Structural Characteristics and Spatial Patterns of the Technology Transfer Network in the Guangdong–Hong Kong–Macao Greater Bay Area

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Abstract: Recently, the Chinese government released the Outline of the Development Plan for the Guangdong–Hong Kong–Macao Greater Bay Area (GBA), raising the development of the GBA urban agglomeration to a national strategy. An efficient technology transfer network is conducive to promoting the integrated and coordinated development and enhancing the scientific and technological innovation capabilities of the GBA urban agglomeration. Therefore, this study uses the patent transaction data for three years (2010, 2014, and 2018), integrates data mining, and uses complex network analysis, based on full-flow and net-flow networks, from the overall characteristics, network node strength, network association, network node importance, and network communities to reveal the structural characteristics and spatial patterns of the technology transfer network in the GBA. The results revealed that: (1) Technology transfer networks (full-flow and net-flow) in the GBA show heterogeneity. (2) Full-flow network presents a clear hierarchy within the GBA, showing a “two poles and two strong” pattern, and technology transfer has the same city preference; outside the GBA, there are close technology transfer regions that have technical and geographical proximity characteristics; the net-flow network presents a “one pole, two strong” pattern, and Guangzhou has become the core region of the net-flow network. (3) Connection objects of the technology transfer network have path dependence and spatial preference. Coexistence of concentration and decentralization characterizes the spatial flow. (4) Spatial distribution of the hub and authority of the technology transfer network is heterogeneous and hierarchical. Each city in the GBA has its own technological advantages. (5) Spatial clustering characteristics of the community within the technology transfer network are obvious. (6) The GBA is dominated by the transfer of patented technology in the high-tech industry, while the transfer of patented technology in the traditional manufacturing industry also plays an important role.

Keywords: Guangdong–Hong Kong–Macao Greater Bay Area (GBA); technology transfer network; structural characteristics; spatial pattern; complex network analysis

1. Introduction

The new economic growth theory suggests that technological progress has become an important driving force of modern economic growth [1]. Regional technological progress mainly depends on independent innovation and technology introduction [2]. Owing to the uneven distribution of scientific and technological resources in different regions, cross-regional technology transfer has become an important way to achieve the flow and sharing of innovative resources; this also promotes regional technological progress and economic growth [3,4]. The role of international technology transfer in
driving national economic growth has become increasingly stronger [5]. Existing research also shows that international technology transfer is an important way to achieve economic growth in developing countries [6–10]. Technology transfer provides an area with the opportunity to exchange knowledge from different regions. Therefore, as a strategy to enhance competitiveness at both the firm level and the industry level, technology transfer has been gaining increasing recognition not just in the developed world, but in many developing economies as well [11]. Therefore, the number of technology transactions between different economies has increased significantly over the past few decades. For instance, the amount of technology imported from the outside of the “Belt and Road” countries (regions) increased from US $54,548.48 million in 2001–2005 to US $13,782.7048 million in 2011–2015 [12].

After going through the two stages of globalization of manufacturing and globalization of services, the world has entered the stage of innovative globalization. The prominent feature of innovation globalization is that various innovation resources centered on technology are rapidly flowing around the world. In the process of innovative globalization, the role of cities as geography and society has not disappeared but has increasingly become the center of modern life. It is also the technology transfer brought about by globalization that has stimulated the status of urban areas as the base of all production activities. Just as Sassen [13–15] puts forward new regionalist ideas such as “global cities”, he believes that global cities are a network-space concept. The formed node is the network, and cities with dominant and dominant capabilities will be the country’s competitiveness in the future. Therefore, in the context of globalization, innovative “flow spaces” with technology flow as the main form of expression have formed between cities, and the interaction of “flow spaces” has formed urban networks.

With the rapid development of transportation and modern communication technology, especially that represented by high-speed rail, air transportation, and 5G technology, the “distance” between cities is continuously decreasing, and communication and interaction between cities have become rapid. Cities have increasingly higher connectivity, which is mainly manifested in the connections among capital, material, knowledge, and technology. With the acceleration of knowledge and technology flow in urban agglomerations, the spatial evolution of technological innovation is becoming increasingly complex, and large spatial systems with complex networks are gradually forming. Relying on a developed intercity transportation network and close economic links, urban agglomerations have become the economic core of the region [16]. At present, innovation has become a new driving engine of urban economic development. Major global urban agglomerations are becoming science and technology innovation centers leading global development [17]. Urban agglomerations gather more innovation elements, and their open innovation development level is higher [18]. Therefore, the city-led spatial patterns of technology transfer are gradually taking shape, and cities are playing the role of knowledge “incubators” and “hubs” [19]. Urban agglomerations act as incubators for knowledge production within the national urban system, as well as hubs for technological flows that connect national and international urban systems [20–22]. A study on the Beijing–Tianjin–Hebei urban agglomeration shows that technology transfer can effectively reduce regional disparities and promote the overall development of urban agglomerations [23].

Practice has shown that planning to build a global science and technology innovation center to gather and deploy international innovation elements to the greatest extent to enhance its own strength has become an important measure for many countries and regions to cope with the latest round of the science and technology revolution. In 2019, the Chinese government issued the “Outline of Development Planning for the Guangdong–Hong Kong–Macao Greater Bay Area (GBA),” which raised the development of the GBA urban agglomeration to a national strategy. One of its strategic positions is the International Science and Technology Innovation Center with Global Impact. Unlike other world-class urban agglomerations, the most typical feature of the GBA is heterogeneity, which is not only reflected in its economy and the size of the population [24], but also in its “one country, two systems, three tariff zones” unique management structure [25]. Therefore, the GBA is essential to promote the integrated and coordinated development of heterogeneous urban agglomerations and to promote the spatial reconfiguration of resource elements, especially innovation elements. Technology transfer is an important part of technological innovation and an important part of the national innovation system. It can break through the geographical boundaries
of technology, realize the cross-regional flow of innovation elements, and promote the benefits of technological spillovers to other regions. Therefore, technology transfer has become an important means of promoting the rational allocation of factors of innovation in the internal spatial structure of the GBA urban agglomeration and promoting their integrated and coordinated development. Thus, a highly efficient technology transfer network plays an important role in promoting the coordinated development of the integration of the GBA urban agglomeration to enhance its scientific and technological innovation.

This article uses the crawler method to obtain data on China’s patent transactions for three years (2010, 2014, and 2018). Based on the “intra” and “extra” dimensions of the urban agglomerations in the GBA, a technology transfer network for the GBA was constructed, and a complex network analysis method was used to systematically inspect structural characteristics and spatial distribution of the technology transfer network in the GBA. This will further clarify the technology transfer path of the GBA and can provide an effective way to optimize the allocation of technological resources in the GBA. A reference for the construction of a multicenter development pattern and collaborative innovation strategy in the GBA can be revived.

This paper is organized as follows. Section 2 provides an overview of the related literature. Section 3 introduces the methodology of this study as well as data source and processing. Section 4 discusses our empirical results and presents our discussion. Finally, Section 5 provides conclusions and policy implications.

2. Literature Review

With the increasing frequency of technology transfer, regional and global technology transfer networks are emerging, and this network construction capability has a significant positive impact on technology transfer between subjects [26].

Existing research has carried out extensive exploratory research on technology transfer networks, mainly focusing on the industry–university–research technology transfer networks of universities, enterprises, and scientific research institutions at the provincial or national level. Ni et al. [27] focused on geographic patterns of pharmaceutical technology transfer captured by patent licensing in China. They found a geographic network of pharmaceutical technology diffusion in China could be visualized, and province-level regions were ranked and classified into three types—input, output, and balance—by various network indicators. Araújo and Teixeira [28] explored the key factors that foster technology transfer within the triad university–industry–government in an international context. Based on technology transfer data of 30 provinces in China since 2000, Wang et al. [29] used a block model to explore the relationship between technology transfer within and between blocks. Coccia [30] analyzed the mobility of technology transfer in geo-economic space and pointed out that the intensity of technology transfer decreased with increasing geographic distance. Based on provincial patent data, Zhang et al. [31] constructed a weighted exponential random graph model to explore the determinants of technology transfer between provinces in China. Based on the Chinese universities patent from 2007 to 2016, Tang and Song [32] constructed a university technology transfer network and used social network analysis and GIS to analyze the network structure and evolution law. Nordensvard et al. [33] used citation network analysis and patent analysis to analyze knowledge flows between wind firms and to identify and compare the position and role of each firm in the knowledge network. Lyu et al. [34] constructed the Zhongguancun enterprise network in Beijing and used social network analysis methods and spatial analysis methods to reveal the spatiotemporal evolution of Zhongguancun enterprise cooperation networks. Ye et al. [35] built knowledge transfer network of China University by collecting data of 42 patent dual-class university, and the results show that the network transition from single to multi-center network center. Dias et al. [36] used data from the Brazilian and Spanish agricultural sectors to build 25 networks, and the results showed that there are complementary resources among the innovation networks to improve innovation performance.

