if it is absurd, it is willed absurdity."

production process. A total of 143 firms were found to be innovating according to this definition.[3] Thus, the effective sample size for this research was 143, including 30 in electronics (21%), 32 in chemicals (22%), 64 in precision and process engineering (45%), and 17 in transport engineering (12%).

4.3 Variables

Variables and their definitions are itemized in Table 1. The dependent variable, innovation performance, was measured as the percentage of total annual sales from new/improved products introduced in the last 3 years. Innovation collaboration, the independent variable, was defined as collaborative relationships in the context of innovation activities, above and beyond normal business relations. Then, local, ASEAN,[4] and global collaborations were measured by the number of different types of partners in Singapore, other ASEAN countries, and major advanced economies (North America, Europe, and Japan),[5] including buyer/customer, supplier, university/research institute, business service provider, technical service provider, and competitor. Similar categorizations of partners have been used in many empirical examinations such as Freel (2003), Doloreux & Mattson (2008). A more precise measure could be the number of partners at each geographic scale. Unfortunately, we did not have this information, and we were also concerned that unreliable recall of such detailed information might introduce additional noise. Furthermore, according to Echeverri-Carroll & Brennan (1999) and Kristensen & Vinding (2001), the number of partners may be a biased measure because as previously explained, a firm may have many local partners, but critical, nonincremental knowledge inputs for innovation are transmitted from a small number of distant partners.

The following controls were included in the statistical analysis: industry dummies, firm age, firm size, firm nationality (foreign vs. local majority ownership), local market orientation, innovation spending intensity, human capital intensity, whether a firm was a government-linked corporation (GLC), and whether a firm received any public R&D support in the last 3 years. Industry dummies, firm age, and size are often important determinants of firm innovation, but their impacts have been so far inconclusive in the literature. The sample firms had a median age of 14 and a median employment of 131. Firm nationality was relevant

[3] As pointed out by an anonymous reviewer, this restriction may bias our results. In particular, if some of the excluded firms attempted to innovate by collaborating with local partners but did not succeed in generating any innovation, omitting such observations would underestimate the hampering effect of local collaboration. A solution for future research is to collect data on both innovation-related collaboration and other types of collaboration (e.g., subcontracting or co-marketing alliances) such that spatial patterns of collaboration, innovation-related or not, could be examined for all firms. For the present research, we argue that the 3-year window in defining this minimum threshold may be long enough to minimize such bias in our results.

[4] ASEAN is short for the Association of South East Asian Nations formed in 1967. It includes Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. This spatial scale was chosen due to its clear political, economic, and geographic boundaries.

[5] Japan was singled out from the rest of Asia based on the flying geese model (e.g. Edgington & Hayter, 2000) in which direct investment and technology transfer from Japanese companies lead the technological development in Southeast Asia. Japan was the second-largest investor in Singapore's manufacturing sector, trialing the USA (Yeung *et al.*, 2001). In our final sample of 143 firms, 71 were subsidiaries of foreign companies, among which 27 were from North America, 15 from Europe, 23 from Japan, and 6 from the rest of the world.

Table 1. Variables

Variable	Description
Innovation performance	Percentage of total annual sales from new/improved products introduced in the last 3 years
Local collaboration	Number of different types of partners for innovation collaboration located in Singapore (0–6): buyer/customer, supplier, university/research institute, business service provider, technical service provider, competitor
Global collaboration	Number of different types of partners for innovation collaboration located in North America, Japan, and Europe (0–6): buyer/customer, supplier, university/research institute, business service provider, technical service provider, competitor
Industry dummies	Electronics, chemicals, transport engineering, precision and process engineering (base category)
Firm age	2000-founding year
Firm size	Log of total employment in 2000
Foreign firm	1 if foreign company, 0 otherwise
Local market orientation	Sales in the Singapore market as a percentage of a firm's total sales
Innovation spending intensity	Total expenditure on the following innovation activities as a percentage of total sales: (1) R&D, (2) acquisition of external R&D services, (3) acquisition of machinery, equipment and software linked to product and process innovation, (4) licensing of external technology linked to product and process innovation, (5) industrial design, market research and marketing expenses linked to product and process innovation, and (6) training directly linked to technological innovation
Human capital intensity	Percentage of university graduates or diploma holders in total employment
GLC	1 if government-linked corporation
Public R&D support	1 if received government assistance/support for R&D in the last 3 years

because Singapore is a well-known location for foreign direction investment. In the sample, 71 (49%) firms were subsidiaries of foreign multinational corporations (MNCs). Foreign firms in Singapore were in general more integrated and probably more innovative than local firms. Local market orientation was useful to account for firms' dependence on the local market for revenue generation. To measure innovation input, we used innovation spending intensity instead of R&D spending intensity because R&D represents only one of the several categories of innovation expenditure (see Table 1). We also controlled for human capital intensity because skills and knowledge of individual employees are another crucial input to the innovation process.

