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City Networks of Online Commodity Services in China: Empirical Analysis of Tmall Clothing and Electronic Retailers

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Abstract: City networks have been a critical topic in the fields of urban geography and regional economics. Numerous studies have explored city networks, focusing mainly on infrastructure and industrial networks. Unlike traditional urban network of which the major measuring indexes are population sizes and entity industries, online commodity service networks could reflect well the influencing of emerging economies, especially the Internet economy, on city networks. This study analyzes and reveals structural features of China's city networks through online commodity services, providing the internet economic approach on city networks. Results indicate that the core cities of online commodity service networks are mainly concentrated in eastern coastal areas. In addition, spatial polarization and layer structure of network connections are obvious, descending from the centers in eastern China to peripheral cities in central and western China. Online commodity services of different cities show apparent differences and uncertainties in terms of specialization rates of international connection, which presents a tendency toward diversification. Online commodity service networks are not only associated with goods production, supply, and consumption in physical space but also reflect virtual information, capital, and technology flows, thus providing a new empirical approach for understanding city networks in information and internet economic age.

Keywords: city networks; online commodity services; intercity relationships; specialization

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1 Introduction

The urban system, focusing on the spatial distribution structure of cities of different types and sizes within a region, country, or the world (Lao et al., 2016), has been a critical topic of urban geography and regional economics. Analysis of hierarchy and network serves as a conclusive approach to studying urban system (Zhao et al., 2015). Interactions between cities relating to industrial division of labor and specialization collaboration form a connected network, whereas differences in agglomeration and diffusion of economic activities lead to different nodes of city in an urban system. Taylor (2001) proposed that research on world city network has received much interest from academics. Numerous studies have explored city networks, focusing mainly on infrastructure (primarily concerned with transportation networks) and economic networks.

Since the 1990s, information technology application has been exerting a fundamental influence on intercity connections. The combination of information technology and economy, as well as space, have altered the traditional concepts of time, space, and distance, and a new spatial connection is formed (O'Brien, 1992; Graham, 1998). The time and space constraints of socio-economic activities have been reduced. Scholars started to focus

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on intercity connections and urban system reconstruction under the influence of information technology, and analyze the Internet city via Internet domain names or user accounts (Moss and Townsend, 2000; Zook, 2001; Wang and Ning, 2004; Brown et al., 2013). Using data on Internet information production and consumption as basis, Zhen et al. (2015) and Kellerman (2000) discussed the nodes and relations in an Internet city. The relationships of social networks, such as Twitter and Sina Weibo, are also employed to reflect the structure of a city network (Zhen et al., 2012; 2016; Wang et al., 2015), which further enriches research on city networks under the context of informatization.

The prosperity of information technology has promoted online shopping and retailing, altering the interaction between retailers and consumers as well as the commodity supply and distribution among different cities. The proliferation of online retailing is expected to reconstruct the economic and social functions of cities (Wyckoff and Colecchia, 1999) and then exert a significant influence on city networks. China Internet Network Information Center (CINIC, 2015) reported that the number of e-shoppers reached 4.13×10^8 by December 2015, accounting for 60% of all Internet users in China. The online retail transactions amounted to 3.88×10^{12} yuan (RMB) (or approximately 6.00×10^{11} US dollars), accounting for 12.9% of total retail sales. This share is much higher than that in the United States (6.4%) (Census, 2015). With the maturing online retail platforms and booming online transactions, almost every city in China is involved in online commodity sales, and overseas shopping emerged (Loo and Wang, 2017). Online commodity services are closely related not only to information flows between cities but also to the internet economy and information infrastructure. The connection of online commodity between cities provides a new approach to measure and understand the spatial characteristics of city networks in the information age (Xi et al., 2014).

Using the commodity data of Tmall Alibaba, the largest business-to-consumer (B2C) e-commerce platform in China, this study aims to explore China's city networks through the connections of online commodity services and the specialization of Chinese cities with online commodity of international brands. The following research questions will be considered: 1) how do online commodity services shape the intercity networks in the information and internet economic age? 2) Are there any differences between different online commodity types? Based on the analyzing the networks of online commodity services, this paper explores the characteristics of Chinese city network to propose effective policies to optimizing urban system towards the prosperity of internet economy.