In recent years, the city became the main place of knowledge innovation and technology diffusion, and the innovation network space with the city as the hub has risen. The organization of innovation city system has been accelerated from the core edge type to the hub network type. Intercity knowledge
and technology flows have become a new trend in urban network system research and a key topic in innovative geography research. Taking the city as the research subject has attracted the attention of many scholars, and then explored the temporal and spatial characteristics of the inter-city technology transfer network and its evolution law. Seo and Sonn [37] employed social network metrics to analyze inter-regional technology diffusion networks using Chinese patent licensing data from 1998 to 2013. Their results show that the influence of the traditional anchor region persists in the hierarchical network structure as new cities enter the network, and there are five anchor regions: The three usual suspects—Beijing, Shanghai, and Shenzhen—plus two that were slightly less expected—Dongguan and Suzhou. Li and Phelps [19] used the data of publications and joint publications to analyze the knowledge centrality of the Yangtze River Delta in China. Ying et al. [38] used the social network analysis method to construct the innovation network of the Yangtze River Delta urban agglomeration based on the inter-city patent transfer data, reveal the flow of patent elements between the cities in the Yangtze River Delta urban agglomeration and their changes, and characterize the evolutionary trend and structural characteristics of the innovation network of the Yangtze River Delta. Gui et al. [39] used the technology transfer data from 2008 to 2015 to build an inter-city technology transfer network in China. The results showed that inter-city transfer of technology was increasingly higher frequency, and the network presented a core radiation pattern. Seo [40] used China’s technology transfer stream network to reveal brokering models in three major regions: Beijing, Shanghai, and Shenzhen. They found that Beijing and Shenzhen tend to transfer technology as a national hub in the national innovation system, rather than as a local hub in large cities. Shanghai seems to be both a local decentralized agency and a national hub, a more balanced broker area. Duan et al. [41] discussed the structural spatial characteristics of the technology transfer network in the Yangtze River Delta from three aspects of the overall, technology supply chain, and technology sales chain, and used the block model to explore the community characteristics of China’s intercity technology transfer network. Based on the patent transfer data of the State Intellectual Property Office from 2000 to 2015, Zhang et al. [42] constructed China’s inter-city technology transfer network, and the results showed that there was a certain geographical differentiation in China’s inter-city technology transfer. Based on the patent transaction data of China’s three major urban agglomerations from 2008 to 2015, Liu et al. [43] analyzed the spatial structure and the temporal evolution of the three major urban agglomeration intercity network technology.

Different from the previous studies (Table 1 lists these studies), this article mainly expands on the following aspects: First, existing studies have comparatively analyzed the structure of technology transfer networks in China’s three major urban agglomerations (Beijing–Tianjin–Hebei, the Yangtze River Delta, and the Pearl River Delta), but few studies analyze the technology transfer network of the GBA. As the GBA rises to become China’s national strategy, the International Science and Technology Innovation Center with global influence is one of its strategic goals. Based on this goal, the urban agglomeration of the GBA, with the unique political system characteristics of “one country, two systems,” is selected as the research object. The technology transfer network is constructed to deeply delve into its spatial structure properties. Second, the technology transfer network is a directed weighted network with self-loops. The existing research mainly explores the ordering of the node importance based on the degree centrality or the betweenness centrality, and since those indexes do not consider the influence of the directionality of the edges on the node importance, they do not fully reflect the importance ranking of the directed graph nodes. Hyperlink-Induced Topic Search (HITS; also known as hubs and authorities) has been used to rank the importance of nodes on the direct graph, which can give us a general estimate of its prominence on the graph. This article will reveal the importance and structural characteristics of the nodes of the GBA technology transfer network from HITS. Third, in analyzing the specific flow of technology transfer, most studies measure it by calculating the net flow of the city. This approach does not fully reflect the network structure characteristics of the net flow of technology transfer. This article’s approach is based on the calculated intercity technology transfer net flow to build a technology transfer net-flow network in the GBA, and it will dig deep into the node characteristics and structural characteristics of the technology transfer net-flow network.
Table 1. Overview of relevant studies.

| Author(s)             | Geographical Scope                  | Study Period       | Methodology                                      | Theme Studied                                                                 |
|-----------------------|-------------------------------------|--------------------|--------------------------------------------------|-------------------------------------------------------------------------------|
| Ni et al. (2014)      | China                               | 2009–2012          | Complex network                                 | Cross-regional pharmaceutical technology transfer                           |
| Araújo and Teixeira (2014) | Europe                           | 2009–2012          | Econometrics                                     | Determinants of international technology transfer                           |
| Wang et al. (2015)    | China                               | 2000–2012          | Complex network                                 | Provincal technology exchange patterns                                      |
| Coccia (2015)         | Northwest of Italy                 | 1997–1999, 2004, 2005, 2008 | Ordinary Least Squares                           | Spatial patterns of technology transfer                                      |
| Zhang et al. (2016)   | China                               | 2002, 2006, 2010   | Complex network and Econometrics                 | Determinants of inter-regional technology transfer                          |
| Tang and Song (2017)  | China                               | 2007–2016          | Complex network analysis and GIB spatial analysis | Network structure and evolution of spatial distribution                     |
| Nordensvard et al. (2018) | North American, European, Indian and China | 2000–2015      | Complex network analysis                         | Wind energy technology transfer                                             |
| Lyu et al. (2019)     | China                               | 1995, 1999, 2003, 2007, 2011, and 2014 | Complex network analysis                        | Spatial evolution of innovation network                                      |
| Ye et al. (2019)      | China                               | 2014               | Complex network analysis                         | Network dynamics                                                             |
| Dias et al. (2019)    | Brazil, Spain                       | 2010–2015          | Qualitative comparative analysis and content analysis | R&D network for innovation performance                                      |
| Seo and Sonn (2018)   | China                               | 1998–2013          | Complex network analysis                         | Regional hierarchy in technology transfer networks                          |
| Li and Phelps (2018)  | The Yangtze River Delta, China      | 2004–2014          | Complex network analysis                         | Structure characteristics of knowledge collaboration networks               |
| Ying et al. (2019)    | The Yangtze River Delta, China      | 2004–2018          | Complex network analysis and Spatial Econometrics | Structure characteristics and influential mechanism of technology transfer network |
| Gui et al. (2019)     | China                               | 2008–2015          | Complex network analysis                         | Structure characteristics of technology transfer network                    |
| Seo (2019)            | China                               | 2009–2010          | Complex network analysis and Econometrics        | Structure characteristics and influential mechanism of technology transfer networks |
| Duan et al. (2019)    | The Yangtze River Delta, China      | 2001–2015          | Complex network analysis                         | Regional integration in the technology transfer                            |
| Zhang et al. (2019)   | China                               | 2000–2015          | Complex network analysis and Econometrics        | Spatial characteristics and proximity mechanism of technology transfer       |
| Liu et al. (2019)     | China’s three urban agglomerations  | 2008, 2012, 2015   | Complex network analysis                         | Spatial dynamics of technology transfer networks                            |
3. Data and Methods

3.1. Regional

This article selected the GBA as the research object, and its scope included Guangzhou, Shenzhen, Foshan, Dongguan, Huizhou, Zhaoqing, Zhuhai, Zhongshan, Guangdong, Jiangmen’s nine prefecture-level cities (namely, the Pearl River Delta urban agglomeration), and Hong Kong and Macao special administrative regions (a total of 11 cities). The total area of the GBA is 56,094 square kilometers. In 2018, the resident population reached 71.1598 million and the total GDP was 10,867.994 billion RMB, accounting for about 11.53% of the total national economy. At present, the GBA already has three super-large cities of Hong Kong, Shenzhen, and Guangzhou, and the population of Dongguan and Foshan exceeds 5 million. Huizhou, Zhongshan, Zhuhai, Zhaoqing, Jiangmen, and Macau are all medium-sized with outstanding economic strength. Table 2 is the basic situation of the cities in the GBA.

| City         | Area (sq. Km) | Population (10 Thousand Persons) | GDP (100 Million RMB) | GDP Per Capita (10,000 RMB) | Proportion of the Three Industries |
|--------------|---------------|----------------------------------|-----------------------|-----------------------------|----------------------------------|
| Guangzhou    | 7434          | 1490.44                          | 22,859.35             | 15.34                       | 1.0:27:3:71.7                    |
| Shenzhen     | 1997          | 1302.66                          | 24,221.98             | 18.60                       | 0.1:41:1:58.8                    |
| Zhuhai       | 1736          | 189.11                            | 2914.74               | 15.41                       | 1.7:49:2:49.1                    |
| Foushan      | 3798          | 790.57                            | 9935.88               | 12.57                       | 1.5:56:5:42.0                    |
| Zhongshan    | 1784          | 331.00                            | 3632.7                | 10.97                       | 1.7:49:0:49.3                    |
| Dongguan     | 2460          | 839.22                            | 8278.59               | 9.86                        | 0.3:48:6:51.1                    |
| Huizhou      | 11,347        | 483.00                            | 4103.05               | 8.49                        | 4.3:52:7:43.0                    |
| Jiangmen     | 9507          | 459.82                            | 2900.41               | 6.31                        | 7.0:48:5:44.5                    |
| Zhaoqing     | 14,891        | 415.17                            | 2201.8                | 5.30                        | 15.8:35:2:49.0                   |
| Hong Kong    | 1107          | 748.25                            | 24,022.44             | 32.10                       | ——                               |
| Macao        | 35            | 66.74                             | 3609.00               | 54.08                       | ——                               |

Due to historical reasons, the GBA urban agglomeration has formed the unique management structure of “one country, two systems, three tariff zones.” The GBA, as an industrial and population agglomeration area on the scale of a city group, is one of China’s most open and economically active regions, and also “one of the most dynamic economic regions in the world”. On February 18, 2019, the “Guangdong–Hong Kong–Macao Greater Bay Area Development Planning Outline” was officially released, marking that the GBA, as China’s important national strategy, has officially entered the implementation stage.

3.2. Data Source and Processing

In order to characterize the technology transfer relationship in the GBA, this article not only discusses the technology transfer within the GBA, but also considers the technology transfer between the GBA and other regions. Technology transfer is the process of transferring technology (or knowledge of such) to organizations/industries to enhance their development. Moreover, it also involves the dynamic diffusion in geographical space and is a conscious knowledge spillover [44]. Due to the immeasurability of tacit knowledge, technology transfer is often determined in terms of patent transfer [45,46], technical talent flow [47,48], R&D cooperation [49,50], international merchandise trade and foreign investment [5,51], and other alternative variables. Because the patent right transfer is based on market supply and demand and has a specific flow direction, it can effectively identify the spatial relationship between supply and demand for technological innovation. Thus, it has become a common indicator for measuring technological innovation transfer [52,53]. A patent is an important and explicit indicator to measure technical knowledge [54]. Patent right transfer, as a kind of legal right transfer, is a
transaction record formed based on the transaction relationship between the assignor and the transferee. Therefore, technology transfer from the perspective of patents has been extensively discussed.