In Singapore, GLCs were managed under four state-owned holding companies, namely Temasek Holdings, Singapore Technologies Holdings, MinCom Holdings, and MND Holdings. Through these holding companies, the government retained significant influence over their management control (Yeung, 1998a). GLCs were often bigger and more capital intensive than other local firms, and they took both a leading and a supporting role in the international expansion of Singaporean companies (Yeung, 1998a). Thirteen firms (9%) in the sample were GLCs. The final control variable was a dummy to indicate whether firms received any public R&D support in the last 3 years. The Singapore government implemented various R&D support programs through its Economic Development Board and

National Science and Technology Board; both local and foreign firms were welcome to participate in these programs (Phillips & Yeung, 2003). A total of 59 firms (41%) in the sample answered yes to this question.

Tobit regression was used to test the hypotheses because some firms, though "innovating", did not report having any new products introduced into the market in the last 3 years (33 out of 143). When testing for interaction effects, a standard practice is to mean-center the two constituent variables before the interaction term is computed. However, Echambadi & Hess (2007) show that mean-centering does not alleviate multicollinearity problems, nor does it change the computational precision of parameters, because results using mean-centering and those without are mathematically equivalent. Nevertheless, we will report results both with and without mean-centering because they allow us to take different perspectives on the findings.

5. Results

5.1 Spatial Patterns of Innovation Collaboration

Table 2 shows the propensity of collaboration with six types of partners located locally, in the neighboring ASEAN countries, and globally, respectively. The propensity of local collaboration is significantly higher than that of global collaboration for three out of six types of partners: university/research institute, business service provider, and technical service provider. When collaboration with ASEAN partners is added to the picture, there is a clear V-shaped pattern of innovation collaboration over geographic scales (Figure 1), corroborating a study by Doloreux & Mattson (2008). The Wilcoxon test in Table 2 shows that the propensity of global collaboration is significantly higher than that of ASEAN collaboration for all six types of partners. One may be concerned that this V-shaped pattern is largely caused by the presence of many foreign firms in the sample. Nonetheless, it remains when foreign firms are excluded from the sample (Figure 2). Therefore, both domestic firms and subsidiaries of foreign MNCs tend to collaborate heavily with local and distant partners for innovation while interacting little with those in neighboring countries. This is not unexpected because Singapore is located within Southeast Asia where all its

Table 2. Spatial pattern of innovation collaboration[a]

	Singapore (%)	ASEAN (%)	Global (%)	Singapore vs. global[b]	ASEAN vs. global[c]
Buyer/customer	60.7	36.5	61.4		***
Supplier	54.5	16.5	57.9		***
University/research institute	66.9	2.1	21.4	***	***
Business service provider	27.6	3.4	17.9	*	***
Technical service provider	43.4	4.1	31.0	*	***
Competitor	10.3	3.4	11.0		**

[a] % of firms that have innovation collaboration partners located in different regions.

[b] Wilcoxon test for Singapore vs. global; ***$p < 0.001$, **$p < 0.01$; *$p < 0.05$.

[c] Wilcoxon test for ASEAN vs. global, ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.