2 Internet-based Commodity Chains and Intercity Connections

Cities have played an important role in globalization as centers of information and commodity exchange. Cities first contributed to globalization as financial centers (Cohen, 1981), then as world cities (Friedmann and Wolff, 1982; Friedmann, 1986), and further as global cities (Sassen, 1991). The world city network, as suggested by Globalization and World Cities, has been specified as an interlocking network in which relations between cities are constituted by intra-firm flows in the advanced producer service sector of the world economy (Taylor, 2001; Taylor et al., 2002; Derudder et al., 2003; Pereira and Derudder, 2010). In general, the world city network has been intensively discussed from the perspective of corporate headquarters, advanced producer services, and transportation networks (Taylor, 2005; Derudder and Witlox, 2008; Wang et al., 2013; Neal, 2016).

Recently, urban scholars note that there are far more complex connections between cities during the Internet period than in earlier eras. Some scholars have analyzed city network through evaluating internet infrastructure and information flows (Townsend, 2001; Malecki, 2002; 2013; Wang and Ning, 2004; Zhen et al., 2015). Besides the information and infrastructure, the social and economic connections between cities are also changed with the rapid development of internet-based activities. Online social interactions of people coming from different geographical location are used to reflect the relationships between cities (Wilson and Graham, 2013; Zhen et al., 2016). As the decentralized nature of Internet-based economy, the global pattern of world city networks is actually being reshaped by the increasing importance of emerging sub-center cities due to influence from information technology development (Zook, 2001). During the times of the Internet and e-business, former establishments of world city networks are rela-

tively incapable of capturing the nature of the new economic processes of production and distribution. This observation is especially true for recent China, where a far-reaching transformation of network + economy is ongoing (Zhen et al., 2015).

The different roles of each country and organization, or even personal involvement in the global economic system, should be identified in terms of value creation and distribution. Such connections can be interpreted with the concept of commodity chain (Daviron and Ponte, 2005; Rossi et al., 2007), including not only the upstream industries but also downstream distribution, such as services and consumption (Gereffi and Korzeniewicz, 1994). With the transformation of urban function from production-oriented to consumption-oriented in the times of Internet economy, commodity services play an increasingly important role in the function and control of cities, especially in the rise of online shopping and commodity services. The large number of B2C/consumer-to-consumer (C2C) stores on Internet platforms serves as the small players (agents), who are also crucial for distributing global products and, often, for owning the power to negotiate and interact with multi-branch enterprises (Coe et al., 2004). In addition, horizontal interactions in online commodity services are increasingly transcending vertical linkages (Moriset and Malecki, 2009), in which feedback from downstream to upstream ends is relatively difficult to give (Bolwig et al., 2008). The online system significantly affects traditional suppliers. For instance, the rise of the giant online-business Alibaba group is believed to be responsible for the considerable decline of the number of retailing agents using traditional shopping system. Predictably, the spatial configuration of online commodity services emerges as a new force to affect the aggromeration and diffusion of city functions. Thus, online commodity service which is the prominent link in commodity chains and the most presentation of internet economy could be used to analyze the newly development of city network.

Moreover, network structures of online commodity services are associated to the connection of other factors, including the economic, advanced producer services, and transportation and information infrastructure. Many online commodity services are rooted in the environment of local physical manufacturing and business industry. In turn, the spatial agglomeration of manufacturing and business industry would enhance the development of online commodity services. Due to online commodity service being an innovative economy, the company in the developed areas (being better internet penetration, more new technologies and more high-tech talents) are more likely to be e-commerce operators based on the theory of innovation diffusion (Anderson et al., 2003; Cao et al., 2013). Therefore, the connections of online commodity between cities may be related to regional innovation and information networks. Online commodity connections between cities are also closely correlated with logistic and freight systems for the delivery of online orders. For instance, the developed logistic network and free-shipping policy have stimulated the prosperity of online commodity services and online shopping in the Yangtze River Delta. The spatial distribution and connection of online commodity extensively reflect the characteristics of urban system (Vind and Fold, 2010), showing a comprehensive flows of information, innovation and services.

Several studies have adopted online commodity to analyzing urban system, mainly focusing on the spatial distribution differences of its development (Hashimoto, 2002; Wang and Lu, 2011). Nevertheless, few literatures have been conducted to explore city networks of online commodity (Xi et al., 2015). Furthermore, the city networks based on traditional economic connections have been challenged in an e-commerce world like China. Taking the clothing and electronic retailers of Tmall as an example, this study use the data of online commodity services to develop Chinese intercity network in the internet economy era. It expands empirical research from traditional industrial and infrastructure network to the newly internet economic network.