Based on the above, this article intended to use patent right transfer to measure technology transfer from 2010 to 2018. The data source was from the “patent information service platform” provided by the State Intellectual Property Office of China. The extraction process was as follows: (1) Use the python crawler tool to build the Selenium crawler framework and download the 2010, 2014, and 2018 patent right transfer data from the “patent information service platform.” The data content includes the patent application number, application date, IPC classification number, effective date of registration, right holder before change, change post-right holder, pre-change address, post-change address, and other information. (2) Extract the patent right transfer data related to the GBA; that is, extract the data of the source–sink (origin and destination) of the patent right transfer data that contains the GBA. (3) In order to better characterize the technology transfer relationship in the GBA, the technology transfer territories of Guangdong Province, Hong Kong, and Macau are divided into specific cities, and other regions of Chinese mainland outside Guangdong Province are divided into patent territories by province (patent source–sink territories). Then, the postal code of China corresponds to the corresponding area, and a database of technology transfer in the GBA is constructed. (4) Deduplicate and denoise data from the database of technology transfer in the GBA using Python’s data analysis function again.

3.3. Research Methods

3.3.1. Network Model Construction

The complex network theory states that when the constituent units are abstracted into nodes and the interactions between the units are abstracted as edges, they can be studied as complex networks. This article intends to abstract the source–sink area of technology transfer as a node and abstract the technology transfer relationship between the source–sink area as an edge. The number of transfers is used as the weight of the edges to build a directed weighted network for technology transfer in the GBA. To explore the structural characteristics and spatial patterns of the technology transfer network in the GBA there are two types of nodes; one is the internal cities of the GBA and the other prefecture-level cities in Guangdong Province, termed as collection $d(\mathbf{d}_1, \mathbf{d}_2, \ldots, \mathbf{d}_n)$. The collection has a total of 23 nodes. Another provincial-level administrative region other than Guangdong, Hong Kong, and Macao is termed as collection $\mathbf{e}(\mathbf{e}_1, \mathbf{e}_2, \ldots, \mathbf{e}_n)$; there are 31 nodes in this collection. Although the types of nodes are distinguished, the technology transfer of GBA does not exist in collection $\mathbf{d}$ only. It also exists between collections $\mathbf{d}$ and $\mathbf{e}$. Because the technology transfer network is a directed graph network, there is a two-way technology transfer relationship between nodes. Therefore, there may be differences in the amount of bidirectional transfer between nodes. In this study, the difference between the two-way transfers between nodes is taken, and the absolute value of the difference is used to form the net flow between the nodes. The direction of the numerical large edge indicates the direction of net flow. Based on the above, this article intends to construct a directed weighted network for technology transfer in the GBA based on a full-flow network and a net-flow network. In full-flow network transfer, there are two-way connected edges between the network nodes. The weight of the two-way connected edges of the network is the actual amount of technology transfer between nodes, as shown in Figure 1a. Simultaneously, the source–sink self-transfer relationship, that is, the self-loop of the network node, is considered. In the net-flow transfer, there are only one-way connected edges between nodes, and the weight of the connected edges is the net flow. There is no self-looped edge in the net-flow network, as shown in Figure 1b. Based on above, six adjacent matrices are generated for the full-flow and net-flow of GBA in 2010, 2014, and 2018, respectively.
3.3.2. Social Network Analysis

It is generally accepted that strength is an important index of directed weighted graph. The strength of node i in a directed weighted graph is defined as the sum of the edge weights directly connected to the node i. For a directed graph, edges have two different attributes, that is, the edge entering the node and the edge starting from the node. Thus, there are also two different properties for strength, namely, in-strength and out-strength. Also, the strength is equal to the sum of the in-strength and the out-strength. The in-strength is defined as the sum of the weights of the edges of the neighbor node pointing to the node i, and the out-strength is defined as the sum of the weights of the edges of the node i pointing to the neighbor node.

In a directed graph, when considering the node importance, a simple method is to convert the directed graph into an undirected graph and directly measure the node importance of the directed graph with the node importance index of the undirected graph. In other words, the node importance in a directed graph with undirected graph indicators such as degree centrality, intermediate centrality, and near centrality needs to be characterized [55]. However, the node importance index of an undirected graph does not consider the direction of the edges, that has an important effect on the importance of the nodes in the directed network. A typical example of the importance of describing the nodes of a directed network is the working principle of the search engine of the WWW network. Two classic algorithms in the field of search engines are the HITS algorithm proposed by Kleinberg of Cornell University [56] and the PageRank algorithm proposed by Google founders Page and Brin [57]. The core idea of the HITS algorithm is to use two indicators to characterize the importance of the same node in the network from different angles—authoritative value and hub value. The HITS algorithm divides web pages into two major categories: Authority and hub. Authoritative web pages are defined as important web pages that are generally recognized for a particular subject, while hub web pages are defined as web pages that point to multiple authoritative web pages related to a particular subject. Authoritative and hub webpages have mutually strengthened dependencies. A webpage with a high authority value should be pointed to by many webpages with a high hub value, and a webpage with a high hub value should point to many webpages with a high authority value [55]. From the weight propagation model, the importance
of the web page is transmitted through the hub page to the authority page in HITS. Moreover, hub and authority are mutually reinforcing relationship. PageRank is based on a random surfer model, which can be thought of as passing the importance of a web page from one authority page to another authority page. The HITS algorithm needs to calculate two scores for each page, while PageRank only needs to calculate one score, that is, authority. Therefore, this paper used the HITS algorithm with two scores to characterize the importance of nodes in the network, in order to more clearly show the different attribute characteristics of the nodes in technology transfer network of GBA.

3.3.3. Community Mining Algorithm

The community structure is a reflection of the nature of the mesoscale network. The study of the community structure in the network is an important way to understand the structure and function of the entire network. During the technology transfer of the GBA, due to frequent technical exchanges between cities or regions, it is easy to form multiple collections with close internal relations, and the community structure can well reflect the innovation collective of the city or region. Community mining has been widely used in different research fields [58,59]. The splitting algorithm proposed by Girvan and Newman—the GN algorithm—has become a classic algorithm for exploring the structure of network communities. The modularity function is used to measure the quality of the results of the GN algorithm [58]. It can characterize the closeness of the discovered communities. The Louvain algorithm [60] is based on multilevel optimization modularity [61]. Lancichinetti [62] considers it one of the best community discovery algorithms. This study used the Louvain algorithm to quantitatively describe the modularization level of community division. Modularity is calculated as follows:

$$Q = \frac{1}{2m} \sum_{ij} \left[ A_{i,j} - \frac{k_i k_j}{2m} \right] \delta(C_i, C_j)$$

where $m$ is the total number of edges in the graph, $k_i$ is the sum of the weights of all connected edges pointing to node $i$, and $k_j$ is the same. $A_{i,j}$ represents the edge weight between nodes $i$ and $j$.

4. Results

4.1. Analysis of Overall Network Characteristics

The technology transfer network constructed by the GBA of China included a full-flow network and a net-flow network in 2010, 2014, and 2018. Their basic characteristics are shown in Table 3. In 2018, the node count in these networks were both 54, indicating that there is a technology transfer relationship between the cities in the GBA and all provincial administrative areas outside the area. The edge count of the full-flow and the net-flow networks was 917 and 539, respectively. The edge count of the full-flow network was less than twice that of the net-flow network, which indicates that there is only a one-way connection between some nodes in the former, but there is a two-way transfer relationship between most nodes. From the perspective of network density, both full-flow and net-flow networks were sparse networks. The node count was generally stable in 2010, 2014, and 2018. Furthermore, the edge count and density were observed to increase during the study period. Based on the assortativity coefficient listed in Table 3, the assortativity coefficient of both the types of networks were negative during the study period, indicating that both exhibit heterogeneity. The heterogeneity shown by the technology transfer network indicates that cities or provinces with weak technological innovation capabilities want to cooperate with those with strong technological innovation capabilities to improve themselves in this regard. Furthermore, cities with strong technological innovation capabilities are also full of expectations for achieving their own technology upgrades and strengthening their own technology spillovers; thus, forming a negative correlation of the node degrees, that is, heterogeneity, so as to realize the step transfer of technology.
4.2. Network Node Strength Analysis

Because the node strength can fully reflect the technology transfer capability of the node, it is necessary to analyze the node strength. Tables 4 and 5 show the strength of some nodes in the full-flow network and the net-flow network. In 2018, the strength of Shenzhen reached 25,528 and Guangzhou reached 20,073, becoming the dual cores of the full-flow technology transfer network in the GBA. The strengths of Dongguan and Foshan were 9922 and 9898, respectively, and the difference between the two was only 24, which indicates that Dongguan and Foshan have comparable technology transfer capabilities to become sub-central nodes. Zhongshan and Jiangmen were only one-half the strength of Dongguan and Foshan and were in the third level. The strength of Zhuhai and Huizhou fluctuated on the order of 3000, while the strength of Hong Kong and Zhaoqing was not great, and Macau is on the marginal. The strengths of Zhejiang and Jiangsu reached 5892 and 4270, respectively, and the amount of technology transfer in Zhejiang was more than the sum of the strength of the third and fourth, Beijing and Fujian. This shows that in the process of the technological exchanges with the GBA, a small number of provinces and GBA urban agglomerations have close technological exchanges and cooperation. At the same time, Zhejiang, Jiangsu, Beijing, Anhui, and Shanghai were in the top 11 rankings. They occupied five seats, and they belong to the Beijing–Tianjin–Hebei and Yangtze River Delta regions of China. The three major urban agglomerations of Beijing–Tianjin–Hebei, the Yangtze River Delta, and the GBA are the most dynamic and innovative regions in China with technological proximity [43]. Fujian, Guangxi, Jiangxi, and Hunan are all at the forefront of technical exchanges with the GBA, and these four regions border Guangdong province, showing geographical proximity. From the perspective of the net-flow network, the central position of Guangzhou was even more prominent as shown in Table 5. In 2018, its strength was nearly twice that of Shenzhen. The position of Foshan increased, while the strength of Dongguan decreased. The strength of Huizhou, Zhuhai, Jiangmen, Hong Kong, and Zhaoqing was not much different, and the net radiation capacity of the technology was comparable. From the provincial regions outside the GBA, the strength of Zhejiang reached 3204, ranking first in the country. In general, the strength inside and outside the GBA experienced an upward trend from 2010 to 2018, and most nodes increased more than 10 times. Guangzhou, the third place in 2010, became a new pole in 2018, far surpassing Dongguan and Foshan. Moreover, the status of Shanghai and Beijing was reduced, while that of Jiangsu and Zhejiang was strengthened. Notably, Xinjiang, as a frontier region, ranked ninth in the provincial regions outside the GBA in 2014, indicating that Xinjiang actively strengthens its technical ties with the GBA; and it did not enter the top 11 in 2018. It remains challenging to develop technology innovation in western frontier provinces. Additionally, technological proximity and geographical proximity are sustainably developed.