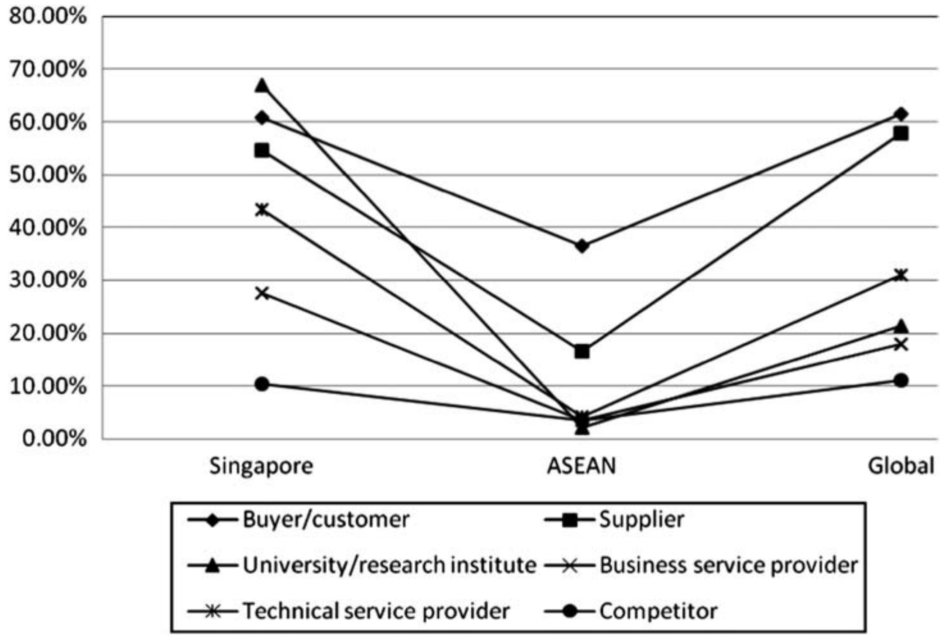

Figure 1. Spatial pattern of innovation collaboration

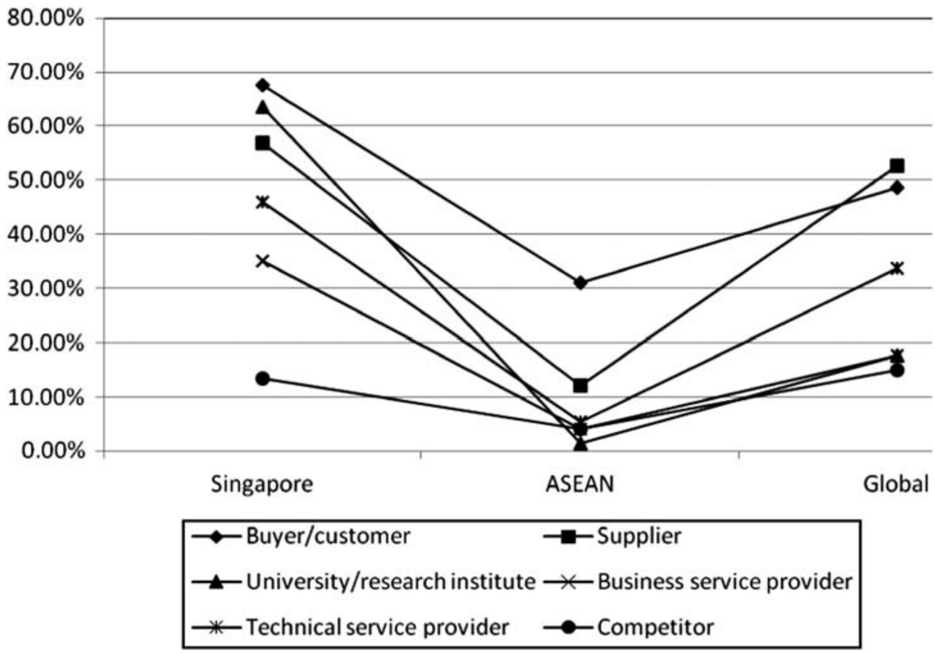

Figure 2. Spatial pattern of innovation collaboration excluding foreign firms

geographic neighbors are at a significantly lower level of technology development. Despite interpenetration of business networks and ongoing economic integration with neighboring countries (Yeung, 1998b; Olds & Yeung, 2004), Singapore-based firms skip neighboring ASEAN countries to favor global collaboration for more sophisticated knowledge inputs.

In the following analysis for hypothesis testing, we focus on innovation collaboration only at the local and global scales because innovation collaboration at the ASEAN scale is rather negligible and in unreported regression analyses its effects on innovation performance are never significant at the 10% level, neither the main effect nor the interaction effects with local or global collaboration.

5.2 Estimation Results

Table 3 presents the Tobit regression results for hypothesis testing. We start with the base model that contains all the control variables and then add independent variables progressively, first the main effects and then the interaction term. Looking at the control variables, three are significant throughout Models 1–4: electronics industry dummy, innovation spending intensity, and human capital intensity. The positive and significant coefficient of the electronics industry dummy is in line with the fact that electronics firms worldwide experience a higher rate of new product innovation, and those of the other two are consistent with many prior studies showing that innovation spending and human capital are major determinants of innovation performance.