3 Data and Methods

3.1 Data and study area

In the context of information technology development, the configuration and connection network of online retailers or branders can reflect status of urban function and ability for innovation agglomeration in the global commodity chain. Using the open application programming interface (API) data from Tmall of Alibaba Group, we mined the registered city information of different online goods and assumed that the total number of goods for sale represents the online commodity service

level of each city. Tmall is largest B2C online shopping platform in China, with nearly 300 000 online retail stores. According to a survey from the China Internet Network Information Center, transaction of Tmall in 2015 accounts for 65.2% of China's online retail market. Clothing and electronic products are also reported as the most popular for online buyers, and Internet users who have purchased clothing and electronic products online reach 79.7% and 44.8%, respectively (CNNIC, 2016). In addition, Tmall supplies most of the clothing and electronic products as physical retail. For online clothing retail, a great difference in spatial configuration between international and Chinese brands exists; therefore, we adopted 57 best-selling international brands and 52 best-selling Chinese brands for empirical analysis. For electronic products, we mainly used 37 best-selling brands.

Data were collected in September 2016. We used python program to retrieve the commodity information of 109 clothing brands and 37 electronic product brands from Tmall website, including the registered city of the online stores, brand information, and commodity item number of each store. A total of 620 000 clothing and 492 000 electronic product items were obtained. Brands, with the number of commodity items less than 1000, were removed from the dataset. We retained 580 487 clothing items from 36 international and 45 Chinese brands as valid samples, as well as 458 246 electronic items from 31 brands. We count the total commodity item amount of different brands in each prefectural city in China (excluding Taiwan, Hong Kong and Macao). This study mainly focuses on 337 prefectural cities as the research units. Ninety-seven cities with a higher number of commodity items are selected as the actual study units, including global cities (Beijing, Shanghai, Guangzhou, *etc*.), regional central cities (Nanjing, Zhengzhou, Chengdu, *etc*.), and small and medium-sized cities in China. Among the selected cities, there are 65 cities located in eastern China, 25 cities in central China and other 8 cities in western China (Fig. 1). Finally, we get the commodity item distribution of 81 clothing brands and 31 electronic product brands in 97 cities, forming a matrix of 97 (cities) × 81 (online clothing brands) and another matrix of 97 (cities) × 31 (online electronic product brands).

3.2 Model

The interlocking network model and the global specialization rate are mainly adopted for the empirical analysis. The details of these two methods are following

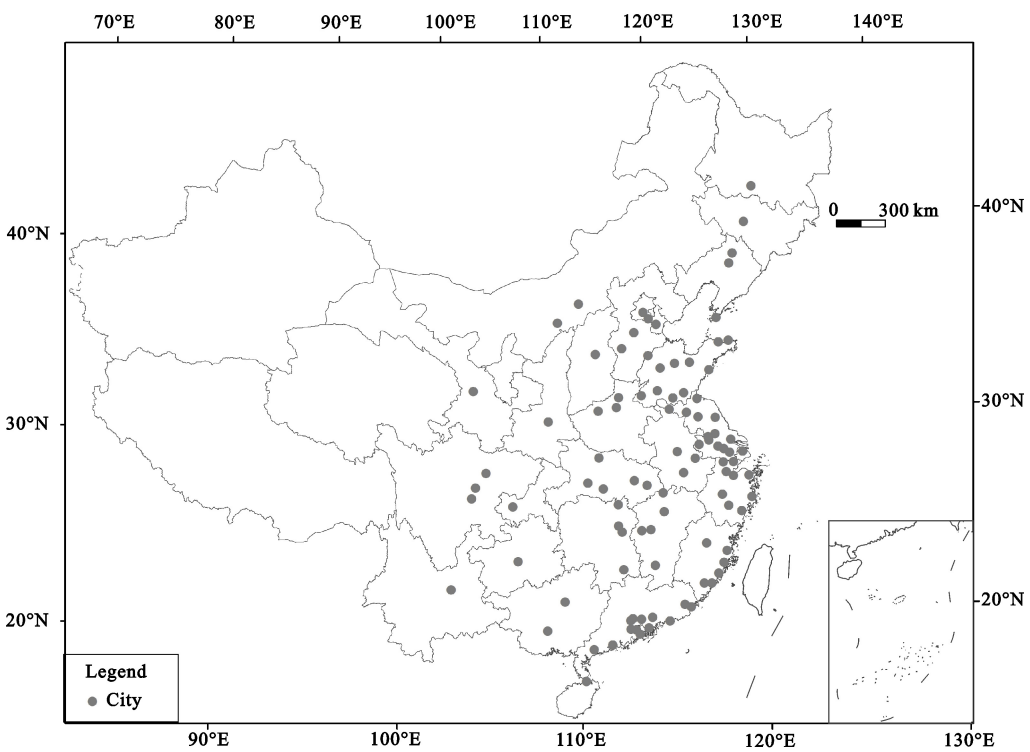

Fig. 1 Distribution of research cities

here. Besides, complex network methods are also used in empirical analysis, including the indices of in-degree and out-degree.