The in-strength and out-strength of a node can be used to analyze the technology transfer ability of the node from two different perspectives. The node strength is equal to the sum of its in-strength and out-strength. It is necessary to explore the relationship between them. Figures 2 and 3 show the relationship between node in-strength, out-strength, and strength. From the perspective of the full-flow network as shown in Figure 2, there was no significant difference between the out-strength and the in-strength of the GBA during the study period. In 2018, the out-strengths of Hong Kong, Zhaoqing, Huizhou, and Dongguan were greater than their in-strengths, and the out-strengths of other cities in the GBA were less than their in-strengths. For Hong Kong, in the technical exchanges with the Chinese mainland, whose out-strength was 415 and in-strength is 285, the out-strength was 1.45 times the in-strength in 2018. This indicates that Hong Kong’s technology output capacity is far greater than its technology absorption capacity. The reason is that Hong Kong, as an international financial and trade center, does not have a strong demand for technological innovation, but it is responsible for the re-export of global capital and technology to Chinese mainland. For provincial regions outside the GBA, only Jiangsu’s in-strength and out-strength were comparable in 2018. The out-strengths of other provinces were much greater than their in-strengths, especially Zhejiang’s, whose out-strength was 4194 and in-strength was 1699; the out-strength was 2.47 times the in-strength. More interestingly, Shanghai and Beijing experience the role change from technology exporter to technology importer and then to technology exporter during the study period. Jiangsu plays the role of technology beneficiary. Zhejiang maintains a continuous technological export to the GBA.
### Table 3. Overall characteristics of the GBA technology transfer network in 2010, 2014, and 2018.

|                | 2010          | 2014          | 2018          |
|----------------|---------------|---------------|---------------|
|                | Statistical Characteristics | Full-Flow Network | Net-Flow Network | Statistical Characteristics | Full-Flow Network | Net-Flow Network | Statistical Characteristics | Full-Flow Network | Net-Flow Network | Statistical Characteristics | Full-Flow Network | Net-Flow Network |
| Node count     | 51            | 51            | 1.02          | 54            | 54            | 1.00          | 54            | 54            | 1.00          |
| Edge count     | 253           | 167           | 1.51          | 506           | 314           | 1.61          | 917           | 539           | 1.70          |
| Assortativity coefficient | −0.36         | −0.35         | /             | −0.40         | −0.40         | /             | −0.37         | −0.24         | /             |
| Network density | 0.09          | 0.07          | 1.43          | 0.17          | 0.11          | 1.55          | 0.35          | 0.19          | 1.84          |

### Table 4. Strength of the GBA technology transfer full-flow network.

| Cities in the GBA | Strength in 2010 | Provincial Regions outside the GBA (Top 11) | Strength | Cities in the GBA | Strength in 2014 | Provincial Regions outside the GBA (Top 11) | Strength | Cities in the GBA | Strength in 2018 | Provincial Regions outside the GBA (Top 11) | Strength |
|-------------------|-----------------|---------------------------------------------|----------|-------------------|-----------------|---------------------------------------------|----------|-------------------|-----------------|---------------------------------------------|----------|
| Shenzhen          | 2731            | Beijing                                     | 188      | Shenzhen          | 10402           | Jiangsu                                     | 1391     | Shenzhen          | 25528           | Zhejiang                                   | 5892     |
| Dongguan          | 1442            | Shanghai                                    | 181      | Foshan            | 3305            | Beijing                                     | 777      | Guangzhou         | 20073           | Jiangsu                                   | 4270     |
| Guangzhou         | 1208            | Jiangsu                                     | 102      | Guangzhou         | 2778            | Shanghai                                     | 763      | Dongguan          | 9922            | Beijing                                   | 2546     |
| Foshan            | 739             | Zhejiang                                    | 99       | Dongguan          | 2768            | Zhejiang                                     | 394      | Foshan            | 9898            | Fujian                                    | 2219     |
| Zhongshan         | 721             | Tianjin                                     | 51       | Zhongshan         | 1242            | Hubei                                       | 270      | Zhongshan         | 4842            | Guangxi                                   | 1541     |
| Zhuhai            | 291             | Taiwan                                      | 50       | Huizhou           | 750             | Hunan                                       | 227      | Jiangmen          | 4284            | Anhui                                     | 1509     |
| Huizhou           | 184             | Jiangxi                                     | 40       | Zhuhai            | 706             | Shandong                                     | 210      | Zhuhai            | 3156            | Shanghai                                   | 1096     |
| Jiangmen          | 88              | Hubei                                       | 47       | Jiangmen          | 440             | Fujian                                       | 199      | Huizhou           | 2560            | Sichuan                                   | 1067     |
| Hong Kong         | 70              | Shanxi                                      | 47       | Hong Kong         | 411             | Sichuan                                     | 181      | Zhaoqing          | 653             | Jiangxi                                   | 1023     |
| Zhaoqing          | 37              | Shandong                                    | 26       | Zhaoqing          | 136             | Jiangxi                                     | 139      | Hong Kong         | 700             | Hunan                                     | 1012     |
| Macao             | 1               | Sichuan                                    | 25       | Macao             | 38              | Tianjin                                     | 114      | Macao             | 3              | Shandong                                   | 994      |

### Table 5. Strength of the GBA technology transfer net-flow network.

| Cities in the GBA | Strength in 2010 | Provincial Regions outside the GBA (Top 11) | Strength | Cities in the GBA | Strength in 2014 | Provincial Regions outside the GBA (Top 11) | Strength | Cities in the GBA | Strength in 2018 | Provincial Regions outside the GBA (Top 11) | Strength |
|-------------------|-----------------|---------------------------------------------|----------|-------------------|-----------------|---------------------------------------------|----------|-------------------|-----------------|---------------------------------------------|----------|
| Shenzhen          | 294             | Shanghai                                    | 139      | Shenzhen          | 1754            | Jiangsu                                     | 615      | Guangzhou         | 4538            | Zhejiang                                   | 3204     |
| Foshan            | 171             | Beijing                                     | 94       | Dongguan          | 738             | Beijing                                     | 477      | Shenzhen          | 2494            | Beijing                                   | 1484     |
| Guangzhou         | 130             | Jiangsu                                     | 68       | Guangzhou         | 560             | Shanghai                                     | 347      | Foshan            | 2290            | Fujian                                    | 1095     |
| Dongguan          | 124             | Zhejiang                                    | 57       | Huizhou           | 450             | Zhejiang                                     | 244      | Zhongshan         | 1642            | Guangxi                                   | 913      |
| Zhuhai            | 81              | Taiwan                                      | 50       | Foshan            | 315             | Fujian                                       | 149      | Dongguan          | 1243            | Jiangsu                                   | 780      |
| Zhongshan         | 61              | Tianjin                                     | 39       | Zhongshan         | 218             | Sichuan                                     | 125      | Huizhou           | 978             | Shandong                                   | 470      |
| Jiangmen          | 30              | Jiangxi                                     | 29       | Hong Kong         | 167             | Hubei                                       | 122      | Zhuhai            | 913             | Sichuan                                   | 445      |
| Hong Kong         | 16              | Hunan                                       | 21       | Jiangmen          | 160             | Shandong                                     | 120      | Jiangmen          | 758             | Anhui                                     | 423      |
| Huizhou           | 15              | Sichuan                                    | 21       | Zhuhai            | 138             | Xinxing                                     | 104      | Hong Kong         | 255             | Hunan                                     | 334      |
| Zhaoqing          | 1               | Fujian                                      | 20       | Zhaoqing          | 44              | Hunan                                       | 93       | Zhaoqing          | 207             | Hubei                                     | 289      |
| Macao             | 1               | Shandong                                    | 18       | Macao             | 30              | Tianjin                                     | 74       | Macao             | 2              | Chongqing                                  | 252      |
From the perspective of the net-flow network (Figure 3), only Hong Kong, Huizhou, and Dongguan had greater out-strength than in-strength, and other cities in the GBA had lower out-strength than in-strength in 2018. Dongguan realized the transformation from net input of technology to net output of technology during the study period, while Guangzhou had the opposite situation. Shenzhen and Foshan changed their roles from technology net input to technology net output and then to technology net output. For provincial regions outside the GBA, only Chongqing’s in-strength was far greater than its out-strength in 2018, and it did not have a close connection with the GBA in the 2010 and 2014. It is worth noting that in recent years, Chongqing actively integrated national strategies such as the “Belt and Road,” the Yangtze River Economic Belt, a new round of western development, and has made efforts to develop new industries, such as big data and high-end manufacturing. The economic and technological innovation strength steadily increased, and technology needs are strong, leading to the absorption of a large number of patented technologies in the GBA. The out-strengths of Zhejiang and Beijing were much greater than their in-strengths, and the gap between other provinces was small.
Since 2014, Zhejiang maintained a huge technological output to the GBA, which shows that Zhejiang play a significant role in technology output to the GBA.

