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Intra- and inter-regional research collaboration across organizational boundaries: Evolving patterns in China

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ABSTRACT

Both intra-regional and inter-regional research collaborations are significant determinants for regional innovation. However, systematic and empirical studies have seldom been reported integrating both of them. The present study advances a research agenda around a two-dimensional quadrant (TDQ) analytical framework to investigate regional research collaboration. It then applies such a framework to the Chinese case by examining collaborative invention patent applications between 1985 and 2008 with China's patent office. The results show that, first, the correlation between innovation capability and collaborative research was evolving, and the correlation between innovation capability and collaboration between enterprises (EE) is weaker than that between academic institutes and enterprises (AE); second, the intra-regional collaboration intensity was higher than the inter-regional one and AE collaboration dominated the regional collaboration; third, during the process of market-oriented reform, China's major innovative regions with different collaborative patterns were shifting from collaborative to independent research, from inter-regional collaboration to intra-regional collaboration, and from AE to EE collaboration, particularly in their inter-regional collaboration.

1. Introduction

As a channel of open innovation, inter-organizational research collaboration boosts the flow of technology and knowledge between actors of an innovation system (Chesbrough et al., 2008; OECD, 1997). With recent advance in information and telecommunication technologies, especially Internet-based applications such as email, MSN, Skype, Facebook, and Twitter, "the tyranny of distance" seems to be no longer that influential (Castells, 1996; Cairncross, 1997). Nevertheless, geographic proximity and spatial physical distance still matter, because innovative actors in close vicinity tend to interact more frequently and intensively than those at a distance (Katz, 1994; Hoekman et al., 2010). Consequently, collaboration within a certain distance is significant, and may explain the difference between regions in their performance in innovation (Döring and Schnellenbach, 2006).

Such difference is not only possibly determined by collaborative research within regional boundaries shaping regional knowledge bases but also possibly influenced by the knowledge spillover or sharing across regional boundaries through collaboration (Yang and Lin, 2012). Thus, intra-regional collaborative research and inter-regional collaborative research are both useful options for organizations to seek external knowledge, which consequently could also strategically narrow the regional difference in innovation. The existing literature has paid more attention to intra-regional or inter-regional collaboration and recognized the significance of distinguishing research collaboration within and across regional boundaries. However, systematic and empirical studies have seldom been carried out regarding the patterns of intra- and inter-regional research collaboration and their respective forms of inter-organizational research collaboration (more details in Section 2).

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Specifically, China, after a series of reform of its S&T system, has become a powerhouse in research and development (R&D). In 2012, China's research intensity (GERD/GDP) reached 1.98%, surpassing the 28 member states of the European Union, which together managed 1.96% (Sun and Cao, 2014). However, in contrast to Europe, which has received empirical examination of its regional collaboration, China, with its territory similar to Europe, has not been given attention in this respect. Indeed, the S&T reform, which started in 1985, boosted the enthusiasm of Chinese enterprises, universities and research institutes to be innovative, of which collaboration has been one of the main approaches.

In March 1985, when the market-oriented economic reform and opening-up had proceeded for several years, Deng Xiaoping made an important speech entitled *The Reform of the S&T System Is to Liberate the Productive Forces* during the National Science and Technology Work Conference. The Chinese Communist Party Central Committee and the State Council subsequently issued the *Decision on the Reforms of the S&T System* (Liu et al., 2011). From then on, China pushed forward to orient its S&T system toward serving the economy (Sun and Liu, 2010), which in turn would increasingly depend on the S&T development and better integrate S&T and the economy.

At this early stage of the S&T development and transition toward a market-oriented economy when the *Patent Law* was also recently enacted, there were not many patent applications, let alone collaborative ones. However, the collaboration between enterprises and academic institutions was encouraged since China's research resources were mainly concentrated at national research institutions such as the Chinese Academy of Science (CAS) and universities while enterprises were weak in terms of their innovative capability. Indeed, organizations were reluctant to collaborate out of the concerns of profit distribution, risk sharing, and ownership of intellectual property right (IPR). Meanwhile, Chinese organizations were still separated by the "*tiao*" (or ministerial) and "*kuai*" (or regional) relationship.

Deng Xiaoping's southern tour in 1992 has restarted China's reform and open-door initiative. The Chinese state has also issued policies to encourage collaboration. For example, in 1992, the State Education Commission (now the Ministry of Education), the State Economic and Trade Commission (repealed in 2003), and CAS lunched the "Joint Development Programme of Industry–University–Research Institution (IUR)" (Sun, 1992). Then, the central government encouraged research collaboration via establishing joint units and cooperation platform, such as joint research and development centers, enterprise technology transfer centers, university science parks, joint committees of university–enterprise cooperation for research collaboration.

In May 1995, the government put forward the *Strategy of Revitalizing through Science and Education* and issued the *Decision on Accelerating Scientific and Technological Development* in the National Science and Technology Conference (Liu et al., 2011). The policy inspired enterprises to be more innovative and to pursue patent protection, and enhancing technological capability became more important for Chinese organizations, which started to concern more about their own economic interests instead of purely following administrative order. But collaboration was not a good choice for innovative organizations in economic transition. There was more collaboration between academic institutions and enterprises but less between enterprises because government and administrative mechanism were in play while market mechanism was still in its infancy.

In August 1999, the Chinese government issued the *Decision on Strengthening Technological Innovation, Developing High Technology and Realizing Industrialization*, clarifying the task to speed up industrialization of S&T achievements. Strengthening the linkages between the economy and S&T has become most important and urgent for the reform of the S&T system. With the deepening of the economic reform after 1992 and in particular after 2000, an organization could decide whether and with whom to collaborate based on its own interests and the market rules, not necessarily considering the "*tiao*" and "*kuai*" administrative relationship.

The government has introduced a series of measures to promote collaboration between innovative actors and to incentivize inter-organizational collaboration, including corporatizing applied-oriented research institutes, setting up technology market and nurturing an environment for IPR protection. With marketization and enterprises enhancing innovation capability, collaboration between enterprises has also increased rapidly. At the same time, local governments have also introduced relevant policies to encourage collaboration to achieve rapid innovation-driven regional economic growth. For example, since 1999 Beijing municipal government has issued a series of policies with respect to high-tech development, technology market, S&T intermediaries, and the development of the Zhongguancun Science Park to drive collaboration between academia and enterprises. In 2007 the local government published a special document to encourage collaboration between industry, universities and R&D institutes via fiscal and tax incentives, S&T programs, and the creation of an environment conducive to innovation.

It is against the above background, in this paper, we advance an analytical framework for identifying regional choices of collaborative or independent innovation, intra- or inter-regional collaboration, and collaboration between enterprises (EE) or between academic institutions (universities and research institutes) and enterprises (AE). Then, we apply the framework to the longitudinal analysis of China's inter-organizational research collaboration in its 31 provinces and municipalities by using invention patenting activities as a measure. In particular, we examine a region's research collaboration patterns and evolving intra- and inter-regional research collaboration and EE and AE collaboration so as to help understand the characteristics of China's regional innovation system. Certainly, findings from the Chinese case may not be applicable to other countries; but the regional collaboration patterns identified in our study could be useful for policymakers elsewhere.

The remainder of the paper is structured as follows. Section 2 reviews relevant literature, Sections 3 and 4 introduce the framework and data used in this empirical study respectively, followed by a discussion of the research results of China's case in Sections 5 and 6. The last section presents conclusions and implications.

2. Intra- and inter-regional research collaboration: a literature review

2.1. Intra-regional research collaboration

Within a regional innovation system, geographic proximity obviously constitutes a clear advantage for establishing or maintaining collaborative and interactive relationship between organizations (Fritsch and Schwirten, 1999; Hussler and Rond, 2007). Therefore, both formal research collaboration by way of co-invention, co-authorship, and alliance, and informal personal relation through private discussion and random communications are effective for knowledge creation, sharing and spillovers. D'Este et al. (2013) found that the geographic proximity has a very strong positive impact on the likelihood of university–industry research partnership formation, and the geographic clustering of technologically complementary firms makes the proximity of industry and university partners far less important.

Strong interaction of innovative actors within a region increases the region-specific knowledge stock and strengthens the region's comparative advantage. In particular, the regional innovation system literature focuses on the relationship between technology, innovation, and industrial location (Cooke et al., 1997); the learning region theory stresses that a region should provide an underlying environment or infrastructure to facilitate the flow of knowledge, ideas and learning (Florida, 1995; Hassink and Klaerding, 2012); the cluster theory emphasizes the impact of the concentration of interdependent and rival firms within the same or adjacent industrial sectors in a small geographic area (Porter, 1994, 1998); and the theory of innovative milieu believes that the environment is an essential component of innovation (Fromhold-Eisebith, 2004). However, these theories pay more attention to the role of regions than actors in innovation, and few directly recognize collaborative research as an important form of interactive learning which is useful for organizations, and especially firms, in emerging economies to build complex technological capabilities (Lamin and Dunlap, 2011).

In fact, regional innovation networks are often formed by a heterogeneous group of actors including firms, universities, technology centers and development organizations (Pekkarinen and Harmaakorpi, 2006). Graf and Henning (2009) found that universities and public research institutes are key actors in all regional networks based on an analysis of four eastern German regional innovation networks. Fritsch and Kauffeld-Monz (2010) found that strong ties – formal network – are more beneficial for the exchange of knowledge and information than weak ties – informal network – in a sample of 16 German regional innovation networks. Having examined the differences across three regional innovation networks in German, Cantner et al. (2010) found that a region that is relatively specialized in a number of broad technological fields exhibits a more closely linked network structure.