3.2.1 Interlocking network model

The item number of the same brand commodity for selling can largely reflect the service value and connection of retailers among different cities. The number of commodity items can represent a city's hierarchical status and inter-connection of the same brand commodity can indicate connectivity between cities. The online commodity connection between two cities could be interpreted from two approaches. One approach is retailer' aspect. There usually has close flows of information, capital and trading service between retailers of the same brand. The size of commodity sold by retailers could be used to represent the intensity of these flows. That is to say, if two cities sale the same brand online commodity, the linkage of this brand commodity could indicate the flows of information, capital and transaction service between the two cities. Another approach is online buyers or online consumers. The connection of certain brand commodity between two cities may denote that online buyers share similar taste and identity for its consumption. Therefore, the online commodity connections between cities are similar to the producer service linkages.

From this point of view, we calculated China's city networks through the item number of online clothing and electronic commodity by referring to the interlocking network model for producers' services (Taylor, 2001; Liu and Derudder, 2012; 2013). We assumed that m online clothing brands are located in n cities. The service value of city i can be defined as the online commodity item number of brand j, which can be expressed by V_{ij}. Thus, the online commodity service value matrix V can be expressed as follows:

$$C_{ab,j} = V_{aj} \times V_{bj} \tag{1}$$

where V_{aj} and V_{bj} are the service value of brand j in cities a and b, respectively, and $C_{ab,j}$ denotes the linkages between cities a and b through online clothing (or electronic) brand j. Therefore, the total connections between cities a and b can be calculated as follows:

$$C_{ab} = \sum_{j=1}^{m} C_{ab,j} \tag{2}$$

Each city has $n-1$ such links at most. The absolute node degree N_a of any city can be shown as follows:

$$N_a = \sum_{i=1}^{n} C_{ai} (a \neq i) \tag{3}$$

In the Equation (3), C_{ai} denotes the connections between cities a and i ($a \neq i$) and N_a represents the absolute node degree in city network. The higher the node degree, the better one city can be integrated into the system of city networks. In addition, the standardized node degree is as follows:

$$P_a = \frac{N_a}{N_h} \tag{4}$$

where P_a is the standardized node degree of city a and N_h indicates the highest connection for city h in the whole network.

3.2.2 Global specialization rate

Commodity service level of international brands in Chinese cities can reflect their global linkage with the origin countries of the brands. Although the flows of commodity between Chinese cities and other countries are difficult to obtain, reflecting the global connection through the specialization rate of international brands among different Chinese cities is possible. The higher the specialization rate, the closer the city's global linkages. The formula of specialization rate is as follows:

$$Q_{ij} = \frac{\dfrac{L_{ij}}{\sum_{i=1}^{n} L_{ij}}}{\dfrac{\sum_{i=1}^{n} L_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{m} L_{ij}}} \tag{5}$$

where Q_{ij} denotes the specialization rate of international clothing brand j in city i within China, and L_{ij} represents the online commodity service value of clothing brand j in city i. Then, m is the number of international brands while n is the number of cities.

Thus, the global connection between a Chinese city and certain country can be expressed through the average specialization rate of all online brands from that country:

$$CD = \frac{1}{n} \sum Q_{ij} \tag{6}$$

CD represents the global connection (average specialization rate) between the Chinese city and origin country of the international brands, and n denotes the

number of brands from the same country.

4 Results

4.1 Node degree

Using equations (1)–(4), the network connectivity of 97 cities is calculated with the data of online clothing commodity items of international and Chinese brands, and online electronic commodity items, respectively. We used degree centrality and in- and out-degree to reflect the degree characteristics of different cities. The degree centrality reflects the linkages of certain city with others cities in the network. The higher the degree centrality one city has, the more intensive commodity related flows the city could obtain. Out-degree reflects city's controlling on the online commodity service, the higher out-degree means the higher status of control. In-degree is adopted to show the ability to attract commodity flows from the higher level city.