The current research on urban technology transfer includes the transfer relationships both between and within cites [6,49]; however, discussion mainly focuses on the former. In fact, the outflow includes the city’s rotation flow, that is, the city’s own technology transfer to itself. In order to further explore the technology transfer capability of the cities to other cities within the GBA, the actual outflow (i.e., actual out-strength) is obtained by subtracting the city’s rotation flow (i.e., rotation out-strength) from the total outflow (i.e., total out-strength). Figure 4 shows the total outflow, rotation flow, and actual outflow of the cities within the GBA in the three different periods. The figure also indicates that Macau’s technology transfer capability was weak, and Hong Kong’s actual outflow was more than its rotation flow. Combined with Hong Kong technology in-strength (Figure 2), Hong Kong’s local capacity for technology demand was relatively weak, and technology output was the main contribution. In 2018, Zhaoqing and Huizhou had more actual outflow than the internal rotation flow within the city, and the actual outflow of Huizhou was twice that of its internal rotation flow. The remaining cities in the GBA had more internal rotation flow than their actual outflow. Shenzhen and Guangzhou are the poles of the GBA, and there was a large gap in the total outflow for Shenzhen; however, the actual outflow in the two cities was around 5000, which shows that the gap between the actual outflow is narrowing. It is worth noting that both Zhuhai and Jiangmen’s rotation flow accounted for more than 80% of the total outflow. The transfer of urban technology patents was mainly concentrated within the city, and the technology transfer ability to other cities or regions was insufficient. Both Dongguan and Foshan were at the same level in terms of total outflow, rotation flow, and actual outflow, but the numbers for Dongguan were higher than those for Foshan. This shows that overall, technology self-digestion and absorption and technology transfer ability of Dongguan are higher than those of Foshan. Overall, in the three periods, the technology transfer was mainly within the city, indicating that the technology local effect of the GBA is prominent.

In summary, in the full-flow network, “two poles and two strong, multi-level sub-echelon surrounding development trend” were formed inside the GBA, showing a clear hierarchical structure and a “pyramid” structure. The two poles refer to the technology distribution center with Shenzhen and Guangzhou as the core; the two strong players refer to Dongguan and Foshan; Dongguan is adjacent to Shenzhen and Guangzhou, and Foshan accelerates the integration process between Guangzhou and Foshan. Dongguan and Foshan have obtained huge technologies spillovers from Shenzhen and Guangzhou, forming a strategic node for the integrated development of the two poles, while playing
as the “regional technical goalkeeper.” In the multi-level echelon structure, Shenzhen and Guangzhou are the first echelon and Dongguan and Foshan are the second echelon of important technology manufacturing bases in the GBA, which play an important role in technology absorption. The third echelon includes Zhongshan, Jiangmen, and Zhuhai, and the fourth includes Hong Kong, Zhaoqing, and Macau. From the perspective of the provincial regions outside the GBA, the areas where technology transfer exists with the GBA have the basic characteristics of geographic proximity and technological proximity. Among them, Zhejiang, Jiangsu, and the GBA have the closest technical exchanges and cooperation. In addition, the western region and the GBA have developed a technological exchange and cooperation relationship, with Sichuan as the core. In the net-flow network, the GBA has formed a “single pole and two strong, multi-echelon hierarchical” development trends. Guangzhou’s status has been highlighted, and it has become a single core, indicating that Guangzhou’s actual technology output capability is strong. Shenzhen and Foshan, as the two strong players in the technology net-flow network, are in the second echelon of the network. Zhongshan and Dongguan are in the third, Huizhou, Zhuhai, and Jiangmen in the fourth, and Hong Kong, Zhaoqing, and Macau in the fifth echelon. From the perspective of provincial regions outside the GBA, the basic characteristics of technology transfer areas with the GBA are geographical and technological proximity. Among them, Zhejiang and the GBA have the closest technology exchange and cooperation. In addition, the western region has formed technical exchanges and cooperation with GBA, with Sichuan as the core.

4.3. Network Association Analysis

Figure 5 shows the adjacent matrix heat maps of the technology transfer full-flow network and net-flow network in the GBA after removing the ring edge in 2010, 2014, and 2018. In the full-flow network of 2018, Guangzhou received the largest number of technology transfers from outside areas. The source of technology transfer was mainly Zhejiang, Beijing, Fujian, and Jiangsu. It absorbed a large number of patented technologies from Zhejiang, but it received less technology transfer from cities within the GBA. Guangzhou and Shenzhen were the two poles in the network, and there was not a lot of technology transfer interaction between the two. Shenzhen’s patent absorption technology ranked second, and its patent technology sources were mainly from Zhejiang, Jiangsu, Fujian, Shanghai, and Dongguan. Zhejiang, Jiangsu, and Fujian all maintained a large amount of technology output to the two poles (Shenzhen and Guangzhou) of technology transfer in the GBA. Beijing–Guangzhou and Shanghai–Shenzhen—four first-tier cities in China—were paired to build a “global channel” for technology transfer in the GBA. The patented technology in Shenzhen mainly flowed to Jiangsu, Dongguan, and Zhejiang, and the patented technology in Guangzhou mainly flowed to Jiangsu and Foshan. Provinces such as Jiangsu and Zhejiang had close technical links with cities in the GBA, such as Shenzhen and Guangzhou. Dongguan and Foshan received a large number of technology transfers due to their proximity to Shenzhen and Guangzhou. The number of high value node pairs of technology transfer increased continuously from 120 to 1250 during the study period. In 2010 and 2014, Shenzhen remained the city with the most receiving technologies, while in 2018, Guangzhou surpassed Shenzhen to become the city with the most receiving technologies.
Zhejiang in 2018. On the whole, the technical connection between Jiangsu and the GBA in the study period continued to strengthen.

**Figure 5.** Adjacent matrix heat maps of the GBA technology transfer network in 2010, 2014, and 2018. (X axis represents the technology output node, the Y axis represents the receiving technology node, and the color depth of each square represents the amount of technology transfer between nodes).

From the perspective of the net-flow network in 2018, Guangzhou was still the city that actually receives the most patented technologies from other regions. Its main net-receiving regions included
Zhejiang, Fujian, and Beijing. Compared with the full-flow network, it was found that there was a peer-to-peer technology transfer between Guangzhou and Jiangsu, resulting in the insignificant technology transfer relationship between Jiangsu and Guangzhou, while the technology transfer from Zhejiang to Guangzhou was much higher than the technology transfer from Guangzhou to Zhejiang. The technology transfer from Beijing and Fujian to Guangzhou was slightly more than the technology transfer from Guangzhou to them. Shenzhen's net technology reception was slightly lower than Foshan and Zhongshan. Foshan received a large amount of net technology output from Zhejiang and Guangzhou. It is worth noting that Zhongshan received a large amount of net technology transfer from Guangxi, a neighboring province. Shenzhen received a significant amount of net technology transfer, mainly from Fujian, Shanghai, and Zhejiang. The nodes with the most net receiving patents show a change trend during the study period. In 2010, Shenzhen had the most net receiving patents. Jiangsu leaped to first in 2014 and Guangzhou became first in 2018.

Figure 6 shows the chord diagrams—the relationship between different nodes and some common features shared with each other—of the GBA technology transfer network in 2010, 2014, and 2018. In 2018, the technology output of Shenzhen and Guangzhou covered a wide area and was not concentrated in a single city or region. It presented a “decentralized” feature and acted as the center of technology transfer in the GBA. From developed areas to backward areas, technology transfer follows a law of technology gradient transfer [63]. Shenzhen has many technology sources, however, in 2010, there was a technical dependence on some nodes. The situation changed significantly in 2018 and the technology transfer volume of each technology source to Shenzhen was relatively even. While Guangzhou’s technology sources were relatively extensive during the study period, a small number of technology sources had a large number of technology exports to Guangzhou in 2018, such as Zhejiang and Beijing. The amount of technology transfer from Zhejiang and Beijing to the GBA was much higher than the amount of technology exported from the GBA to Zhejiang and Beijing in 2010 and 2018 and Beijing received a large number of patents from Shenzhen in 2014. It is worth noting that Foshan’s technology input was much higher than its technology output. At the same time, Foshan’s technology input relied heavily on Shanghai in 2010, and its dependence on Shanghai technology dropped significantly by 2018. The technical connection between Jiangsu and the GBA reached its peak in 2014. It received a large number of patents from Shenzhen but was surpassed by Zhejiang in 2018. On the whole, the technical connection between Jiangsu and the GBA in the study period continued to strengthen.

In the net-flow network, the net output of technology in Guangzhou was uniform during the study period, and there was no centralized flow to a certain area. However, in the process of technical exchanges between Guangzhou and other regions, the amount of input was much greater than the amount of technology output in 2018. It gradually grew into a net technology input city from 2010 to 2018, which focuses on receiving technology transfer from a small number of cities. The source of technology was narrow. There was a huge “technology surplus” between Guangzhou and Zhejiang and Beijing in 2018. The technology transfer volume of Zhejiang and Beijing accounted for more than 50% of the net technology input received by Guangzhou, presenting a “centralized” feature and path dependence. Shenzhen played the role of net input and net output in 2010 and 2014, respectively. In 2018, its output and input were comparable; there was no obvious difference. Shenzhen gradually developed into a technology hub. Zhejiang transferred a large amount of technology to Guangzhou and Foshan in 2018, and the net technology output to Guangzhou and Foshan accounted for more than 50% of Zhejiang’s net technology output to the GBA. There was obvious path dependence and spatial preference for the net technology input in Guangzhou. Foshan, Zhongshan, and Zhuhai absorbed a large number of patents from most parts of the country in 2018 and played the role of technology beneficiaries. The output of Dongguan, Huizhou, and Jiangmen in 2018 was greater than the amount of technology input, which was a net overflow role.
Figure 6. Chord diagrams of the GBA technology transfer network in 2010, 2014, and 2018: (a,b) are the full-flow network and net-flow network, respectively. (The node pointed by the arrow is the node receiving the technology, and the other end is the technology output node. The thickness of the line corresponds to the amount of technology transfer).
4.4. Network Node Importance Analysis