In Model 2, including the two innovation collaboration variables does not significantly add to the model fit (Δ log likelihood $= 0.854$, $p = 0.428$). The coefficient of local collaboration is not significant, lending no support for Hypothesis 1. Given that these firms are all co-located in Singapore, collaborating with other local actors does not elevate their innovation performance above and beyond various beneficial effects of agglomeration. It seems that conscious local networking effort merely duplicates what is already accessible through various informal and spontaneous mechanisms of local buzz. Next, although the coefficient of local collaboration is negative and that of global collaboration is positive, a coefficient equality test shows that the difference between the two is not statistically significant ($F = 1.698$, $p = 0.195$). Therefore, global collaboration is not more effective than local collaboration in elevating innovation performance and vice versa, supporting Hypothesis 2.

In Model 3, we include the interaction term with mean-centering to test Hypothesis 3, the complementarity hypothesis. This gives rise to significant model improvement (Δ log likelihood $= 1.907$, $p = 0.052$). As the coefficient of the interaction term is positive and significant, Hypothesis 3 is supported. This interaction effect suggests that locally embedded firms receive higher returns from global collaboration than locally isolated firms, or globally connected firms are able to better capitalize on local knowledge flows than those firms with only local partnerships. To illustrate the interaction effect, we plot the marginal effect of local collaboration over the sample range of global collaboration, while holding all other variables at their median levels. It is important that estimated coefficients of Tobit regression cannot be interpreted as marginal effects like those of OLS (Ordinary Least Squares) regression; they have to be scaled by a term that is a function of all estimated coefficients and σ (see Greene, 2003, Chapter 22). It can be seen in Figure 3 (full sample)

Table 3. Tobit regression for innovation performance

	Model 1	Model 2	Model 3[a] (with mean-centering)	Model 4 (without mean-centering)
Constant	−15.944 (10.898)	−11.713 (11.410)	−18.972 (12.207)	−2.603 (12.128)
Electronics	20.689** (8.009)	20.091** (7.989)	18.920** (7.911)	18.920** (7.911)
Chemicals	7.168 (6.845)	4.253 (7.171)	5.848 (7.149)	5.848 (7.149)
Transport engineering	10.707 (9.377)	9.185 (9.504)	9.963 (9.388)	9.963 (9.388)
Firm age	0.322 (0.268)	0.305 (0.271)	0.352 (0.269)	0.352 (0.269)
Firm size	−0.147 (2.157)	−0.149 (2.181)	0.379 (2.172)	0.379 (2.172)
Foreign firm	2.610 (6.665)	2.367 (6.652)	2.589 (6.560)	2.589 (6.560)
Local market orientation	0.045 (0.095)	0.016 (0.097)	0.015 (0.095)	0.015 (0.095)
Innovation spending intensity	0.678*** (0.237)	0.663*** (0.236)	0.677*** (0.233)	0.677*** (0.233)
Human capital intensity	0.486*** (0.167)	0.473*** (0.168)	0.533*** (0.170)	0.533*** (0.170)
GLC	−9.852 (10.847)	−12.065 (10.926)	−13.085 (10.823)	−13.085 (10.823)
Public R&D support	2.181 (6.367)	2.541 (6.418)	0.836 (6.415)	0.836 (6.415)
Local collaboration (β_1)		−2.162 (1.986)	−2.435 (1.980)	−7.151** (3.236)
Global collaboration (β_2)		2.426 (2.297)	1.231 (2.349)	−4.960 (4.388)
Local × global			2.350* (1.200)	2.350* (1.200)
σ	29.606	29.459	29.073	29.073
Log likelihood	−555.821	−554.967	−553.060	−553.06
Δ Log likelihood		0.854	1.907*[b]	1.907*[b]
Test for $\beta_1 = \beta_2$		$F = 1.698$	$F = 1.082$	
N	143	143	143	143

Note: ***$p < 0.01$; **$p < 0.05$; *$p < 0.10$, two-tailed test, standard errors in parentheses.