Table 1 shows the top 30 cities of higher standardization values of online international and Chinese clothing brands distributed between 0 and 1. From the city network connectivity of international clothing brands, the result shows that Shanghai is the highest and plays an

Table 1 City's standardized node degree based on online clothing commodity of international and Chinese brands (Top 30)

Rank	Online clothing commodity of international brands				Online clothing commodity of Chinese brands			
	City	Degree centrality	In-degree	Out-degree	City	Degree centrality	In-degree	Out-degree
1	Shanghai	1.000	0.185	1.000	Shanghai	1.000	0.492	1.000
2	Hangzhou	0.778	0.315	0.905	Suzhou	0.956	0.679	0.792
3	Xiamen	0.666	0.351	0.726	Hangzhou	0.693	0.639	0.994
4	Beijing	0.650	0.488	0.822	Guangzhou	0.638	0.726	0.803
5	Guangzhou	0.618	0.393	0.853	Quanzhou	0.622	0.690	0.709
6	Lianyungang	0.608	0.348	0.393	Beijing	0.618	0.738	0.807
7	Quanzhou	0.536	0.637	0.657	Xiamen	0.577	0.500	0.658
8	Suzhou	0.536	0.652	0.666	Hefei	0.479	0.567	0.573
9	Shenzhen	0.509	0.595	0.758	Jinan	0.471	0.786	0.628
10	Changsha	0.356	0.699	0.593	Wuhan	0.462	0.607	0.677
11	Jinhua	0.355	0.586	0.604	Zhengzhou	0.379	0.837	0.484
12	Wenzhou	0.304	0.702	0.444	Jiaxing	0.321	0.718	0.514
13	Wuhan	0.276	0.667	0.551	Nanjing	0.316	0.893	0.558
14	Zhengzhou	0.259	0.860	0.391	Jinhua	0.314	0.595	0.495
15	Jiaxing	0.244	0.491	0.425	Wuxi	0.269	0.520	0.376
16	Hefei	0.235	0.836	0.498	Luoyang	0.260	0.063	0.172
17	Shijiazhuang	0.216	0.979	0.394	Changsha	0.251	0.599	0.361
18	Jinan	0.215	0.622	0.394	Chengdu	0.241	0.591	0.465
19	Chengdu	0.213	0.839	0.503	Ningbo	0.237	0.579	0.429
20	Fuzhou	0.195	0.824	0.465	Baoding	0.232	0.270	0.115
21	Wuxi	0.181	0.857	0.365	Taizhou (Jiangsu)	0.221	0.536	0.149
22	Dongguan	0.171	0.920	0.478	Nanchang	0.212	0.726	0.316
23	Nanjing	0.170	0.830	0.519	Wenzhou	0.206	1.000	0.450
24	Nanchang	0.169	0.899	0.366	Shaoxing	0.196	0.702	0.297
25	Shenyang	0.152	0.982	0.334	Shijiazhuang	0.171	0.694	0.386
26	Ningbo	0.150	0.958	0.434	Lianyungang	0.165	0.437	0.204
27	Tianjin	0.146	0.592	0.482	Fuzhou	0.148	0.825	0.395
28	Xuzhou	0.137	0.604	0.240	Nantong	0.142	0.726	0.285
29	Nantong	0.121	0.801	0.326	Zhenjiang	0.140	0.246	0.187
30	Baoding	0.120	0.574	0.153	Weifang	0.127	0.202	0.153

absolutely dominant function, followed by Hangzhou (0.778), Xiamen (0.666), Beijing (0.650), Guangzhou (0.618) and Lianyungang (0.608). This implies that all the international clothing brands sold in other cities could be found in Shanghai, thus Shanghai owns the most intensive information, capital and other flows generated by online international clothing retailers, as well as the greatest identity from online purchasers. By contrast, cities with network connectivity less than 0.2 reach more than 80% in the 97 cities. Cities with higher node degree centrality are concentrated in the eastern coastal area, where the highest degree of internationalization regions in China is located. Predictably, advantages of online commodity service of international clothing brands further strengthen the status of these cities in Chinese urban system and internet economic development. However, traditional regional centers in central and western China, such as Xi'an, Zhengzhou, and Chongqing, keep the lower node degree centrality and functional status in the city's hierarchical structure.