Figures 7 and 8 show the distribution of the authority and hub values of the full-flow network in the GBA during the study period. In general, a small number of nodes occupied the core position of technology transfer, and a large number of nodes surrounded the core nodes during the 2010–2018 period. Shenzhen occupied a dominant position from 2010 to 2018. In terms of hub and authority, Shenzhen was considerably more important than Guangzhou, which ranked second. Shenzhen and Guangzhou were both at the same level of strength, but from the perspective of node importance, Shenzhen played a leading role in technological innovation in the GBA. Although Shenzhen and Guangzhou were the technology hubs of the GBA and even the national technology hubs, Shenzhen’s hub value was much higher than that of Guangzhou. The main reason is that the source of technology input in Guangzhou is mainly concentrated in some cities, resulting in fewer hub nodes than the number of hub nodes connected to Shenzhen. From the authority value perspective, Shenzhen, as a comprehensive and innovative national science and technology center that China is focusing on, played an important role in the construction of the GBA. In addition, Shenzhen had abundant scientific and technological innovation resources and strong technology transfer capabilities, thus becoming the core authority of the GBA. Although the Guangzhou authority value was inferior to that of Shenzhen, Guangzhou also had its advantages. As a key science and education town in South China, there are a large number of high-level universities in the region. Scientific and technological innovation has a solid foundation, rich innovation resources, and a strong technology transfer ability. The hub and authority values of Dongguan, Foshan, Huizhou, and Zhongshan showed a stepwise decrease; these cities are geographically adjacent to Shenzhen and Guangzhou. They were also continuously integrating into Shenzhen and Guangzhou, playing the role of technology undertaker and technology diffuser, that is, the technology is spread to other neighbors through “local buzz.” To sum up, in the full-flow network, each city in the GBA had its own advantages and focuses. Cities within the GBA are seeking to strengthen inter-city cooperation, connecting Shenzhen and Guangzhou, exploring breakthroughs in the administrative boundaries of cities, strengthening the hierarchical transmission mechanism for technology flows, undertaking more patented technology resources, and strengthening their own technological innovation capabilities to enhance their functional positioning. For provincial regions outside the GBA, the hub and authority values in Beijing–Tianjin–Hebei were higher than that in the Yangtze River Delta in 2010, but after 2014, the hub and authority values in the Yangtze River Delta were higher than that in Beijing–Tianjin–Hebei. Moreover, the hub and authority values of Jiangsu and Zhejiang were higher than those of other provinces in 2018, which shows that Jiangsu and Zhejiang’s technology transfer status is relatively more important compared to that of other provinces.

Figure 7. Hyperlink-Induced Topic Search (HITS) (hub) schematic diagram of the GBA technology transfer full-flow network in 2010, 2014, and 2018: (a,b) are outside and inside the GBA, respectively.
was relatively small, and there was not much di

The technology sources in Guangzhou and Foshan were mainly nodes with high hub values such as

node had a high authority value. The authority values of major cities in the GBA were similar.

although the hub values of some nodes were high, the number and quality of the source nodes of these

It can be seen in 2018 that the hub values of Zhejiang, Beijing, and Fujian were higher than those of

Guangzhou and Shenzhen. From Figures 5 and 6, it can be seen that Zhejiang and Beijing transferred a

large amount of the patented technology. As a result, they gathered a large number of high-quality
technological innovation cities, thus showing high hubs. Furthermore, Shanghai’s hub value ranked

first in 2010, while after 2014, its hub value declined sharply. However, Zhejiang’s hub rose to the top in

2018. In the GBA, except for Guangzhou and Shenzhen, the hub values of other nodes were relatively

evenly distributed. It is worth noting that Shantou, as an external city in the GBA, had a relatively

small hub value in 2010 and 2014 and had a higher hub value than some cities located within the GBA in

2018, showing a strong hub. For provincial regions outside the GBA (Figure 10), the authority value was relatively small, and there was not much difference between provincial regions. This indicates that although the hub values of some nodes were high, the number and quality of the source nodes of these nodes were not too high, resulting in a low authority value. In the cities within the GBA (Figure 10), the authority values of Guangzhou and Foshan were higher than those of other cities such as Shenzhen. The technology sources in Guangzhou and Foshan were mainly nodes with high hub values such as Zhejiang and Beijing. When a node was pointed to by multiple nodes with a high hub value, then that node had a high authority value. The authority values of major cities in the GBA were similar.
nodes with a high hub value, then that node had a high authority value. The authority values of major cities in the GBA were similar.

Figure 9. HITS (hub) schematic diagram of the GBA technology transfer net-flow network: in 2010, 2014, and 2018: (a) and (b) are outside and inside the GBA, respectively.

Figure 10. HITS (authority) schematic diagram of the GBA technology transfer net-flow network in 2010, 2014, and 2018: (a) and (b) are outside and inside the GBA, respectively.

Overall, the HITS spatial distribution of the technology transfer network was heterogeneous and hierarchical. Each city in the GBA had its own technological advantages. Guangzhou and Shenzhen emphasized technological innovation and highlighted complementarity. Jiangsu, Zhejiang, and Beijing had strong technological ties with the GBA due to their strong innovation capabilities. Provinces such as Sichuan, Chongqing, and Guizhou had strong technical ties with the GBA due to their own industrial needs.

4.5. Community Analysis

Figures 11 and 12 show the community division of the GBA technology transfer network. In 2018, the technology transfer full-flow network was divided into 12, 10, and 11 communities from 2010 to 2018; 11 cities of the GBA did not form an integrated community at the three periods. Shenzhen, Guangzhou, Dongguan, Foshan, Zhongshan, Huizhou, Zhaoqing, and other cities became the core nodes of major communities, driving the GBA toward being an international technology innovation center. In 2010 and 2014, Shenzhen was the core node of the largest community. Guangzhou was the core node of the largest community and Shenzhen was the core node of the second largest community in 2018. Figure 12 shows that the number of net-flow network communities decreased sharply compared to the full-flow network. The net flow network was divided into seven, five, and three communities in the study period. It can be seen that the net flow network gradually reduced the number of communities as time went by, which shows that the GBA is constantly strengthening the integration of technology within and outside the region. The net flow network was divided into three communities in 2018; mainly two communities, and the third community contained only four nodes. One of the communities takes Shenzhen, Dongguan, Jiangsu, Fujian, Huizhou, Shanghai, and other regions as core nodes and contains 30 nodes in total. Another community takes Guangzhou, Foshan, Zhejiang, Zhuhai, Jiangmen, and other regions as core nodes and contains a total of 20 nodes. The third community contains only four nodes, namely Zhongshan, Henan, Heilongjiang, and Guangxi. This community was in a marginal position in the GBA technology transfer net-flow network. Obvious geographic spatial clustering of the two main communities can be seen from Figure 12, which is more obvious in the GBA. There were two communities in the east–west direction connecting Guangzhou and Shenzhen. Shenzhen and Guangzhou were the core nodes of the two communities and played an important technology spillover role in their respective communities. However, as a distribution center of the net-flow network, Shenzhen had a good cluster development trend, and Guangzhou was a net benefit node of the net-flow network technology. As a result, the comprehensive radiation capability of Shenzhen’s technology far exceeded that of Guangzhou.
According to the previous analysis, the GBA formed a pattern of two poles and two strong, but these two categories mainly include agriculture, clothing manufacturing, weaving, and other primary industries and traditional handicraft industries; Section B is for operation and transportation; Section C is for chemical metallurgy, mainly including heavy chemical industrial patents such as oil and steel; Section E is for fixed buildings; part F is for mechanical engineering, lighting, heating, and blasting; Section G is for physics, mainly including instruments manufacturing and nuclear engineering; section H is electrical, mainly including basic electrical components and electronic communication technology. According to the international patent classification table, patents are divided into eight categories. Section A is for human necessities, Section D is for textile and papermaking, and these two categories mainly include agriculture, clothing manufacturing, weaving, and other primary industries and traditional handicraft industries; Section B is for operation and transportation; Section C is for chemical metallurgy, mainly including heavy chemical industrial patents such as oil and steel; Section E is for fixed buildings; part F is for mechanical engineering, lighting, heating, and blasting; Section G is for physics, mainly including instruments manufacturing and nuclear engineering; section H is electrical, mainly including basic electrical components and electronic communication technology.

According to the international patent classification table, patents are divided into eight categories. Section A is for human necessities, Section D is for textile and papermaking, and these two categories mainly include agriculture, clothing manufacturing, weaving, and other primary industries and traditional handicraft industries; Section B is for operation and transportation; Section C is for chemical metallurgy, mainly including heavy chemical industrial patents such as oil and steel; Section E is for fixed buildings; part F is for mechanical engineering, lighting, heating, and blasting; Section G is for physics, mainly including instruments manufacturing and nuclear engineering; section H is electrical, mainly including basic electrical components and electronic communication technology.

According to the previous analysis, the GBA formed a pattern of two poles and two strong, but these four node cities are located inside the Pearl River Delta. In order to further explore the technology transfer situation of Guangdong, Hong Kong, and Macao, Hong Kong and Macao were included; and the analysis of technology branch transfer between six cities was focused on, such as Shenzhen, Guangzhou, Dongguan, Foshan, Hong Kong, and Macao (2018 as shown in the Table 6, 2010 see in Table A1 of Appendix A, 2014 see in Table A2 of Appendix A). This will help identify the development status of the current technology transfer in the GBA by industry sector and will help the GBA to occupy a more favorable position in the new round of industrial upgrading.

**Figure 11.** Division of the GBA technology transfer full-flow network communities: (a,b) are the outside and inside the GBA, respectively; (Guangdong Province is dyed by a community in Shenzhen.).

**Figure 12.** Division of the GBA technology transfer net-flow network communities: (a,b) are the outside and inside the GBA, respectively; (Guangdong Province is dyed by a community in Shenzhen.).