Meanwhile, research also shows that the strongly developed network or technology transfer within regional boundaries does not necessarily produce greater innovation (Love and Roper, 2001). In fact, overemphasizing intra-regional collaboration might even create barriers for regional development. For example, a region might be stuck in its existing knowledge base at the expense of diversity of ideas, which is likely to induce local technological trajectories mainly toward inferior solutions and to lead to the status quo of "path lock" (Fitjar and Rodriguez-Pose, 2011). Tavassoli and Carbonara's (2014) empirical analysis of 81 Swedish functional regions provided robust evidence that both the variety and intensity of internal and external knowledge significantly impacted patent applications at these regions. Thus, intra-regional networks appear to be significantly different with respect to the degree of interaction as well as their orientation (Graf, 2011). Indeed, the orientation toward intra-region research collaboration is not the only choice for an organization or a region.

2.2. Inter-regional research collaboration

In reality, collaborative research is not confined within a region. Knowledge sharing and flow through collaboration also occur over long distance (Kalantaridis and Bika, 2011), mainly because of technological proximity (Scherngell and Hu, 2011), relationship proximity (Ponds et al., 2010), and institutional proximity (Hoekman et al., 2009). Meawhile, inter-regional collaboration diversifies the ideas within the local knowledge base (Gertler and Levitte, 2005; Boschma and Ter Wal, 2007).

Indeed, inter-regional research collaboration is central to European countries. Based on the inter-regional networks of co-inventors in Sweden, Ejermo and Karlsson (2006) found that spatial affinity extends beyond the region when the region has limited R&D-related resources, is close to the other regions, and is relatively small in size. Maggioni et al. (2011) revealed that within five specific industries Italian inventors were spread across the country, but patent applicants were geographically concentrated in few industrial districts and metropolises, which "drained" brains from other regions.

By analyzing inter-regional research collaboration in 29 European countries, Hoekman et al. (2009) found evidence for the existence of elite structures. That is, collaboration is more likely to occur between regions of excellence measured by publishing and patenting activities and between political capitals. Sebestyén and Varga (2013) found that quality of inter-regional knowledge networks in Europe is related to the level of knowledge accumulated by the partners in the networks ("knowledge potential"), the extent of collaboration among partners ("local connectivity") and the position of partners in the entire knowledge network ("global embeddedness"). Using data on joint research projects funded by the European Framework Programme (FPs) as proxies of cross-region collaborative activities, Scherngell and Barber (2011) provided evidence that geographic distance significantly affected patterns of industrial R&D collaboration, while the effect of geographic distance on the public research was much smaller. Similarly, Scherngell and Lata (2013) found that while geographic distance between two regions exerted a negative effect on the probability for their collaboration, the effect significantly decreased between 1999 and 2006, as the FPs helped to the realization of European Research Area through increasing the probability for collaboration at a longer distance.

Within the EU, the effect of technological proximity is stronger than geographic factors for inter-regional collaboration (Scherngell and Barber, 2009; Hoekman et al., 2010). Similar findings have been reached in the Chinese case as well (Scherngell and Hu, 2011; Liang and Zhu, 2002). Of course, inter-regional collaboration is more costly than intra-regional collaboration. Bottazzi and Peri's (2003) empirical study of 86 European regions in the period of 1977 and 1995 shows that knowledge spillovers were very much localized and existed within a distance of 300 km, and that with the "border effect," knowledge spillovers were much more obvious and intense between regions of the same country than of different ones. Using data of co-publications in 33 European countries between 2000 and 2007, Hoekman et al. (2010) found that the bias to collaborate with physically proximate partners did not decrease, while the bias toward collaboration within territorial borders did decrease over time. In this sense, the ongoing process of European integration is removing territorial borders, but does not render collaboration less sensitive to physical distance. That is, the distance and the "border effect" are still crucial for inter-regional collaboration.

2.3. Intra- and inter-regional research collaboration

As both intra-regional collaborative research and inter-regional collaborative research are vital for innovation, it is necessary for a region to maintain an appropriate balance between the two (Krätke, 2010). Boschma and Ter Wal (2007) demonstrated that in southern Italy the local knowledge network was quite weak and unevenly distributed among the local firms and either local or non-local connection mattered for local firms. Based on patent data from 1994 to 2001 in Sweden, Wilhelmsson (2009) found the similar phenomenon — the spatial distribution of inventor networks was not uniform and inventor networks were more likely to exist in densely populated areas with a diversified industry. Based on a survey in the metropolitan region of Hanover–Brunswick–Göttingen in northern Germany, Brandt et al. (2009) found that only 35% of the respondents in the ICT industry reported inter-regional linkages and the share was 30% in the automotive industry. Using the same survey data, Krätke (2010) found that 66% of all registered network relations may be characterized as inter-regional, with connections to actors within the metropolitan region accounting for the rest. Based on a survey of 1604 firms in Norway, Fitjara and Rodríguez-Pose (2013) demonstrated that a firm's engagement with external actors such as universities, research institutes and consultancy firms was closely related its innovation with both 'Science, Technology and Innovation' (STI) and 'Doing, Using and Interacting' (DUI) modes and that collaboration with inter-regional actors was much more conducive to innovation than collaboration with local partners, especially under the DUI mode.

Hidas et al. (2013) confirmed that the prevalence of regional agglomeration effects for R&D and the inter-regional R&D collaborations in EU's FPs significantly contributed to regional knowledge production. FPs may indeed induce knowledge flows between regions that are located further away, complementing intra-regional knowledge production process. Wanzenböck et al. (2014) showed that internal capacity and external spatial spillover were important for a region's centrality in the co-patent network and the FPs network, but they did not provide evidence for the existence of substantial spillover effects in joint publications.

Scholars have also attended the issue of regional research collaboration in other countries. Based on the analysis of Statistics Canada's 1999 Survey of Biotechnology Use and Development, Gertler and Levitte (2005) found that both local and global linkages were important for knowledge circulation and successful innovation at firms. Using Chinese co-patent application data in the U.S. Patent and Trademark Office (USPTO), Gao et al. (2011) examined the intra-regional, inter-regional and inter-national knowledge exchanges from 1985 to 2007. The results revealed that intra-regional and inter-national collaborations were the main channels of knowledge exchange between Chinese regions while inter-regional knowledge exchange was relatively weak, and that the inter-regional network began to show characteristics of a core–periphery structure. The core included Beijing, Guangdong, Hubei, Jiangsu and Shanghai, the periphery Chongqing, Guizhou, Hebei, Hunan, Inner Mongolia and Yunnan with the rest being semi-periphery. He and Wong (2012) found that both local and non-local collaborations were important for Singapore's manufacturing firms, representing complementary spurs to innovation. Amit et al. (2013) found that the innovation networks have been formed by subsidiaries of MNCs (including ABB, Alcatel-Lucent, AMD, Cisco, Dell, GE, Google, IBM, Intel, Microsoft, Philips, Siemens and Texas Instruments) in Bangalore, India, which first developed as hierarchical networks and then was extended to the local markets.[1]

Marzucchi et al. (2012) found that the networking activities of a regional innovation system were affected by regional innovation policies and that government's subsidy could help firms to extend cooperation beyond the regional borders. Bathelt and Henn (2014) argued that combinations of trans-regional electronic and digital communication with temporary face-to-face meetings provided efficient ways of linking different locations of production, research, and marketing with one another.

2.4. The limitations of the existing literature and the motivation of the present study

The above literature is the cornerstone for understanding inter-organizational research collaboration within and across regional boundaries and plays critical roles in the present study. But the literature also has obvious limitations. First, most of the existing studies have emphasized localized collaboration within clusters or regions and inter-national collaboration (Bathelt and Henn, 2014). Gao et al. (2011) integrated intra-regional, inter-regional and inter-national research collaborations into one analytical framework. Their results revealed that inter-regional collaboration was relatively weak in China. In fact, when using a region as the unit of analysis, for a vast country like China or area such as Europe, inter-regional research collaboration is also very important, especially given the situation where Chinese organizations have not engaged in a large extent in international collaboration in patenting.

Second, the existing literature has provided evidence for the significance of the intra- and inter-regional collaborative research in innovation. But questions remain unanswered regarding the preference of collaborative or independent innovation and the balance between intra- and inter-regional collaboration. Indeed, most of the regions balance their collaboration, though unintentionally, thus illustrating

[1] Within the first part, the networks start with a non-local nature (phase A) and get embedded into local networks (phase B and phase C), finally developing into non-local (phase D) market ties that enable MNC headquarters to source innovation from the host country.

regional patterns of research collaboration. As inter-organizational research collaboration involves several dimensions, we need to integrate them into an analytical framework so as to identify the collaboration patterns.

Third, forms of collaboration – between enterprises (EE) or between an academic institution and an enterprise (AE) – are also a primary factor influencing the performance of a regional innovation system (Cooke et al., 1997), and different collaboration forms function differently for regional innovation (Ma et al., 2013). While the literature pays attention to inter-organizational collaboration forms within regional boundaries (Hong, 2008; Graf and Henning, 2009), economic geography and innovation studies do not go further to examine the forms of inter-organizational collaboration across regional boundaries, let alone the differences between forms of organizational collaboration within and across regions.

In order to expand the existing literature, this study advances a research agenda around a two-dimensional quadrant (TDQ) analytical framework and attempts to apply it to the examination of evolving regional research collaboration patterns within or across regional boundaries and collaboration between enterprises and between enterprises and academic institutions. Not only are the results useful for understanding the characteristics of China's regional innovation system, the framework and findings based on it will also have implications for the study of research collaboration in other countries.