Consistent with international brands, Shanghai continues to occupy the highest network connectivity based on online commodity services of Chinese clothing brands. The node degree centrality of Suzhou is 0.956, which is very close to that of Shanghai, followed by Hangzhou, Guangzhou, Quanzhou, and Beijing, with their node degree centrality ranging from 0.618 to 0.693. The node degree centrality for 76% of cities (74 out of the 97 cities) is less than 0.2. Several cities with highly industrial agglomeration of clothing manufacturing are also the center of online commodity services, such as Suzhou and Quanzhou. These cities are usually near to large cities and have good transportation and information infrastructure networks, indicating a close functional contact between online commodity service and clothing manufacturing. The Internet provides a new channel for clothing manufacturing cities to sell products besides the physical commodity distribution. At the same time, Hefei, Jinan, Wuhan, Zhengzhou, Chengdu, and other regional center cities (provincial capital) become a relatively high node degree centrality and play an important role in the networks of online clothing commodity services.

With the city network connectivity of online electronic commodity (Table 2), the result shows that the node degree centrality of Shenzhen is highest (also with the highest out-degree). Several cities are second to Shenzhen, including Shanghai, Beijing, Guangzhou, Dongguan, and Hangzhou with the node degree centrality from 0.328 to 0.658. These cities are regions in which China's electronic and telecommunication equipment manufacturing industry clusters are located (Zhang et al., 2014), and industrial clusters provide the basis for the supply of commodity for online sales. However, the remaining cities mainly located in central and western China have a very small value of node degree centrality. In general, it can be seen that the city network of online electronic commodity exhibits a highly polarized feature. Especially, Shenzhen performing as the distinguished core in city network, dominates the flows as well as the value and consumption needs of electronic commodity.

Table 2 City's standardized node degree based on online electronic commodity (Top 30)

Rank	City	Node degree centrality	In-degree	Out-degree
1	Shenzhen	1.000	0.029	1.000
2	Shanghai	0.658	0.062	0.984
3	Beijing	0.536	0.216	0.904
4	Guangzhou	0.414	0.269	0.880
5	Dongguan	0.333	0.370	0.792
6	Hangzhou	0.328	0.382	0.820
7	Wuhan	0.275	0.423	0.779
8	Nanjing	0.268	0.363	0.836
9	Fuzhou	0.197	0.558	0.687
10	Chengdu	0.152	0.651	0.661
11	Suzhou	0.152	0.678	0.644
12	Hefei	0.120	0.854	0.510
13	Quanzhou	0.119	0.380	0.308
14	Jinan	0.106	0.801	0.575
15	Zhengzhou	0.104	0.840	0.548
16	Xiamen	0.092	0.943	0.507
17	Yangzhou	0.090	0.575	0.486
18	Taizhou (Zhejiang)	0.082	0.883	0.409
19	Ningbo	0.082	0.745	0.490
20	Changsha	0.075	0.867	0.382
21	Xuzhou	0.073	0.747	0.437
22	Qingdao	0.066	0.922	0.394
23	Zhuhai	0.061	0.784	0.348
24	Chongqing	0.058	0.965	0.344
25	Yangjiang	0.058	0.579	0.258
26	Wenzhou	0.058	0.682	0.233
27	Changzhou	0.055	0.788	0.288
28	Weifang	0.051	0.727	0.316
29	Shantou	0.050	0.749	0.264
30	Shijiazhuang	0.049	0.903	0.292

In the city network of online clothing and electronic commodities, it can be seen that the core cities are mainly concentrated in the eastern coastal areas of China, including Shanghai, Beijing, Guangzhou, Shenzhen, Hangzhou, and other cities. The core cities, the most advantageous centers in different commodity networks, have the highest hierarchical positon with the agglomeration of population and the prosperity of economy. These core cities also have the predominant basis of manufacturing industries. In the Internet age, traditional clothing and electronic product manufacturing center cities that can provide price-favorable goods also become the core cities of online retailing service. However, there are differences between the online clothing and electronic commodity networks. The primate city of online clothing commodity network is Shanghai, while the absolute core of online electronic commodity is Shenzhen. For online electronic commodity, the degree centrality of several network center cities is more prominent than that for the online clothing commodity. So, the hierarchy of cities in the networks would be differently formed with different commodities.

We further used the node degree to analyze rank-size distribution. According to the rank-size rule, Zipf's model is adopted to evaluate the distribution structure of node degree. The formula is as follows:

$$P_k = P_1 K^{-q} \tag{7}$$

where K is the rank of one city (K = 1, 2, 3, …, N, where N represents the number of all cities). P_k denotes the node degree of city k, and P_1 is the node degree of the primate city. q is the parameter.