### 4.6. Sector Patented Technology Transfer Analysis

According to the international patent classification table, patents are divided into eight categories. Section A is for human necessities, Section D is for textile and papermaking, and these two categories mainly include agriculture, clothing manufacturing, weaving, and other primary industries and traditional handicraft industries; Section B is for operation and transportation; Section C is for chemical metallurgy, mainly including heavy chemical industrial patents such as oil and steel; Section E is for fixed buildings; part F is for mechanical engineering, lighting, heating, and blasting; Section G is for physics, mainly including instruments manufacturing and nuclear engineering; section H is electrical, mainly including basic electrical components and electronic communication technology. According to the previous analysis, the GBA formed a pattern of two poles and two strong, but these four node cities are located inside the Pearl River Delta. In order to further explore the technology transfer situation of Guangdong, Hong Kong, and Macao, Hong Kong and Macao were included; and the analysis of technology branch transfer between six cities was focused on, such as Shenzhen, Guangzhou, Dongguan, Foshan, Hong Kong, and Macao (2018 as shown in the Table 6, 2010 see in Table A1 of Appendix A, 2014 see in Table A2 of Appendix A). This will help identify the development status of the current technology transfer in the GBA by industry sector and will help the GBA to occupy a more favorable position in the new round of industrial upgrading.
Table 6. Distribution of patent transfers by industry sector among six cities in 2018.

| Source–Target          | A    | B    | C    | D    | E    | F    | G    | H    |
|------------------------|------|------|------|------|------|------|------|------|
| ShenZhen-ShenZhen      | 624  | 845  | 429  | 17   | 223  | 415  | 1383 | 1436 |
| ShenZhen–Guangzhou     | 45   | 17   | 5    | 0    | 9    | 20   | 28   | 53   |
| ShenZhen–Dongguan      | 37   | 99   | 21   | 2    | 11   | 16   | 51   | 96   |
| ShenZhen–Foshan        | 10   | 13   | 10   | 1    | 1    | 9    | 5    | 21   |
| Shenzen–Hongkong       | 0    | 4    | 0    | 0    | 1    | 2    | 0    | 0    |
| **Total**              | 716  | 978  | 465  | 20   | 245  | 462  | 1467 | 1606 |
| Guangzhou–Guangzhou    | 466  | 597  | 316  | 24   | 189  | 238  | 474  | 767  |
| Guangzhou–Shenzhen     | 55   | 50   | 16   | 3    | 3    | 22   | 30   | 19   |
| Guangzhou–Dongguan     | 21   | 28   | 13   | 2    | 2    | 7    | 15   | 9    |
| Guangzhou–Foshan       | 59   | 114  | 36   | 17   | 34   | 39   | 21   | 26   |
| **Total**              | 601  | 789  | 381  | 46   | 228  | 306  | 540  | 821  |
| Dongguan–Dongguan      | 175  | 722  | 180  | 36   | 43   | 151  | 183  | 272  |
| Dongguan–Shenzhen      | 18   | 47   | 12   | 3    | 14   | 28   | 19   | 31   |
| Dongguan–Guangzhou     | 13   | 30   | 11   | 5    | 2    | 7    | 3    | 5    |
| Dongguan–Foshan        | 2    | 6    | 5    | 3    | 1    | 1    | 0    | 6    |
| Dongguan–Hongkong      | 1    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| **Total**              | 209  | 806  | 381  | 47   | 60   | 187  | 205  | 314  |
| Foshan–Foshan          | 373  | 568  | 105  | 28   | 159  | 312  | 113  | 245  |
| Foshan–Shenzhen        | 18   | 27   | 6    | 1    | 1    | 5    | 4    | 3    |
| Foshan–Guangzhou       | 28   | 37   | 14   | 0    | 8    | 27   | 11   | 9    |
| Foshan–Dongguan        | 3    | 10   | 3    | 0    | 0    | 4    | 2    | 1    |
| Foshan–Hongkong        | 0    | 0    | 3    | 0    | 0    | 0    | 0    | 0    |
| **Total**              | 422  | 642  | 131  | 29   | 168  | 348  | 130  | 258  |
| Hongkong–Hongkong      | 26   | 9    | 5    | 0    | 7    | 6    | 40   | 12   |
| Hongkong–Shenzhen      | 2    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Hongkong–Guangzhou     | 2    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Hongkong–Foshan        | 4    | 0    | 0    | 0    | 0    | 0    | 4    | 1    |
| **Total**              | 34   | 9    | 5    | 0    | 7    | 6    | 40   | 13   |
| Macao–Macao            | 0    | 0    | 0    | 0    | 0    | 1    | 0    | 0    |
| **Total**              | 0    | 0    | 0    | 0    | 0    | 1    | 0    | 0    |

Note: The top two section are shown in bold.

It is well established that sections G and H are closely related to high-tech industries such as precision instrument manufacturing and electronic communication technology. In 2010, as shown in Table A1, section G and section H of Shenzhen were the industries with the most technology transfer in Shenzhen, accounting for 18% and 24%, respectively. In addition, in 2018, section G and H were still the industries with the most technology transfer in Shenzhen. Meanwhile, section G and section H accounted for 25% and 27% of the total transfer in Shenzhen, accounting for 52% of the total transfer in Shenzhen. It shows that the high-tech industry is the leading and pillar industry of Shenzhen, and the high-tech industry is constantly strengthening. Vertically, in 2018, the transfer volume of Shenzhen’s section G and section H was more than twice that of Guangzhou’s section G and section H, which fully shows that Shenzhen’s high-tech industry had a leading position in the GBA. In 2010, section A and section F were the two industries with the most technology transfer in Guangzhou. In 2018, section H and section B in Guangzhou were the two sectors with the most transfer volume, accounting for 21% and 22%, respectively. This shows that in recent years, Guangzhou has made sustained efforts in the high-tech industry, the proportion of the primary industry has dropped significantly, and the high-tech industry has continued to grow. In 2018, section B was the most transferred department in Dongguan and Foshan. However, section H occupied second place in Dongguan and section A still occupied an important position in Foshan. At the same time, Dongguan’s high-tech industry transfer volume (section G and section H) accounted for 25% of Dongguan’s total technology transfer volume, while Foshan’s high-tech industry transfer volume (section G and section H) accounted for 18% of its total transfer volume. Compared with 2010, Dongguan and Foshan’s high-tech transfer volume increased significantly, which shows that Dongguan and Foshan strengthened their industrial layout in the field of high-tech in recent years, but Dongguan’s dominant position in the field of high-tech was more prominent. In 2010, Hong Kong’s technology transfer was mainly concentrated in section G and section
H, while in 2018, it was concentrated in section A and section G, and the transfer volume of section H decreased slightly, indicating that Hong Kong’s high-tech industry is shrinking and declining.

We continued to further examine the technology transfer relationship between Guangdong, Hong Kong, and Macau. In 2010, Hong Kong’s technology transfer to Guangdong was mainly concentrated in section G and section H, and Shenzhen was Hong Kong’s main technology receiving place in 2010. In 2014, the number of Hong Kong’s section G and section H patent transfers to Guangdong showed a downward trend. By 2018, Hong Kong did not transfer section G and section H patents to Guangdong, but mainly concentrated on section A. In recent years, Guangdong actively integrated innovation resources, promoted the economic transformation and development, and seized the high-tech commanding heights, which led to Guangdong and Hong Kong achieving a transposed development model. However, at the same time, Guangdong still had a certain gap with Hong Kong in areas such as medicine, which led to Hong Kong’s continued transfer of section A patents to Guangdong. It is worth noting that the peak period of technology transfer from Shenzhen and Guangzhou to Hong Kong occurred in 2014, and only Dongguan and Foshan had technology transfer to Hong Kong in 2018. It can be seen that Hong Kong’s technology demand capacity weakened further. Due to its weak technological innovation ability and demand, Macau had few technical exchanges with Hong Kong and Guangdong. Generally speaking, the technology flow in Guangdong, Hong Kong, and Macau was mainly based on human necessities (section A) and traditional manufacturing (section C). Therefore, the cooperation between Guangdong, Hong Kong, and Macao in the field of high-tech industries should be strengthened, and the depth and breadth of cooperation should be continuously expanded to contribute to building a world-class bay area.

5. Conclusions and Policy Recommendations

5.1. Conclusions

This study uses 2018 patent transaction data, integrates data mining, and uses complex network analysis to build a full-flow network and a net-flow network for technology transfer in the GBA. The structural characteristics and spatial patterns of the technology transfer network in the GBA were studied from six aspects, including overall characteristics, network node strength, network association, network node importance, network communities, and sector patented technology transfer analysis. The main research conclusions are as follows:

Firstly, the GBA technology transfer network includes a full-flow network and a net-flow network. The full-flow network with a weighted self-loop is based on the actual flow of technology and the net-flow network is based on the net transfer volume between regions. For both the networks, the assortativity characteristics of technology transfer are heterogeneous. This means that the nodes with strong technological innovation ability prefer to be connected to the nodes with weak innovation capabilities, creating an economic or technological potential gap between the nodes.

Secondly, the full-flow network presents an obvious hierarchical structure and a “pyramid” type spatial structure within it. Shenzhen and Guangzhou are located at the absolute core of the network and are the technology distribution centers of the entire network. Dongguan and Foshan are the secondary centers and play the role of “regional technology goalkeeper.” Other cities in the GBA form the third and fourth echelons, and the entire space structure has a pyramid shape. Outside the GBA, regions with close technology transfer with the GBA present technological and geographic proximity. Most cities in the GBA account for more than 50% of the total outbound traffic, showing obvious intra-city characteristics. The net-flow network presents a development trend of “single pole and two strong, multi-echelon hierarchical,” with Guangzhou as the absolute core location of the net-flow network. Shenzhen and Foshan show two strong trends, and other cities in the GBA show echelon development trends.

Thirdly, the connected objects of the technology transfer network have spatial preferences, and the spatial flow shows the characteristics of coexistence of concentration and decentralization.
Concentration is reflected in the net-flow network, and the technology sources of the cities in the GBA are mainly concentrated in Zhejiang, Beijing, and Fujian. Decentralization is reflected in full-flow networks. There are many and diversified sources of technology transfer in major cities (such as Shenzhen and Guangzhou) which are not restricted to a certain area.

Fourthly, the HITS spatial distribution of the technology transfer network is heterogeneous and hierarchical. Each city in the GBA has its own technological advantages. Guangzhou and Shenzhen have their own focuses on technological innovation, highlighting complementarity.