[a] In Models 3 and 4, coefficient estimations and standard errors are the same except for the constant and main effects of local and global collaborations. Following Echambadi & Hess (2007), their coefficients and standard errors are mathematically linked. For example, the coefficient of local collaboration, −2.435, can be obtained by coefficient without mean centering + mean value of global collaboration × coefficient of the interaction term ($-2.435 = -7.151 + 2.007 \times 2.350$). Their standard errors can also be calculated from results in Model 4 using the variance and covariance of estimated coefficients that are available in standard statistical packages.

[b] Relative to Model 2.

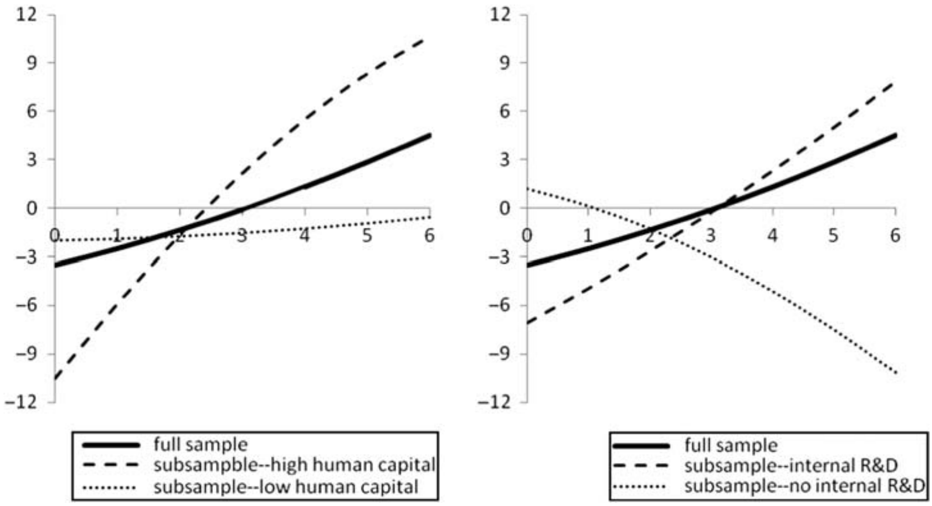

Figure 3. The marginal effect of local collaboration over the sample range of global collaboration

that as global collaboration increases, the marginal effect of local collaboration turns from negative to positive, illustrating the interaction effect between the two.

In Model 4 where the two independent variables are not mean-centered, all results including the interaction effect remain the same except the main effects of local and global collaborations. However, these two coefficients and their standard errors are mathematically linked to those in Model 3 where mean-centering is performed (Echambadi & Hess, 2007). It must be noted that Hypothesis 2 cannot be tested with Model 4, where the coefficient of local collaboration tells its influence on innovation performance when global collaboration is zero, and the coefficient of global collaboration tells its influences when local collaboration is zero. Nevertheless, it makes sense to compare their coefficients when the other is at its mean as in Model 3. Similar to Model 2, a coefficient equality test in Model 3 supports the hypothesis that one does not enhance innovation performance more than the other ($F = 1.082$, $p = 0.300$).

It is interesting to note in Model 4 that local collaboration is negatively and significantly associated with innovation performance when firms do not have any global connections. However, at the mean level of global collaboration, the negative effect of local collaboration becomes much smaller and insignificant (Model 3). This finding has a twofold meaning. On the one hand, local embeddedness can yield low innovation performance if global collaboration is lacking, which reveals the hampering effect of spatial lock-in. On the other hand, what stands against the tendency of spatial lock-in is global collaboration. Taken together, this is consistent with the statistical support for Hypothesis 3.

5.3 Extensions

According to Sutton & Staw (1995, p. 376), one indication of strong theory is that it is possible to discern conditions in which the main hypothesis is most and least likely to hold. We follow this line and study whether absorptive capacity conditions the effect of simultaneous local and global collaborations on innovation performance. Managing locally bounded and globally dispersed partnerships demands disparate competencies. Local collaboration is more permeable, porous, and diffused, providing timely access to thicker, more tacit knowledge, whereas global collaboration is more proprietary, close, and targeted, transmitting knowledge between two far-flung parties through contractual insurance (Owen-Smith & Powell, 2004; Whittington *et al.*, 2009). It is plausible that strong absorptive capacity is necessary for firms to benefit from both local and distant knowledge flows.