3. A framework for studying regional research collaboration

As a kind of inter-organizational relationship, research collaboration exists in a variety of forms such as alliances, joint ventures, supply agreements, licensing, co-branding, and franchising (Parmigiani and Rivera-Santos, 2011). Empirically, data on co-authorship and co-invention/co-patent are used to measure research collaboration since they provide a valuable source of information on the outcomes of collaboration (Scherngell and Hu, 2011; Liang and Zhu, 2002; Gao et al., 2011). Following the convention in this line of research (Hong, 2008; Hong and Su, 2012; Motohashi, 2008), we use patent co-assigneeship to measure such inter-organizational relationship.[2]

We use patents as a proxy for collaborative activities, with the understanding that such a measure has limitations. First, patents are just one type of collaborative research outcomes and collaboration also generates papers, copyrights, trade secrets, and other outputs. Meanwhile, importance of patentable collaboration varies across industries as collaboration may aim to develop a new product instead of a new patent. Thus, patents do not cover all outcomes of research collaboration. Second, besides formal outcomes such as patents, collaboration is mostly informal. Partners collaborate across organizations for exchanging and sharing their tacit knowledge, not necessary for tangible outcomes with codified knowledge.

These being said, patents still provide basic, useful, and effective information. In the context of our study, a patent with two or more different assignees from two or more organizations is regarded an outcome of successful research collaboration. We could then base on the residential information of assignees disclosed in the patent document to determine whether the collaboration is intra-regional when all assignees of the patent reside in one region or inter-regional when all assignees of the patent reside in two or more different regions.

The inter-organizational research collaboration could be further divided into that between academic institutions (AA) if patent assignees are only from academia, that between enterprises (EE) if assignees are only from enterprises, and that between academic institutions and enterprises (AE) if assignees involve both types of organizations[3] (Fig. 1). Clearly, enterprise is the principal player of innovation, and research collaboration linked to enterprises – AE and EE collaboration – is more important than AA collaboration for a regional innovation system. Meanwhile, as the total research collaboration is a portfolio consisting of three forms of collaboration, it is suffice to examine two of the three. In other words, if AE and EE collaborations are determined, the rest can be attributed to AA collaboration.

The two-dimensional quadrant (TDQ) lends us a useful tool to advance our research agenda. Scholars have used TDQ to construct various theoretical frameworks, such as the classification of scientific research that includes a Pasteur's quadrant (Stokes, 1997), the classification of legal system for innovation (Waarden, 2001), the classification of technological development for government policy (Dolfsma and Seo, 2013), and the classification of industrial policy (Appelbaum et al., 2012). However, few have used TDQ in empirical research on regional collaboration in innovation with probably the exception that Kim and Song (2013) use a two-dimensional quadrant to identify the roles of companies in the network of patent infringement lawsuits. In this study, we use TDQ to propose that a region's collaborative research shows the specific characteristics of its organizations in innovation — who prefer collaboration and with whom to collaborate (Fig. 2). The TDQ-based analysis could enhance our understanding of a region's characteristics in research collaboration.

First, an organization that chooses collaborative or independent research represents its preference of open or close innovation and the combined preference of all organizations in a region congregates the region's innovation pattern. We categorize a region's innovative activities into four patterns according to its regional innovation capability and research collaboration level. Our study uses the number of invention patents per hundred thousand population[4] of a region to measure regional innovation capability (IC) and the share of collaborative invention patents of the total invention patents in a region to measure the region's collaboration intensity (CI). We can therefore identify a region's specific innovative pattern and position in a TDQ of innovation capability (IC)/collaboration intensity (CI) (Fig. 2(A)). A "leader" region not only possesses

[2] The present paper only studies collaboration between organizations, and therefore patents filed by individuals are excluded.

[3] Research collaboration between academic institutions and enterprises (AE) is the same as that between enterprises and academic institutions (EA) in this paper.

[4] We use the indicator of population that is the average value of annual usual residents in each time period—1985–1992, 1993–2000, 2001–2008, 1985–2008. Data is from New China 60 Years Statistics Compilation (1949–2008).

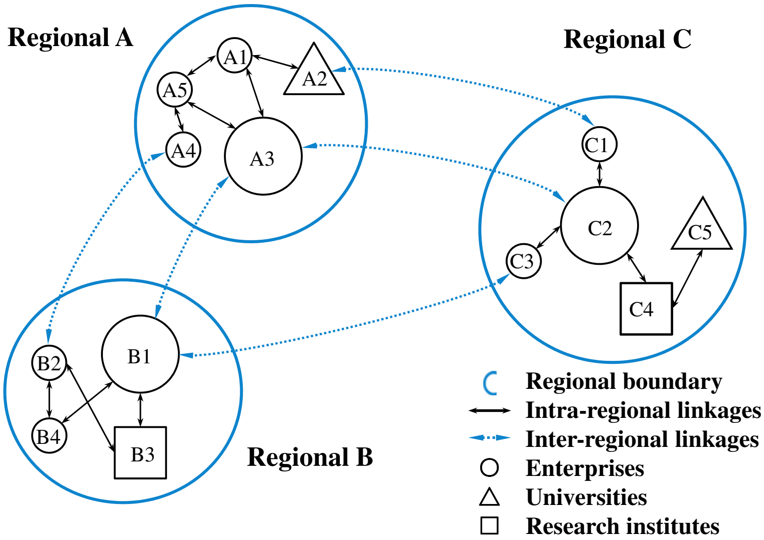

Fig. 1. Intra- and inter-regional research collaboration based on co-assigneeship of patents.

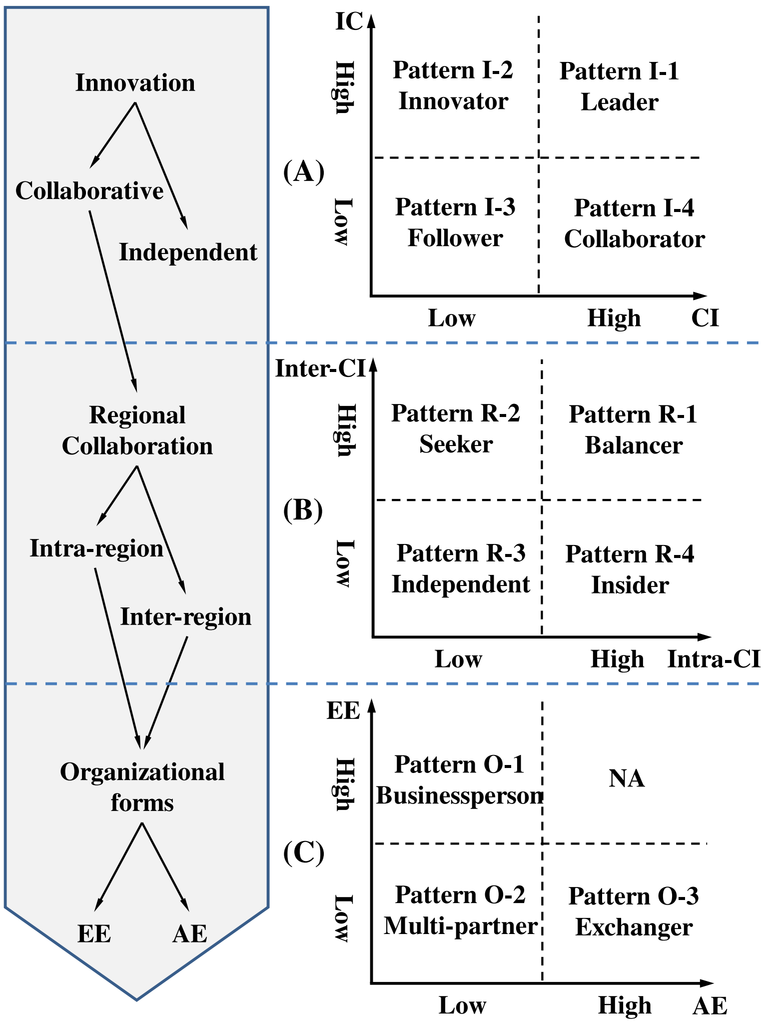

Fig. 2. An analytical framework of regional collaboration.

strong innovation capability, its organizations also exchange knowledge with others within or across regions by conducting a wide range of inter-organizational collaborative research. Therefore, the region exerts its leadership through knowledge diffusion. An "innovator" region has strong innovative capability and actively pursues innovation, but its organizations lack intention to collaborate with others, preferring instead to take advantage of its intra-organizational resources. A "follower" region has neither strong innovative capability nor strong desire for collaboration so that it just follows both the leader and the innovator. Finally, a "collaborator" region is one whose organizations have strong desire for collaboration and attempt to draw on outside resources through collaboration; but such region's innovative capability is relatively weak.

Second, organizations could choose to collaborate with intra-regional or inter-regional partners. Therefore, we further categorize regional collaboration activities into four patterns according to a region's intra- and inter-regional collaboration intensity (CI). Intra-CI and inter-CI, defined as the share of intra-regional and inter-regional collaborative invention patents of the total invention patents in a region respectively, can be used to measure intra- and inter-regional collaboration intensity. Similarly, we can identify a region's specific collaborative pattern and position in a collaborative TDQ according to its intra-CI/inter-CI level (Fig. 2(B)). With high level of both intra- and inter-regional collaboration, a "balancer" region shows a good balance between inward and outward orientation toward collaboration. Its organizations could integrate and use the intra- and inter-regional knowledge and other resources. A "seeker" region prefers exchanging and sharing knowledge with a collaborative partner from outside the region so that its organizations could absorb heterogeneous external resources; but its intra-regional collaboration is relatively weak. An "insider" region prefers collaborative research within regional boundaries via geographic proximity, and therefore is less likely to seek partners from outside the region for knowledge exchange. And finally, an "independent" region lacks both intra-regional and inter-regional linkages compared to other regions; in other words, its organizations prefer independent research based on its intra-organizational resources.