Fifthly, the spatial clustering characteristics of internal communities in the technology transfer network are obvious. In the full-flow network, major cities in the GBA are responsible for leading the innovative development of other cities in the Pearl River Delta and also play an important role in connecting other provinces outside the region. In the net-flow network, two major communities, with Shenzhen and Guangzhou as the core, have been formed, leading the GBA to move toward being a global technology innovation center.

Finally, the high-tech industry continues to develop, while the manufacturing industry in the secondary industry still plays an important role. The high-tech patent transfers such as sections G and H are mainly focused on Shenzhen and Guangzhou. At the same time, Guangzhou, Dongguan, and Foshan have all formed a two-wheel drive development model with high-tech and traditional manufacturing.

5.2. Policy Recommendations

Based on the research findings on the structural characteristics and spatial patterns that have emerged during the technology transfer process in the GBA, this article proposes the following policy recommendations:

First, strengthen the technological connections between core city nodes. Shenzhen and Guangzhou both lie in the same province and are geographically similar. They are the core cities for technology transfer in the GBA, making the strengthening technology cooperation feasible; however, the technology transfer relationship between the two cities is not close. Therefore, these cities should strengthen the top-level design ideas, make use of the core engine linkage development, and strengthen the role of poles.

Second, the sub-central cities in the GBA should expedite their connection with core cities. Dongguan should expedite and strengthen the technological docking with Shenzhen and Guangzhou and actively undertake the industrial transfer of Shenzhen and Guangzhou. Foshan should accelerate the integration process of Guangzhou and Foshan, actively connect with the pace of economic development in Guangzhou, and build a Shenzhen–Dongguan–Guangzhou–Foshan science and technology innovation corridor to form a strategic node for the development of technology integration in the GBA.

Third, other cities in the GBA should strengthen their functional positioning and achieve inter-city development. The service industries in Hong Kong and Macau account for over 90%, and their innovation capacity is relatively insufficient. Therefore, it should be positioned as “financial + technological innovation” and provide financial support for other technological innovation centers in the GBA with its global financial center status. Other cities should also actively connect with core and sub-central cities to realize the transformation and upgrading of their own innovative industries. For example, Huizhou should actively connect with Guangzhou, Shenzhen, and Dongguan, and Zhongshan with Guangzhou and Foshan for further development.

However, the present study has certain limitations. First, the number of patent right transfer instead of the number of technology transfers are used for the analysis. Although patent right transfer can reflect technology transfers to a certain extent, the forms of technological innovation are more diverse than just patents. Second, there is no denying that Hong Kong and Macao have advantages in some areas such as finance. Therefore, it is necessary to conduct research on integrating technological patents with financial capital flow on the grounds that the former points to manufacturing and hi-tech industry.
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**Conflicts of Interest:** The author declares that there are no conflicts of interest.

**Appendix A**

**Table A1.** Distribution of patent transfers by industry sector among six cities in 2010.

| Source–Target          | A      | B   | C | D | E  | F  | G | H |
|------------------------|--------|-----|---|---|----|----|---|---|
| Shenzhen–Shenzhen      | 106    | 93  | 39| 4 | 110| 130| 148| 194|
| Shenzhen–Guangzhou     | 2      | 2  | 2 | 0 | 0  | 3  | 1 | 2 |
| Shenzhen–Dongguan      | 2      | 5  | 1 | 0 | 0  | 3  | 3 | 9 |
| Shenzhen–Foshan        | 0      | 0  | 0 | 0 | 2  | 2  | 0 | 0 |
| **Total**              | **110**| **100**| **42**| **4**| **112**| **138**| **152**| **205**|
| Guangzhou–Guangzhou   | 82     | 44  | 41| 5 | 12 | 46 | 45 | 41|
| Guangzhou–Shenzhen     | 0      | 1  | 1 | 0 | 3  | 1  | 2 | 3 |
| Guangzhou–Dongguan    | 1      | 4  | 2 | 1 | 0  | 0  | 0 | 3 |
| Guangzhou–Foshan      | 0      | 2  | 0 | 0 | 1  | 10 | 0 | 1 |
| **Total**              | **83**| **51**| **44**| **6**| **16**| **57**| **47**| **48**|
| Dongguan–Dongguan     | 57     | 76  | 17| 4 | 6  | 46 | 34 | 129|
| Dongguan–Shenzhen      | 3      | 1  | 6 | 2 | 0  | 2  | 2 | 2 |
| Dongguan–Guangzhou     | 5      | 0  | 1 | 0 | 0  | 0  | 0 | 0 |
| Dongguan–Foshan        | 0      | 0  | 0 | 1 | 0  | 0  | 0 | 1 |
| **Total**              | **65**| **77**| **24**| **7**| **6**| **48**| **36**| **132**|
| Foshan–Foshan          | 44     | 44  | 7 | 7 | 3  | 75 | 17 | 25|
| Foshan–Shenzhen        | 1      | 1  | 0 | 0 | 1  | 1  | 0 | 0 |
| Foshan–Guangzhou       | 7      | 0  | 0 | 0 | 0  | 6  | 0 | 0 |
| Foshan–Dongguan        | 0      | 2  | 0 | 0 | 0  | 0  | 0 | 1 |
| **Total**              | **52**| **47**| **7**| **7**| **4**| **82**| **17**| **26**|
| Hongkong–Hongkong      | 2      | 3  | 1 | 0 | 0  | 2  | 7 | 0 |
| Hongkong–Shenzhen      | 0      | 0  | 0 | 0 | 2  | 6  | 12 | 12|
| Hongkong–Guangzhou     | 1      | 0  | 0 | 0 | 0  | 0  | 0 | 1 |
| Hongkong–Dongguan      | 1      | 1  | 0 | 0 | 1  | 1  | 1 | 4 |
| Hongkong–Macao         | 1      | 0  | 0 | 0 | 0  | 0  | 0 | 0 |
| **Total**              | **5**| **4**| **1**| **0**| **5**| **14**| **17**| **17**|
| Macao–Macao            | 1      | 0  | 0 | 0 | 1  | 0  | 0 | 0 |
| Macao–Hongkong         | 1      | 0  | 0 | 0 | 0  | 0  | 0 | 0 |
| **Total**              | **2**| **0**| **0**| **0**| **1**| **0**| **0**| **0**|

Note: The top two section are shown in bold.
Table A2. Distribution of patent transfers by industry sector among six cities in 2014.

| Source–Target          | A    | B    | C    | D    | E    | F    | G    | H    |
|------------------------|------|------|------|------|------|------|------|------|
| Shenzhen–Shenzhen      | 259  | 291  | 170  | 3    | 117  | 202  | 419  | 1097 |
| Shenzhen–Guangzhou     | 2    | 2    | 0    | 0    | 0    | 2    | 9    | 11   |
| Shenzhen–Dongguan      | 15   | 52   | 21   | 2    | 0    | 5    | 17   | 25   |
| Shenzhen–Foshan        | 0    | 1    | 1    | 0    | 0    | 0    | 9    | 0    |
| Shenzhen–Hongkong      | 6    | 3    | 0    | 0    | 0    | 0    | 5    | 2    |
| Total                  | 282  | 349  | 192  | 5    | 117  | 209  | 459  | 1135 |
| Guangzhou–Guangzhou    | 109  | 172  | 84   | 6    | 44   | 94   | 97   | 81   |
| Guangzhou–Shenzhen     | 4    | 4    | 2    | 1    | 0    | 2    | 14   | 10   |
| Guangzhou–Dongguan     | 5    | 6    | 2    | 0    | 2    | 4    | 2    | 2    |
| Guangzhou–Foshan       | 3    | 10   | 3    | 0    | 5    | 0    | 0    | 0    |
| Guangzhou–Hongkong     | 2    | 2    | 0    | 0    | 1    | 0    | 1    | 0    |
| Total                  | 123  | 194  | 91   | 7    | 50   | 98   | 116  | 93   |
| Dongguan–Dongguan      | 89   | 186  | 46   | 10   | 16   | 56   | 98   | 133  |
| Dongguan–Shenzhen      | 14   | 26   | 8    | 0    | 0    | 8    | 7    | 22   |
| Dongguan–Guangzhou     | 1    | 1    | 0    | 0    | 0    | 0    | 2    | 6    |
| Dongguan–Foshan        | 2    | 1    | 0    | 0    | 1    | 0    | 1    | 0    |
| Total                  | 106  | 214  | 54   | 10   | 17   | 64   | 108  | 161  |
| Foshan–Foshan          | 83   | 175  | 32   | 9    | 48   | 390  | 43   | 131  |
| Foshan–Shenzhen        | 6    | 2    | 0    | 0    | 0    | 2    | 1    | 3    |
| Foshan–Guangzhou       | 1    | 1    | 0    | 0    | 0    | 2    | 3    | 3    |
| Foshan–Dongguan        | 0    | 0    | 0    | 0    | 0    | 0    | 1    | 0    |
| Total                  | 90   | 178  | 33   | 9    | 48   | 394  | 48   | 137  |
| Hongkong–Hongkong      | 23   | 5    | 3    | 0    | 2    | 2    | 5    | 33   |
| Hongkong–Shenzhen      | 6    | 1    | 1    | 0    | 1    | 1    | 7    | 7    |
| Hongkong–Guangzhou     | 0    | 2    | 0    | 0    | 0    | 0    | 2    | 0    |
| Hongkong–Dongguan      | 1    | 2    | 2    | 0    | 3    | 0    | 2    | 2    |
| Total                  | 30   | 10   | 6    | 0    | 3    | 6    | 14   | 42   |
| Macao–Macao            | 1    | 0    | 3    | 0    | 0    | 0    | 0    | 0    |
| Macao–Hongkong         | 1    | 0    | 3    | 0    | 0    | 0    | 0    | 0    |
| Total                  | 2    | 0    | 6    | 0    | 0    | 0    | 0    | 0    |

Note: The top two sections are shown in bold.

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