In Table 4, we perform subsample analysis by dividing firms into two groups based on two measures of absorptive capacity, whether a firm has above median *Human capital intensity* and whether a firm has done any *internal R&D* in the last 3 years, respectively. The first measure follows Cohen & Levinthal (1990) that individual expertise lays the foundation for a firm's absorptive capacity. The choice of the second is consistent with their argument that internal R&D plays a dual role, generating innovation and contributing to absorptive capacity. We had to rely on a dummy variable indicating the presence of internal R&D because although we had information on firms' R&D expenditure, this reading did not distinguish between internal R&D and purchase of external R&D services.

In Model 5, regressions are run separately for 70 firms with high human capital intensity (more than 25% employees are university graduates or diploma holders) and 73 firms with low human capital intensity (25% or less employees are university graduates or diploma holders). Similar subsample analysis is performed in Model 6 depending on whether firms conduct internal R&D or not. In both models, the interaction effect is larger or more positive for the subsample of high absorptive capacity. This difference is significant at the 10% level in Model 5 and at the 5% level in Model 6. A conclusion can be drawn that the stronger a firm's absorptive capacity, the more it can benefit from synergistic recombination of local and distant knowledge flows. This is graphically displayed in Figure 3; for the high absorptive capacity subsamples (high human capital or internal R&D), the marginal effect of local collaboration increases quickly over the sample range of global collaboration, whereas this pattern is not observed for the low absorptive capacity subsamples (low human capital or no internal R&D).

6. Discussion

This paper seeks to contribute to the literature by critically reviewing the local versus nonlocal debate and statistically testing three hypotheses regarding the relationship between innovation collaboration and innovation performance at the firm level. We find that local collaboration does not bring any additional benefit, given the fact that all the firms are co-located in a small island nation. Nor can we conclude that global collaboration has a stronger impact on innovation performance than local collaboration. Perhaps most important, we find a positive interaction effect between local and global collaborations on innovation performance. Although the main effect of local collaboration is negative and global collaboration is not more strongly related to innovation performance, we cannot assert that local collaboration is counterproductive or global collaboration is unimportant. Instead, firms with a mix of local and global partnerships will be the most innovative, whereas firms that do not embed themselves locally or connect with distant partners in advanced economies will be distinctively disadvantaged.

These findings as a whole indicate that the importance of spatial proximity has been exaggerated, and a one-sided focus on local learning and knowledge exchange may actually hamper innovativeness of firms. An increasing number of studies have already challenged the

Table 4. Subgroup Tobit regression for innovation performance

	Model 5 (with mean-centering)		Model 6 (with mean-centering)	
	High human capital	Low human capital	Internal R&D	No internal R&D
Constant	−17.934 (19.492)	−25.428 (15.359)	−25.862* (13.436)	16.285 (23.083)
Electronics	−3.712 (11.121)	33.021*** (9.250)	11.802 (8.130)	59.028** (21.805)
Chemicals	−0.276 (9.578)	9.347 (9.671)	1.910 (7.680)	8.993 (14.153)
Transport engineering	4.756 (12.825)	16.147 (11.816)	18.085 (11.143)	22.390 (18.652)
Firm age	−0.070 (0.437)	0.459 (0.288)	0.388 (0.294)	0.777 (0.550)
Firm size	4.847* (2.790)	−4.774 (3.021)	2.417 (2.431)	−6.950* (3.944)
Foreign firm	−1.301 (9.210)	9.910 (7.797)	1.040 (7.145)	−7.228 (13.290)
Local market orientation	−0.228 (0.146)	0.143 (0.113)	0.047 (0.108)	−0.090 (0.167)
Innovation spending intensity	0.663* (0.395)	0.732*** (0.250)	1.167*** (0.278)	−0.041 (0.412)
Human capital intensity	0.691** (0.279)	1.739*** (0.495)	0.545*** (0.187)	0.405 (0.340)
GLC	−14.122 (15.605)	−7.841 (14.144)	−18.520 (12.604)	−3.282 (19.339)
Public R&D support	−1.675 (8.201)	7.549 (8.633)	−4.841 (7.248)	−23.128 (17.584)
Local collaboration	−2.244 (3.111)	−4.609* (2.509)	−4.097* (2.209)	−2.474 (3.893)
Global collaboration	0.170 (3.164)	1.777 (3.037)	−0.026 (2.638)	2.158 (4.596)
Local × global	5.460*** (1.906)	0.876 (1.337)	3.749*** (1.264)	−2.784 (2.905)
SUEST[a] test of coefficient difference for local × global	$\chi^2 = 3.617$* ($p = 0.057$)		$\chi^2 = 3.862$** ($p = 0.049$)	
σ	27.277	24.042	26.785	25.050
Log likelihood	−288.356	−248.163	−407.754	−130.835
N	70	73	100	43

Note: ***$p < 0.01$; **$p < 0.05$; *$p < 0.10$, two-tailed test, standard errors in parentheses.