Then, the natural logarithm of both sides of the above formula is calculated as follows:

$$\ln P_k = \ln P_1 - q \ln K \tag{8}$$

If Formulas (7) and (8) are significant, the rank-size structures of node degree are in accordance with Zipf's law. The size of Zipf's parameter q reflects the spatial distribution of node degree. When the value is equal to or greater than 1, the degree rank-size distribution of online commodity service complies with the Pareto pattern. It suggests that the degree centrality are more concentrated and only few cities belong to middle-rank. However, the concentrations of degree centrality are reduced when q becomes smaller, and the middle-rank cities are increased.

Fig. 2 shows the rank-size curves of node degrees of different online commodity services (the end cities with the lowest degrees are truncated). The curves of online international and Chinese clothing commodity are in accordance with the rank-size rule, and the determination coefficients (R^2) of the equations exceed 0.8. The q values of the equations with international and Chinese commodity services are all larger than 1, which indicates that the node degree rank-size structure of online clothing commodity service defers from the Pareto distribution. Therefore, the discrepancy of node degree among cities is quite different. Whether the node degree of online clothing commodity service of international brands, or that of Chinese brands is showing a high primate degree is unknown. The number of middle-rank cities is small. It indicates that there are fewer middle-rank cities based on the connectivity of international clothing commodity because the q value of international clothing commodity is higher than that of Chinese clothing commodity. Meanwhile, online clothing commodities of international brands have more agglomeration in the primate city.

With the rank-size curves of node degrees of online electronic commodity, due to the determination coefficient (R^2) of the equation is less than 0.8, so the estimation of the curve is not significant. However, the q value of the equation is far greater than 1, which indicates that the curve of online electronic commodity also conforms to the rank-size rule. It illustrates that the node degree centrality is concentrated at the primate cities and the number of middle-sized cities is limited. This finding

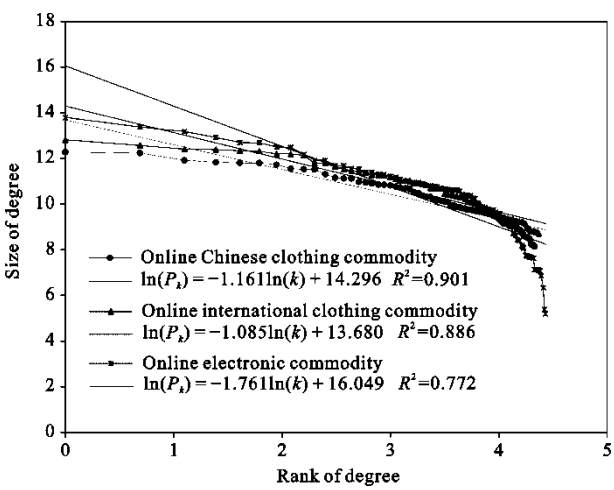

Fig. 2 Degree rank-size distribution of different online commodity. k is the rank of node degree and P_k represents the value of node degree

further verifies that the center cities present an exceptionally-prominent dominance in the city network of online electronic commodity.

Comparing city's rank-size distribution of online clothing commodity (both international brands and Chinese brands) and online electronic commodity, the q values of node degree centrality regression curves are all greater than 1, which indicates that the city's node degree centralities of both products are obeyed to the Pareto distribution pattern and primate city distribution. That is, the importance of the cities in the network is quite different, with the prominent center cities, the obviously vulnerable small and medium-sized cities, and the higher primate degree. On the whole, the node degree centralities are concentrated to a small number of cities with different online retail products. However, the spatial differences of node degree centrality of online electronic commodity are more significant than that of online clothing commodity. The node degree centralities of online electronic commodity are obviously aggregated at the high-grade cities.

4.2 Distribution of intercity connections

We used the interlocking network model to calculate the intercity network connectivity among 97 cities. Based on ArcGIS software, intercity network connections are divided into five levels by the natural discontinuous point classification method. Then, the highest three levels of intercity network connections are expressed in Figs. 3–5. Further, we mainly focus on the symmetrical matrix of the top 15 cities ranked by node degree (Tables 3–5).