Third, organizations can choose to collaborate with enterprises or academic institutions. We, therefore, distinguish inter-organizational forms of regional collaboration in an organizational TDQ by the EE/AE level as well (Fig. 2(C)). The level of EE collaboration and the level of AE collaboration are defined as the share of patents out of inter-enterprise collaboration and the share of patents out of collaboration between academic institutions and enterprises of the total collaborative patents in a region respectively. As the shares of various inter-organizational collaborative forms add up to one, there are only three patterns on the organizational TDQ. A "businessperson" region prefers inter-enterprise or business-oriented research collocation (EE-dominated collaboration pattern) in order to gain complementary resources and share risk in innovation. Such collocation is most likely to be governed by market mechanism. An "exchanger" region has more academic institution–enterprise collaboration (AE-dominated collaboration pattern). In such a region, enterprises approach academic institutions for solving technical problems, or academic institutions want to commercialize their research achievements. There is no one collaborative form dominating inter-organizational collaboration in a "multi-partner" region.

Obviously, the threshold for distinguishing high and low level is central to the categorization of regions. The average value is used to distinguish the high and low level in IC/CI quadrant and intra-CI /inter-CI quadrant because of the universality of TDQ, which could be applied to other cases of similar characteristics (Kim and Song, 2013). Certainly, such categorization could also be influenced by the distribution of regions' data, in particular the number of regions in each quadrant. However, it is not necessary to have an equal number of regions in each quadrant. With regard to the EE/AE TDQ, 50% is used as a threshold for high or low level of collaboration. The AE, EE and AA collaboration is added up to 100%. If in a region either AE or EE collaboration is more than 50%, the region's research collaboration is dominated by either AE or EE form; if both AE and EE collaboration is less than 50%, it indicates that AA collaboration is increased. It is clear that while the EE/AE TDQ only includes two of the three collaborative forms, it actually displays the distribution of three collaborative forms.

4. Data

The data are the cornerstone in the empirical analysis of research collaboration. The patent data, despite having several limitations, have been widely used in the innovation studies, including in the studies of regional collaboration. In particular, using the data of Chinese patent applications at USPTO, Gao et al. (2011) show that inter-regional research collaboration in China was relatively weak comparing to intra-regional and inter-national collaboration. Chinese patent applications in USPTO have been growing rapidly since 1985. Inventors involved in international collaborative research tend to apply patents in international patent offices such as USPTO and the European Patent Office (EPO) due to the international orientation of these patent offices. Patent data in these offices are suitable for investigating inter-national research collaboration, but do not fully reflect the reality of regional research collaboration. A previous study comparing patenting activities in the U.S. and China actually used data from patent offices from both countries rather than depending merely data from USPTO (Liu and Sun, 2009). Given the fact that China's domestic inventors mainly apply patents in SIPO, this study uses the co-assigneeship data of Chinese invention patents applied with SIPO to investigate China's intra- and inter-regional research collaboration. SIPO maintains a database with complete patent information since 1985, when China enacted its Patent Law, authorizing SIPO the responsibility of handling patent applications in China (Hong, 2008). The database, which contains title of an invention; dates of application, publication, and grant; names and addresses of assignees and so on, has been widely used in the study of China's technological innovation (Hong and Su, 2012).

Studies using the Chinese invention patent data available at SIPO expand the literature based on the USPTO data (Gao et al., 2011). In fact, there are several advantages for this approach. First, while USPTO receives an increasing but still a small portion of Chinese invention applications, the majority of the Chinese patent applications, including those coming out of intra- and inter-regional collaboration, has gone to SIPO.

Table 1
An overview of research collaboration in China (1985–2008).

Periods	Total patents		Intra-regional collaborative patents		Inter-regional collaborative patents	
	National count	Sum of regional counts	Number	%	Number	%
1985–2008	751,913	766,965	10,313	1.34	7540	1.00
1985–1992	37,889	38,471	810	2.11	507	1.34
1993–2000	92,332	93,479	1162	1.24	712	0.77
2001–2008	621,692	634,585	8341	1.31	6321	1.02

Source: Calculated by authors based on data from SIPO.

Therefore, the SIPO data provide a more comprehensive picture of innovation in China. Second, we only use the data of invention patent applications, because the quality of invention patents is much higher than that of utility models and designs. Although the overall quality of patents filed with SIPO might be lower than that applied to USPTO, this does not affect our investigation of research collaboration. Third, we use the date of patent applications rather than patent grants because not only the rates of grants are low but also the application date represents the time when the collaboration leading to the patent was actually completed (Trajtenberg et al., 2006).

The process of extracting patent information from the SIPO database is as follows. At first, we retained patents with two or more assignees by filtering out those with one assignee, no assignee, and individual assignee at the time of application. Then, we obtained from the database such assignee information as patent number, names of inventors, names of assignees, and residence information of the first assignee including street address, city, province, and zip code (if available). Thirty-one provinces are used as the units of analysis. Through Internet search, we obtained the residence information on other assignees. In this way, our data bring together information on geographic locations of all co-assignees listed on a patent. The geographic locations are where the research leading to patent applications was carried out rather than the headquarters or locations of holding companies of the entities, which reflect the spatial distribution of research activities.

Then, we counted the numbers of intra- and inter-regional collaborative patents. It's worth noting that our focus is region, and China consists of 31 regions, thus we counted regional numbers of patent applications and collaborative patent applications first. At the regional level, each region's number of patent applications is fixed (see Appendix Table 1). The total numbers of intra- and inter-regional collaborative patent applications are summed by regional counts.

At the national level, when a patent has assignees residing in the same region, an intra-regional collaborative research occurred and therefore the patent is counted once at both the national and regional level, and the share of intra-regional collaboration is the number of its patents accounting for the total patents of national count. When a patent has assignees residing in two or more different regions, its production involved an inter-regional collaborative research, and therefore the patent is counted once for every region involved in the collaboration. Consequently and obviously, the total number of patent applications summed by regional counts this way is higher than direct national count. And the share of inter-regional collaboration is the number of its patents accounting for total patents summed by regional counts (see Table 1).

Finally, we distinguished types of organizations involved in collaboration. By appropriately setting search conditions, we determined a patent jointly applied by enterprises and academic institutions or by enterprises. For enterprises, assignee names could be a company (*Gongsi*), a factory (*Chang*), a group (*Jituan*), an enterprise (*Qiye*), or a combination of several of them (e.g., *Qiye Jituan Gongsi*). Similarly, the assignee names of academic institutions could be a university (*Daxue*), a college (*Xueyuan*), a school (*Xuexiao*), a R&D institute (*Yanjiusuo* or *Yanjiuyuan*), a lab (*Shiyanshi*), a designing institute (*Shejiyuan*) or an academy of sciences (*Kexueyuan*). We first searched patents whose assignees include enterprises (Set 1) and patents whose assignees include academic institutions (Set 2). Then we searched Set 1 for patents whose assignees also contain academic institutions (Set 3–AE collaboration) before figuring out collaboration between enterprises by subtracting Set 3 from Set 1 (Set 4–EE collaboration) and collaboration between academic institutions by subtracting Set 3 from Set 2 (Set 5–AA collaboration).

Our analysis covers invention patent applications that SIPO had received between 1985 and 2008. In order to illustrate the dynamics of collaborative innovation, we divided the entire period into three periods of equal length – 1985–1992, 1993–2000, and 2001–2008 – for two reasons. One is the evolution of China's patent system and IPR protection. Patent Law of the People's Republic of China was promulgated in 1984 and was in force in 1985, and acceded to *the Paris Convention for the Protection of Industrial Property* in 1985. So 1985 is the start year of patenting in China.

Second, these years are also coincidently important from the perspective of China's reform and open-door policy, especially with respect to technology and innovation. In 1985, the Chinese state issued the *Decision on the Reforms of the Science and Technology System*; in 1992, Deng Xiaoping's southern tour deepened Chinese economic reforms and heralded China into a new era of S&T and innovation development. Then in 2001, China joined the World Trade Organization (WTO) and became a member of the TRIPS agreement,[5] which indicates that

[5] The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) is an international agreement administered by the World Trade Organization (WTO) that sets down minimum standards for many forms of intellectual property (IP) regulation as applied to nationals of other WTO members. It was negotiated at the end of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) in 1994.

Chinese S&T system began to be integrated into the global innovation network.

5. An overview of inter-organizational research collaboration in China

Between 1985 and 2008, SIPO received a total of 751,913 patent applications based on direct national count and 766,965 patent applications based on sum of regional counts taking into account inter-regional collaboration (see Table 1).[6] Of them, 10,313 patents are outcomes of intra-regional collaborative research with an intra-regional collaboration intensity (intra-CI in Fig. 2) of 1.34%; and 7540 patents resulted from inter-regional collaborative research, whose inter-regional collaboration intensity (inter-CI in Fig. 2) is 1.00%. These indicate that not only research collaboration within or across regions in China measured by joint invention patent application was extremely weak but also organizations slightly favored within-region over across-region collaboration. The latter finding suggests that geographic proximity or spatial distance probably was more important than other proximity factors in China during that period.

AA, EE and AE collaboration accounted for 8.56%, 13.88% and 77.56% of the intra-regional collaboration respectively, and 11.66%, 22.33% and 66.01% of the inter-regional collaboration respectively (see Table 2 and Fig. 3). The statistics means that AE collaboration dominated research collaboration in China, whereby enterprises, motivated by acquiring knowledge, tended to collaborate with academic institutions instead of enterprises.

The first period of 1985–1992 witnessed the smallest number of co-patent applications but the rates of intra-CI and inter-CI research collaboration being 2.11% and 1.34% respectively, the highest among the three periods. Intra-regional AA, EE and AE collaboration accounted for 19.88%, 38.02% and 47.53% respectively, and the gap between EE and AE collaboration was not large; but inter-regional AE collaboration accounted for 75.54% while the share of inter-regional EE collaboration, 6.11%, was not only much smaller than that of intra-regional EE collaboration (38.02%) but also smaller than the share of inter-regional AA collaboration (18.34%).