[a] SUEST is short for seemingly unrelated estimation in Stata that combines estimation results and makes it possible to test for coefficient differences between groups.

old wisdom that only local is important, and our research goes further by showing that dynamic regions should be characterized by both dense local knowledge circulation and strong nonlocal connections to outside knowledge sources. Paraphrasing the influential work by Powell *et al.* (1996) on network as the "locus of innovation", we propose that the locus of innovation lies in the intersection between local and nonlocal networks. We join Yeung (2009) and others to highlight the importance of extending the analytical focus from local systems of innovation to an unbounded spatial system, in which the entire portfolio of a firm's network relationships, within or outside the local area, is examined and compared.

Several limitations of this research point toward avenues for future investigation. Perhaps most concerning is that the unique research setting of Singapore limits the generalizability of our findings. The literature on national or regional innovation systems suggests that location- or history-specific factors affect in fundamental ways spatial patterns of innovative activities and the actual working of agglomeration economies (Lundvall, 1992; Beaudry & Breschi, 2003). This limitation, nonetheless, may be less serious than one would think. As "new and valuable knowledge will always be created in other parts of the world" (Bathelt *et al.*, 2004, p. 46), even the most advanced regions and clusters in the world need both local and extra-local connections to promote innovation. For example, the Boston region is arguably the most innovative biotechnology cluster in the world, yet it is not only the most connected internally but also the most linked externally (Owen-Smith *et al.*, 2002, pp. 37–38). A key difference with the Singapore case, however, is that these external links are primarily with organizations in other parts of the USA. Obviously, this is because unlike Singapore that has no hinterland, the USA has an array of competitive clusters across different industries and located in different states. In any case, it is important for future research to extend our study by investigating innovation collaboration across different spatial scales, and in particular whether the local-global complementarity hypothesis is supported in different national or regional settings.

Another limitation is that our reliance on cross-sectional survey data did not allow us to address the concern of reverse causality. Our study was unable to tell whether firms with superior innovation performance tend to collaborate both locally and globally or firm that collaborate both locally and globally tend to have superior innovation performance. It is highly desirable that future studies collect longitudinal data to examine the co-evolution between collaboration across different spatial scales and innovation performance. Furthermore, the discovered relationship between innovation collaboration and innovation performance may reflect the presence of some omitted, unobserved variables that drive both outcomes. In unreported robustness checks, we followed Blundell *et al.* (1995) by using pre-sample patent counts (collected from the Intellectual Property Office of Singapore and scaled by firm size) to proxy firms' underlying innovation capability—high-capability firms are attractive partners for both local and global collaborations and in the meanwhile excel in generating new product sales. This robustness check was not as successful as we would like; while the local–global interaction effect remained positive and significant, the coefficient of pre-sample patent counts, to our surprise, was negative though not significant. It seemed that this pre-sample control was not an adequate proxy to capture unobserved, heterogeneous innovation capability across firms because one would expect this variable to be positively and significantly related to innovation performance.

In addition, our measures of local and global collaborations need to be improved. In particular, one should take into account not just the number of different types of innovation partners, but also additional attributes such as the intensity and direction of knowledge transfer. Future research should also include collaboration with other newly industrialized economies (South Korea, Hong Kong, and Taiwan) and big emerging economies such as mainland China and India. Our study lumped together North America, Europe, and Japan as "global", yet a more fine-grained spatial analysis of innovation collaboration would distinguish among these three locations, as the distance between Singapore and Japan is much shorter than that between Singapore and Europe or North America. Moreover, firms may have other means to access global knowledge flows such as establishing branches or acquiring other firms in distant locations. In our study, collaboration within a corporation but across different locations was not accounted for, and our empirical design did not allow us to compare alternative mechanisms of accessing global knowledge flows. We bring up these issues as suggestions for future research.

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