In the second period of 1993–2000, only 1.24% and 0.77% of the patent applications came out of intra- and inter-regional collaboration, the lowest in the three periods. Of the intra-regional collaboration, the share of AE collaboration witnessed the biggest increase to reach 79.26%, which was at the expense of both the EE and AE collaboration (8.86% and 11.88%). For inter-regional collaboration, compared to the first period, there was a little change with AA, EE and AE collaboration accounting for 19.94%, 8.99% and 71.07% respectively.

In the third period of 2001–2008, the numbers of patent applications involving intra-regional and inter-regional collaboration were 8341 and 6321 respectively, the largest in the numbers in the three periods, but the rates of collaboration were still lower than those in the first period. Intra-regional AE collaboration accounted for 78.32% of the total, decreased slightly, meanwhile, intra-regional AA collaboration decreased

[6] This file gathers all actual assignees' names listed on a patent and all their addresses and not the innovators' addresses.

Table 2
Three forms (numbers) of inter-organizational collaboration in China (1985–2008).

Periods	Intra-regional collaboration			Inter-regional collaboration		
	AA	EE	AE	AA	EE	AE
1985–2008	883	1431	7999	879	1684	4977
1985–1992	161	308	385	93	31	383
1993–2000	138	103	921	142	64	506
2001–2008	584	1224	6533	644	1589	4088

Notes: "AA" means research collaboration between academic institutions including universities and research institutions, "EE" means research collaboration between enterprises, "AE" means research collaboration between academic institutions and enterprises.
Source: Same as Table 1.

to 7% but EE collaboration increased to 14.67%; the inter-regional collaboration shows a similar trend as intra-regional collaboration — AA, EE and AE collaboration accounted for 10.19%, 25.14% and 64.47% respectively.

With a fast-growing economy measured by rapid growth in gross domestic product (GDP), R&D expenditure, and high-tech exports, China has also witnessed a dramatic increase in the number of patent applications. Nevertheless, the number of collaborative patents had not grown as rapidly as the surge of patent applications. This has significantly led to the decrease in the collaborative patent applications after 1992, particularly after 2000. Collaboration leading to joint patent applications first decreased then increased, and the rate of collaboration in the third period still did not recover to the level seen in the first period. Meanwhile, inter-organizational forms in intra- and inter-regional collaboration showed different evolutional trends. For the intra-regional collaboration, the patterns of collaboration transformed from the "multi-partner" to the "exchanger," and the share of EE collaboration dropped significantly first then increased but AA collaboration decreased over time. Patterns of inter-regional collaboration show the characteristics of the "exchanger" all the time, however, the share of EE collaboration increased and AA collaboration decreased over time.

The above analysis shows that the market-oriented economic and S&T reform has encouraged collaboration between enterprises, specifically those cross regions, while intra-regional collaboration more likely happened between academic institutions and enterprises. But collaboration between academic institutions, either within or across regions, remained undesirable given that collaboration was not valued highly in performance evaluation.

6. Regional characteristics of inter-organizational research collaboration in China

Based on the analytical framework described above (Fig. 2), in this section, we are reporting the results of intra- and inter-regional collaboration and AE and EE collaboration in China.

6.1. Collaborative or independent

First of all, identifying a region's preference of collaborative or independent innovation is not the purpose of this paper. In

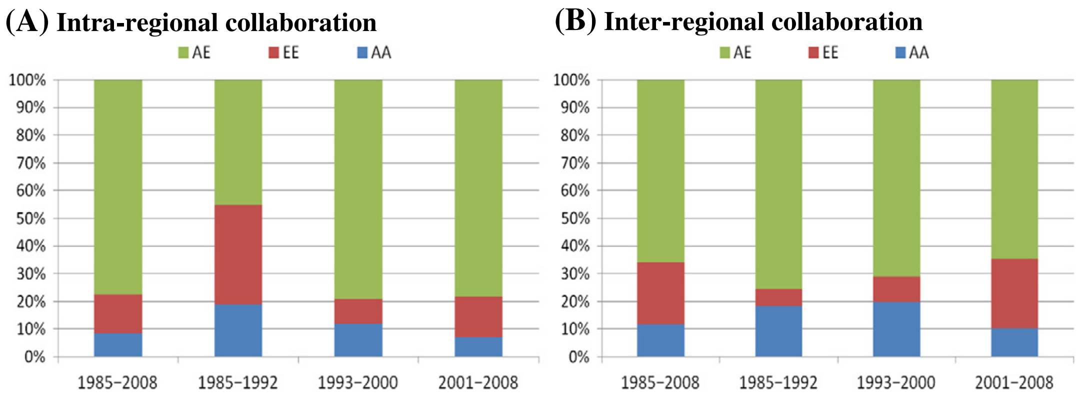

Fig. 3. Three forms (share) of inter-organizational collaboration in China (1985–2008). Notes and sources: Same as Table 2.

order to save space, we only provide an overall result of the CI/IC quadrant (1985–2008) rather than all results in each period (see Fig. 4).

Located in coastal China and most economically advanced, Beijing, Shanghai, and Zhejiang are core actors of China's innovation system. In particular, Beijing was far ahead as the leader in both collaboration intensity (CI) and innovation capability (IC) measures, followed by Shanghai and Zhejiang that occupied similar positions with lower CI. Besides these "leader" regions, Tianjin and Guangdong, also located in the coast and economically advanced, were "innovators" although their rates of research collaboration were lower than 3.32%, the average.

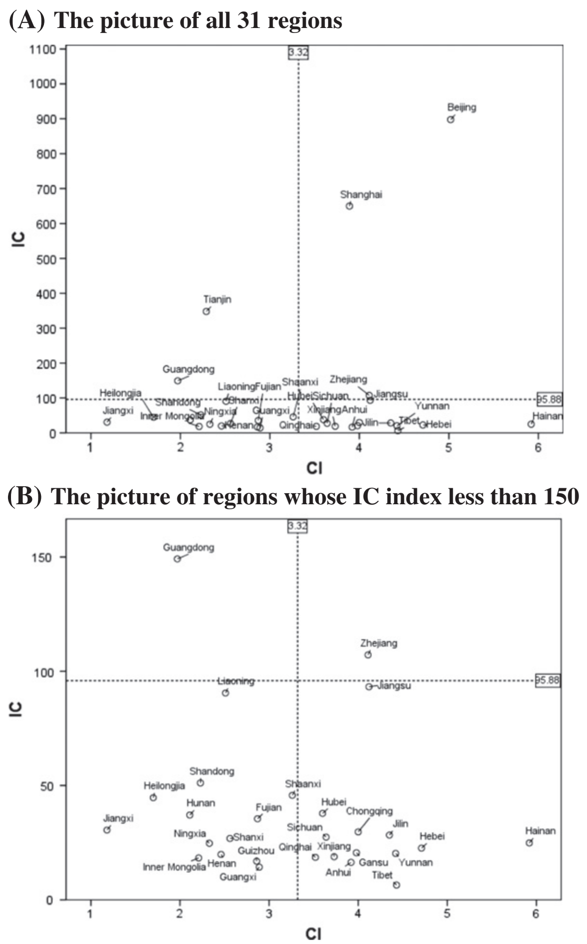

Fig. 4. Regional innovation patterns according to innovation capability and research collaboration. Source: Same as Table 1.

With fewer patents, Hainan had the highest collaboration intensity because of its weaker S&T base and small-scale R&D activities. Jiangsu, Henan, Anhui, Chongqing, Gansu, Hebei, Hubei, Jilin, Qinghai, Sichuan, Tibet, Xinjiang, and Yunnan are "collaborators," whose innovation capability was relatively weak. Of them, Jiangsu and Hubei possessed rich S&T resources and industrial bases, Sichuan and Chongqing were relatively strong in their S&T resources as the result of relocation of many national defense oriented research institutes and enterprises during the Cultural Revolution. The rest provinces were "followers" although Liaoning occupied a leadership position in innovation capability and Shaanxi's rate of research collaboration was also higher.

There were more "collaborators" than "innovators" and "leaders" combined, which suggests that organizations within regions with weak innovation capability prefer to collaborate with others; but collaborative research did not necessarily lead to active patenting and improve regional innovation performance. Of the top seven innovative regions — Beijing, Shanghai, Tianjin, Guangdong, Zhejiang, Jiangsu and Liaoning, only Beijing, Shanghai, and Zhejiang were "leaders." That is, collaboration was not necessarily favored by organizations within the top innovative regions where only some organizations pursued exchange knowledge with others. A culture of research collaboration has yet to emerge.

We then quantitatively investigate the correlation between main indicators with regard to regional innovation and collaboration (see Table 3). During the first period, there was no statistically significant relationship between innovation capability (IC) and forms of collaborative research (CI, EE and AE) at China's regional level. Entering the second period, the Pearson's correlation coefficient between IC and CI was 0.615 and statistically significant at the 0.01 level. In the third period, the correlation between IC and CI disappeared, but the correlation coefficient between IC and AE was 0.445 and

Table 3
The correlation matrix of main indicators by Pearson correlation coefficient (1985–2008).

1985–1992	IC	CI	EE	AE	1993–2000	IC	CI	EE	AE
IC	–				IC	–			
CI	0.218	–			CI	0.615**	–		
EE	−0.233	0.15	–		EE	−0.207	−0.497**	–	
AE	0.224	0.226	−0.357*	–	AE	0.292	0.431*	−0.689*	–
2001–2008	IC	CI	EE	AE	1985–2008	IC	CI	EE	AE
IC	–				IC	–			
CI	0.009	–			CI	0.205	–		
EE	−0.236	0.281	–		EE	−0.255	0.160	–	
AE	0.445*	−0.214	−0.830**	–	AE	0.418*	−1.02	−0.796**	–

Note: The number of sample is 31 regions. Source: Calculated by authors.
* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

statistically significant at the 0.05 level. Between 1985 and 2008, there was weak correlation between IC and AE, but no significant correlation between IC and CI. Furthermore, the negative correlation between AE and EE was increasingly strengthening from 1985 to 2008; the correlation between CI and AE/EE was only statistically significant in the second period.

Generally, the correlation between innovation capability and collaborative intensity was evolving. There was strong and significant correlation between IC and CI between 1993 and 2000 and the correlation between IC and EE was weak than that between IC and AE. This indicates that the collaboration between academic institutions and enterprises was more important for regional innovation development in China. Similarly, based on a survey of 950 industrial enterprises in Beijing, Guan et al. (2005) found that the more the collaboration between enterprises and academic institutions, the higher the technology novelty of the innovation; furthermore, collaboration during the new product development process did enhance the technology level of enterprises and could supplement to a certain extent the poor R&D and innovation capability of an enterprise. Our result provides new evidence to substantiate this argument at the regional level. The collaboration between academic institutions and enterprises could improve regional innovation capability.

6.2. Intra- or inter-regional collaboration

Regional co-patent application patterns of 31 Chinese provinces measured by the inter-CI/intra-CI level had experienced remarkable changes. In the first period (Fig. 5-A), most of the provinces and municipalities were located around the center point (average values of the inter-CI/intra-CI TDQ, or 2.12, 2.36), with nine "seeker" and twelve "insider" regions. Entering the second period (Fig. 5-B), most regions shifted to the left, or experiencing a lower rate of intra-regional collaboration, but there were more "independent" and "balancer" than "seeker" and "insider" regions. The third period (Fig. 5-C) shows a different situation in which more regions became "independent" and "insider" and only three were "balancers." During the entire period of 1985 to 2008, the distribution of regions was dispersed with seven "balancers," five "seekers," seven "insiders," and twelve "independents." In sum, the distribution of regional collaboration patterns emerged from different periods is that while there were more "seekers" or "insiders" at one period and more "independents" at another, just a few regions became "balancers."

In fact, co-patent applications concentrated on a few regions. The top innovative regions – Beijing, Shanghai, Zhejiang, Jiangsu, Guangdong, Tianjin, and Liaoning – produced a total of 64.57% of the invention patent applications, 70.23% of the intra-regional co-patents, and 67.59% of the inter-regional co-patents. Here, we only pay attention to these regions with large-scale patent applications and presumably higher innovative capability.

Between 1985 and 2008, both Beijing and Shanghai were collaboration "balancers," while Beijing's inter-CI was far greater than that of Shanghai's. Zhejiang and Jiangsu were the "insiders," but their inter-CIs were close to the average value of 2.04, thus their roles in collaboration seem to be similar to those of the "balancers." These suggest that maintaining a balance between inter- and intra-regional collaboration is necessary for the "leaders" who process relatively strong intra-regional collaboration capability. In particular, Beijing and Shanghai, as the national S&T centers, diffused their technological knowledge through inter-regional research collaboration, but Zhejiang and Jiangsu were relatively weak in this regard. As "innovators," Tianjin and Guangdong were "independents" in collaboration, which provides further evidence that the relationship between innovation capability and collaboration intensity was weak.

At the same time, the major regions diverged in their paths in the three periods. As an innovation "leader," Beijing transformed itself from a collaboration "seeker" to a "balancer," suggesting that it no longer just sought partners for transferring its technology, but focused on within-region collaboration. Shanghai and Zhejiang also transformed themselves from collaboration "seekers" to "balancers" then to "insiders" — Shanghai as a knowledge creator started with an attempt to seek partners for knowledge transfer, while Zhejiang was known for its clusters of small and middle-sized enterprises (SMEs), which were more likely to seek external technological knowledge to support their development. Jiangsu transformed itself from an "independent" to a "balancer" and then to an "insider." The

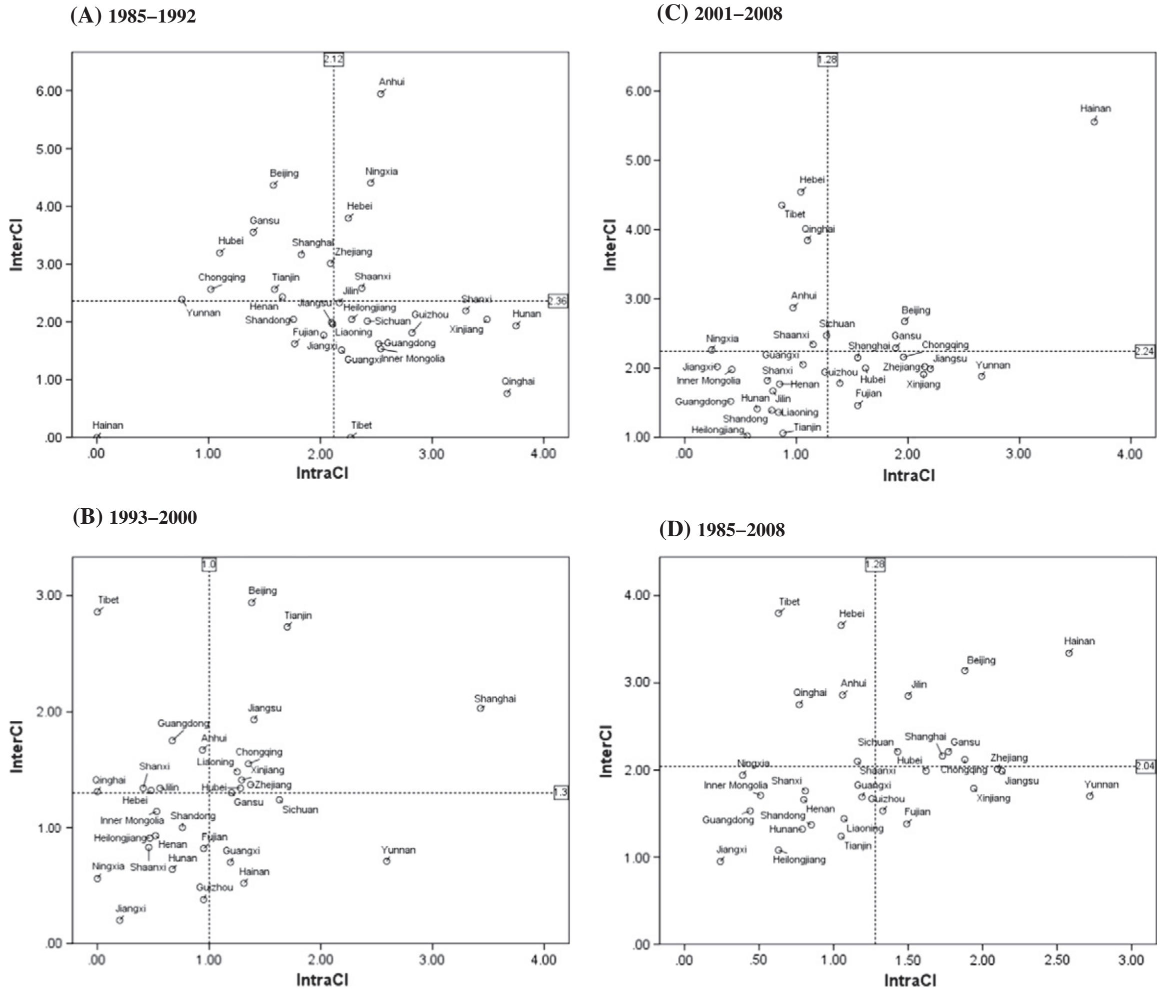

Fig. 5. Inter- and intra-regional research collaboration patterns in China during various periods. Note: The inter-CI is higher than the intra-CI at the regional level although the former is lower than the latter at the national level. This is because if a patent application collaborated by organizations at two or more different regions, it is counted one inter-regional collaboration at the national level but two or more inter-regional collaborations at the regional level. But the intra-regional collaboration is the same at the regional and national levels. Source; Same as Table 1.

evolution of these innovation "leaders" from collaboration "seekers" or "balancers" to "insiders" indicates that innovative regions were strengthening their intra-regional research collaboration through the efforts of local governments that promoted regional development by internal knowledge communication and sharing (Kafouros et al., 2014). In the meantime, Tianjin was a "seeker" at first, became a "balancer," and then ended the period as an "independent," Guangdong had transformed itself from an "insider" to a "seeker" and then to an "independent," and Liaoning also had experienced a transformation from an "independent" to a "balancer" and then to an "independent" again. In particular, for Guangdong, most R&D activities are concentrated at enterprises, thus its innovation is closer to the production and market (Breznitz and Murphree, 2011). These seem to suggest that organizations in these regions prefer to carry out research themselves instead of working with others, representing a significant departure from their previous active collaborative pattern.

6.3. EE or AE collaboration

The distribution of intra- and inter-regional collaboration between academic institutions and enterprises and between enterprises has been changing as well (Fig. 6). In the first period, most of the Chinese provinces and municipalities were "exchangers" in terms of intra-regional collaboration, locating closely to the vertical central line of the TDQ with only three provinces standing out as "multi-partners." In particular, Tibet was at the original point and did not collaborate with any region, eight provinces were located on the horizontal axis indicating no EE collaboration, Inner Mongolia and Chongqing were on the central point indicating that both had equal AE and EE collaboration, and Jiangsu was on the vertical central line in which AE collaboration accounted for half and EE and AA collaboration another half. For inter-regional collaboration, most of the provinces and municipalities were located in the central part of the "exchanger" quadrant, and only Yunnan was a "multi-partner." In particular, Tibet and Hainan were on the original point, seven provinces were on the horizontal axis, and Guizhou was on the vertical central line.

Entering the second period, for intra-regional collaboration, Jiangxi became the only "businessperson," although most of the other provinces and municipalities still were "exchangers" and only two provinces were "multi-partners." In particular, three provinces still were on the original point and the number of regions on the horizontal axis decreased. For inter-regional collaboration, most of the provinces and municipalities were in the "exchanger" quadrant and were close to the horizontal axis, and only Yunnan and Chongqing were "multi-partners." And Hainan and Ningxia were on the horizontal central line.

The third period shows a different pattern in which more regions increased their EE collaboration. For intra-regional collaboration, now most regions became "exchangers" and two were still on the horizontal axis, meanwhile there were only one "businessperson" and three "multi-partners." For intra-regional collaboration, the distribution of provinces looks like an inverted-diagonal although most still were located in the "exchanger" quadrant with three "businesspersons" and six "multi-partners."

Examining the entire period between 1985 and 2008, we find that the distribution of regional collaboration patterns was similar to that in the third period. The changes involved Hebei and Ningxia that became intra-regional collaboration "multi-partners," and Guangxi that became an "exchanger"; Tibet moved to the central point and Jiangxi became an inter-regional collaboration "multi-partner" from a "businessperson." In sum, most regions showed the "exchanger" pattern, just a few regions gradually moved to the "multi-partner" and "businessperson" quadrants.

Here, again, we would like to focus on the major innovative regions — Beijing, Shanghai, Zhejiang, Jiangsu, Guangdong, Tianjin, and Liaoning. From 1985 to 2008, all seven regions were in the "exchanger" quadrant. However, the seven regions showed different patterns between intra- and inter-regional collaboration and diverged in their evolution paths in the three periods. Intra-regional collaboration showed a very interesting phenomenon that in Beijing and Shanghai, the national S&T centers, academic institutions just did not work

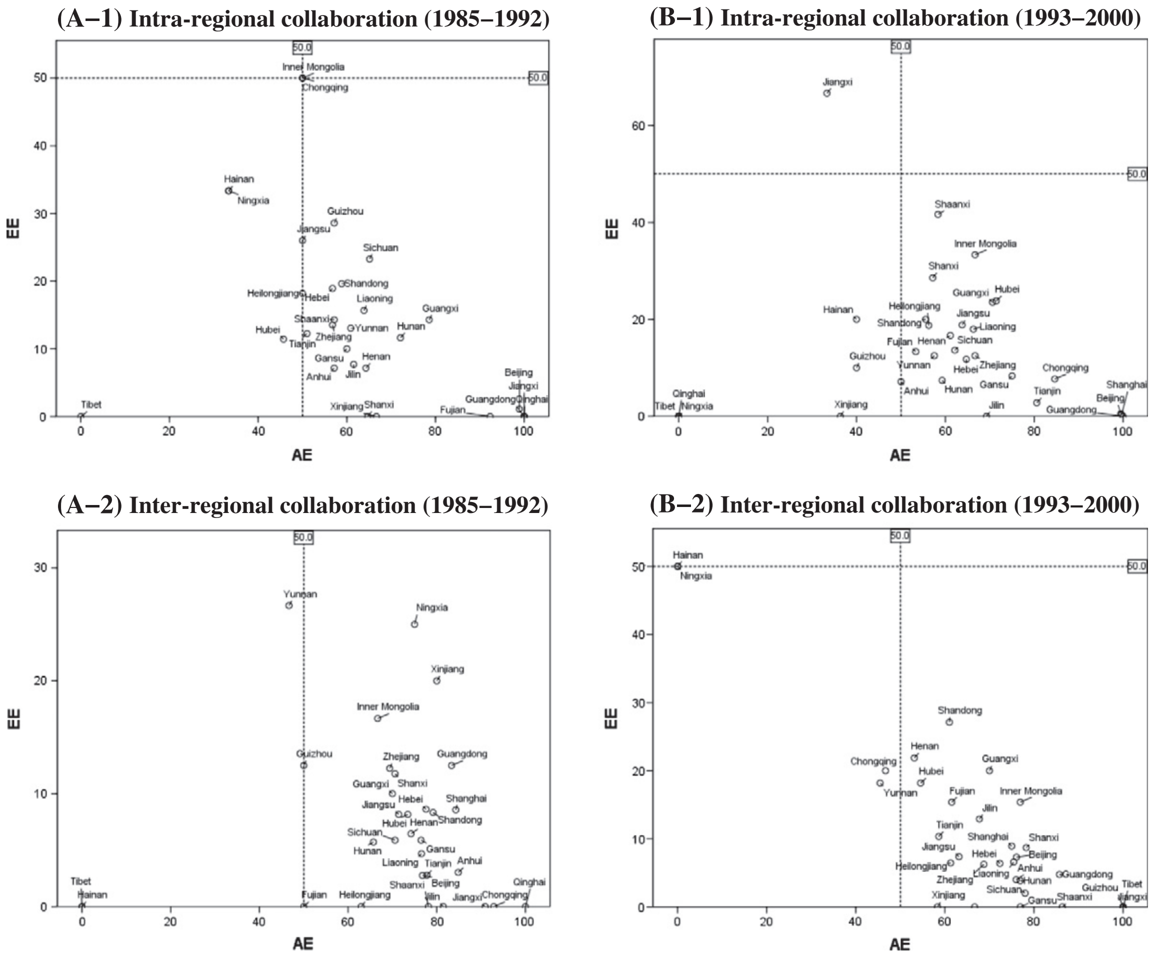

Fig. 6. Inter-organizational patterns of inter- and intra-regional research collaboration in various periods. Notes: "EE" means research collaboration between enterprises, "AE" means research collaboration between academic institutions and enterprises. Source: Same as Table 1.

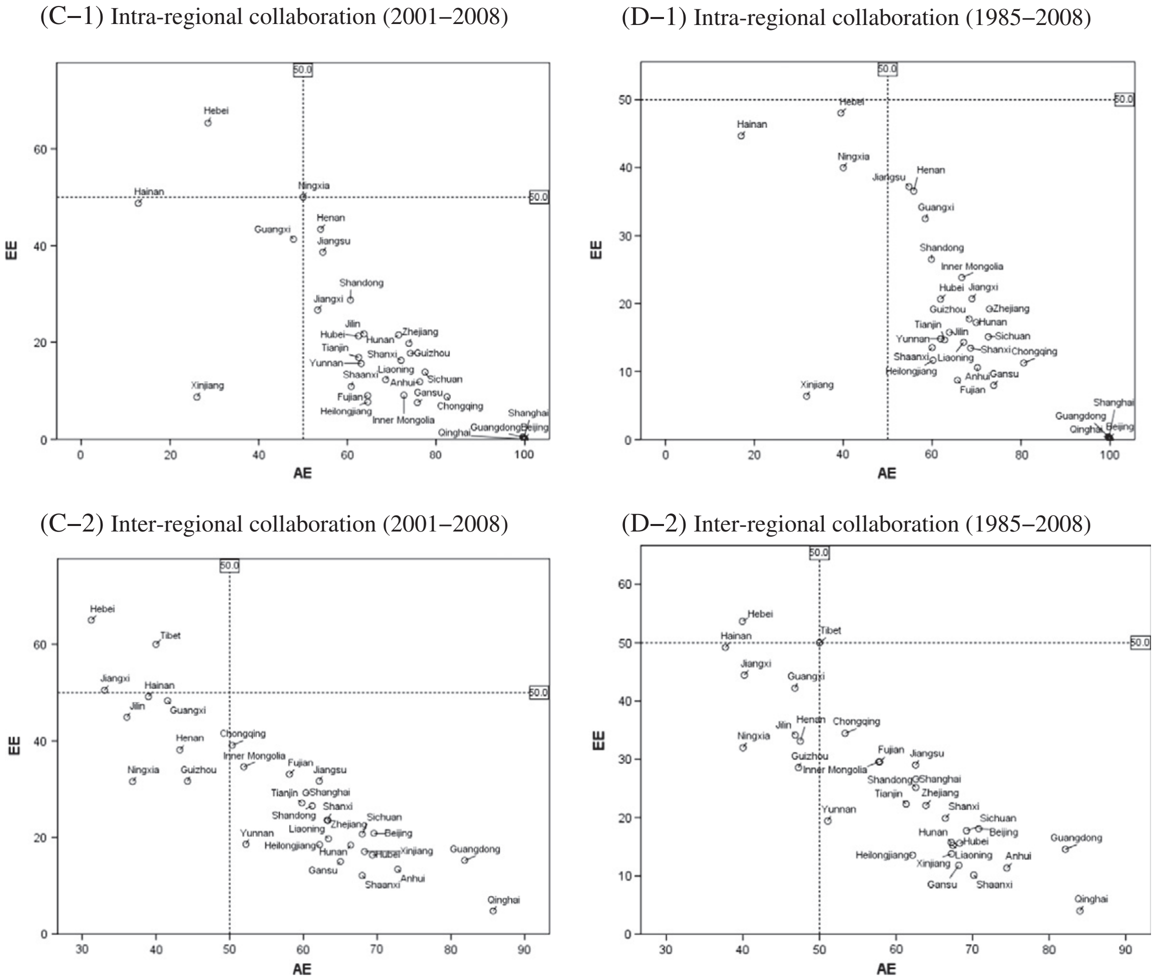

Fig. 6 (*continued*).

with each other. Jiangsu, Zhejiang and Tianjin all witnessed more AE and EE collaboration, Liaoning's increase in AE collaboration had been at the expense of EE collaboration. For inter-regional collaboration, all seven regions presented a similar trend. This may suggest that enterprises had enhanced their innovative capability or gained economic interests through collaborating with academic institutions. However, China's current academic evaluation system does not encourage collaboration between academic institutions.

7. Conclusions and implications

In recent years, scholars and policy-makers have become more interested in inter-organizational research collaboration, which is a core element of an innovation system. Most of the literature has focused on either intra-regional or inter-regional collaboration but has seldom systematically studied both intra-regional and inter-regional collaborations as well as forms of inter-organizational collaboration. In this study, we try to fill in this gap by proposing an analytical framework to study intra- and inter-regional research collaboration simultaneously and their difference in the forms of collaboration.

We have proposed to examine the evolving regional innovation patterns in the context of a region's innovative capability and collaboration intensity; regional collaboration patterns in the context of a region's intra- and inter-regional collaboration, and a region's EE and AE collaboration in the context of organizational collaboration patterns, with the results displayed visually in several two-dimensional quadrant (TDQ). We have then applied the framework to the study of characteristics of evolving research collaboration in China through analysis of invention patent applications at SIPO, China's patent office. Using domestic data to study regional research collaboration is advantageous in that the data show a more comprehensive picture of the patenting activities by domestic innovators.

First, our result shows that inter-regional collaboration is more important than intra-regional collaboration in most regions, which is in contrast to the finding from the study using the USPTO data that intra-regional and inter-national collaboration has contributed to regional collaborative patenting activities (Gao et al., 2011). Our results could enrich the existing research on China's regional research collaboration. In particular, a "collaborator" region did not always possess strong innovative capability and an "innovator" region does not always favor collaboration with others. The empirical analysis of innovative patterns shows that the correlation between innovation capability and collaboration intensity was evolving. There were strong correlation between IC and CI between 1993 and 2000 and the correlation between IC and AE collaboration was stronger than that between IC and EE collaboration at the regional level. China's major innovative regions show different patterns in terms of inter-organizational collaborative forms although all were located in the "exchanger" quadrant. These results could provide the significant evidence for policymaking to support the construction of a regional innovation system with local characteristics.

Second, collaboration within a region still is central to patenting activities in China whose most innovative regions during the period of the study preferred independent research to collaborative research and preferred intra-regional collaboration to inter-regional collaboration. Indeed, China's shifting pattern of research collaboration is the result of the market-oriented reform and public policies to encourage collaboration. Under the central planned economic system, an organization most likely followed administrative orders to collaborate with other organizations within the same "*tiao*" or administrative system which were not necessarily located within the boundary of a region. However, with the market-oriented reform, organizations have to consider the cost of collaboration among other factors. Collaboration with other organizations within a region or under different "*tiao*", or collaboration giving geographic proximity more consideration could reduce the cost caused by spatial distance, which explains why more intra-regional than inter-regional collaboration had happened recently. In the meantime, government has also introduced relevant policies to encourage collaboration, especially that between academic institutions and enterprises, to generate new technologies and achieve rapid innovation-driven economic growth.

On the face of it, evolution of China's research and innovation patterns appears to differ from what has been found in the existing studies of the Western countries, where inter-regional collaboration is on the rise although intra-regional collaboration still dominates (Bottazzi and Peri, 2003; Marzucchi et al., 2012). In fact, with the spatial agglomeration of innovation increasing, the advantage of geographic proximity for collaborative research decreased because of resource limitation and knowledge homogeneity. A high level of intra-regional collaboration may reduce opportunities for an organization to access to resources outside of its region (Knoben, 2009). With the marketization advancing and the innovative capability enhanced, it is likely that enterprises attempt to seek more heterogeneous knowledge across regional as well as institutional boundaries, and that China will see more inter-regional collaboration in the future following the Western experience.

Third, while most of the Chinese regions were "exchangers" focusing on AE collaboration, EE collaboration was increasing as well. In addition, there was more inter-regional than intra-regional EE collaboration, but more intra-regional than inter-regional AE collaboration. These results could be attributed to the balance between administrative mechanism and market-oriented mechanism. Strengthening AE collaboration or the linkage between research and economic development is the mandate of the reform of the S&T system. From the organizational perspective, research collaboration aims to seek new knowledge, share research uncertainty and gain more profit. It is obvious that local government policies are more effective for intra-regional collaboration than inter-regional collaboration (Marzucchi et al., 2012). The knowledge spillover effect of academic institutions to enterprises was more likely felt within regions, which also explains the effect of geographic proximity. On the other hand, the market-oriented reform may have promoted more inter-regional EE collaboration.

Our study has been constrained at two fronts, which could be the direction for future research. Methodologically, our analytical framework, developed from TDQ models, enables us to explore the patterns of innovation and collaboration, intra- and inter-regional collaboration, and AE and EE collaboration. However, relative to the network analysis approach (Gao et al., 2011; Fritsch and Kauffeld-Monz, 2010; Krätke, 2010; Hussler and Rond, 2007), our approach is unable to process information on complex inter-regional collaborative relations, identify regional collaborative partners and regional positions in a collaborative network, nor could it reveal the spatial dimension and structural feature, visualization of intra- and inter-regional research collaboration. Thus, we will follow up with a network analysis of intra- and inter-regional research collaboration.

China is a vast country where significant differences exist between regions. With this national context, scholars applying our approach to other countries need to consider their territory sizes, administrative divisions, and S&T institutions. For countries in the size of a Chinese province, inter-regional collaboration in the Chinese context could become their international collaboration. Certainly, we should consider the difference between regional and national boundaries. Then, administration in China consists of several levels, from province, prefecture, county to township, which could have specific but different organizational forms of research collaboration. Moreover, the Chinese state controls its public research system, although the reform of the S&T system has been trying to break such monopolistic power for some three decades. The state not only formulates public policies but also is responsible for innovation at state-own enterprises (SOEs), national R&D institutes, and universities. To a large extent, the state could change the dynamics of regional distribution of innovative organizations by constructing new public academic institutions and attracting enterprises to invest in innovation, which could further influence the patterns of regional collaboration, although it has become difficult to do so with the deepening of the market-oriented reform.

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Appendix A

Appendix Table 1
Intra- and inter-regional research collaboration in China by regions and time periods.

Region	1985–2008					1985–1992		1993–2000		2001–2008	
	Total number	Intra-regional collaboration		Inter-region collaboration		Intra-CI [%]	Inter-CI [%]	Intra-CI [%]	Inter-CI [%]	Intra-CI [%]	Inter-CI [%]
		Number	%	Number	%						
Guangdong	114,433	501	0.44	1750	1.53	2.52	1.62	0.67	1.75	0.41	1.52
Beijing	114,190	2143	1.88	3588	3.14	1.58	4.36	1.38	2.94	1.97	2.67
Shanghai	85,018	1468	1.73	1839	2.16	1.83	3.16	3.43	2.03	1.55	2.15
Jiangsu	65,725	1400	2.13	1306	1.99	2.1	1.99	1.4	1.93	2.2	1.99
Zhejiang	48,227	1011	2.1	969	2.01	2.09	3.01	1.37	1.37	2.15	2.02
Shandong	44,609	381	0.85	612	1.37	1.76	2.04	0.76	1	0.78	1.39
Liaoning	36,535	392	1.07	525	1.44	2.11	1.96	1.25	1.48	0.84	1.36
Tianjin	31,093	328	1.05	385	1.24	1.59	2.56	1.7	2.73	0.88	1.06
Hunan	23,600	186	0.79	311	1.32	3.75	1.93	0.67	0.64	0.65	1.41
Sichuan	22,199	318	1.43	490	2.21	2.42	2.01	1.63	1.24	1.27	2.47
Hubei	21,585	349	1.62	429	1.99	1.1	3.19	1.28	1.34	1.62	2
Henan	18,064	145	0.8	299	1.66	1.66	2.43	0.52	0.93	0.85	1.77
Heilongjiang	16,434	103	0.63	177	1.08	2.28	2.04	0.47	0.91	0.56	1.02
Shaanxi	15,938	185	1.16	335	2.1	2.37	2.58	0.46	0.83	1.15	2.34
Hebei	14,490	152	1.05	531	3.66	2.25	3.79	0.48	1.32	1.04	4.54
Jiangxi	12,329	29	0.24	117	0.95	2.03	1.77	0.2	0.2	0.29	2.02
Fujian	11,515	172	1.49	159	1.38	1.77	1.62	0.95	0.82	1.55	1.46
Anhui	9845	104	1.06	282	2.86	2.54	5.94	0.94	1.67	0.97	2.87
Chongqing	8509	160	1.88	180	2.12	1.02	2.56	1.35	1.55	1.96	2.16
Shanxi	8317	67	0.81	146	1.76	3.3	2.19	0.41	1.34	0.74	1.82
Yunnan	8187	223	2.72	139	1.7	0.76	2.39	2.59	0.71	2.66	1.88
Jilin	7193	108	1.5	205	2.85	2.17	2.33	0.56	1.34	0.79	1.67
Guangxi	6444	77	1.19	109	1.69	2.19	1.51	1.19	0.7	1.06	2.05
Guizhou	5939	79	1.33	91	1.53	2.82	1.81	0.95	0.38	1.39	1.78
Gansu	4971	88	1.77	110	2.21	1.4	3.55	1.2	1.3	1.89	2.29
Inner Mongolia	4154	21	0.51	71	1.71	2.54	1.53	0.53	1.14	0.42	1.98
Xinjiang	3243	63	1.94	58	1.79	3.49	2.04	1.29	1.41	2.14	1.91
Hainan	1824	47	2.58	61	3.34	0	0	1.31	0.52	3.67	5.55
Ningxia	1289	5	0.39	25	1.94	2.45	4.4	0	0.56	0.24	2.26
Qinghai	908	7	0.77	25	2.75	3.67	0.76	0	1.31	1.1	3.84
Tibet	158	1	0.63	6	3.8	2.27	0	0	2.86	0.8	4.35

Source: Same as Table 1.

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