In terms of online clothing commodity network of international brands, we find that 33 pairs of cities with a linkage of more than 10 000, account for 0.71% of the total 4656 linkages. Moreover, 51 pairs of cities have a linkage between 5000 and 10 000, and 408 pairs of cities have a linkage between 1000 and 5000, accounting for 1.10% and 8.76%, respectively. The remaining 90% of city pairs are less than 1000. The network linkages show a significant index declining trends. With the symmetrical matrix in Table 3, we further find that the linkages of Shanghai-Hangzhou (26 968), Shanghai-Xiamen (23 100), Shanghai-Beijing (23 088), and Shanghai-Lianyungang (22 854) are the highest, which are significantly higher than that of other city linkages.

The result indicates obvious spatial differences in Chinese intercity network systems based on online clothing commodity of international brands (Fig. 3). Beijing, Shanghai, Guangzhou, Xiamen, and other core cities of the network are mainly concentrated in the eastern coastal areas of China, especially in the Yangtze River Delta region. However, the network concentration level of cities in the central areas of China was significantly lower than that in eastern coastal areas. Although

Table 3 Intercity connection matrix based on online clothing commodity service of international brands

	Shanghai	Hang-zhou	Xiamen	Beijing	Guang-zhou	Lianyun-gang	Quan-zhou	Suzhou	Shenzhen	Chang-sha	Jinhua	Wenzhou	Wuhan	Zheng-zhou	Jiaxing
Shanghai	0														
Hangzhou	26968	0													
Xiamen	23100	15441	0												
Beijing	23088	16706	13734	0											
Guangzhou	20298	15415	11658	12404	0										
Lianyungang	22854	16783	15134	15828	10143	0									
Quanzhou	17099	12704	11382	9303	11728	3040	0								
Suzhou	18256	13162	11976	11749	10122	11343	8730	0							
Shenzhen	18385	12655	10556	10866	9760	11525	7642	8734	0						
Changsha	12431	8781	8422	8119	5981	11153	3006	6253	6025	0					
Jinhua	11101	8732	7884	7348	6136	9241	4154	5874	5680	4893	0				
Wenzhou	9416	7212	5983	6160	5259	7424	3838	4902	4718	3520	3383	0			
Wuhan	8687	6779	5675	5654	4671	7312	3457	4061	4251	3543	3277	2714	0		
Zhengzhou	8349	6302	5720	5494	4473	7766	2469	3799	4143	3569	3115	2740	3656	0	
Jiaxing	5800	5275	3804	3592	5698	1158	5726	3214	2877	1272	2008	1912	1450	1591	0

Changsha, Wuhan, Zhengzhou, and other cities in the central areas play the role of regional economic centers, they are non-core cities in the clothing commodity network of international brands. In addition to Chengdu, most of the cities in China's western areas are at the fringes of the network. In general, the intercity network based on the online clothing commodity of international brands shows a functional decay trend from east to west. On the one hand, this configuration was caused by the spatial differences of factors related to online retailing, such as global trade, degree of globalization, development of infrastructure and information network, and other factors. On the other hand, spatial differences of online commodity services of international brands may further aggravate the polarization between the core and periphery cities in the Chinese intercity network. The control and function of core cities will be further strengthened in the networks of Internet and global commodity information, capital and value flows, while periphery cities will face more and more marginalization due to their weakness in the Internet world. Perhaps, the core-fringe polarization of city function related to information technology and internet economy might be expanded.

Table 4 shows the network characteristics of the top 15 cities based on the online clothing commodity network of Chinese brands. The table shows that the top seven intercity linkages of more than 10 000 are Shanghai-Suzhou (19 245), Shanghai-Hangzhou (12 782), Shanghai-Guangzhou (10 569), Shanghai-Beijing (10 122), Suzhou-Hangzhou (11 010), Suzhou-Beijing (11 155), and Guangzhou-Quanzhou (10 560). The linkage between Shanghai and Suzhou is much higher than that of other intercity linkages. It also shows that Shanghai and Suzhou are two distinct core cities with their network linkage and hierarchy, which are greatly different from online clothing commodity network of international brands. Following these two cities, Beijing, Guangzhou, Hangzhou, and Quanzhou are the sub-core nodes.

Overall, the core cities of online clothing commodity network of Chinese brands are mainly concentrated in the Yangtze River Delta, Pearl River Delta, Fujian Province, and other eastern China areas (Fig. 4), which are famous prominent centers of clothing manufacturing. The advantage of clothing production provides product support for the development of online retailers due to the effects of spatial proximity. Hefei, Wuhan, and other cities in central China also dominate online clothing commodity networks of Chinese brands. However, Chengdu, Kunming, and other cities in western China are still at the fringes of the network with the

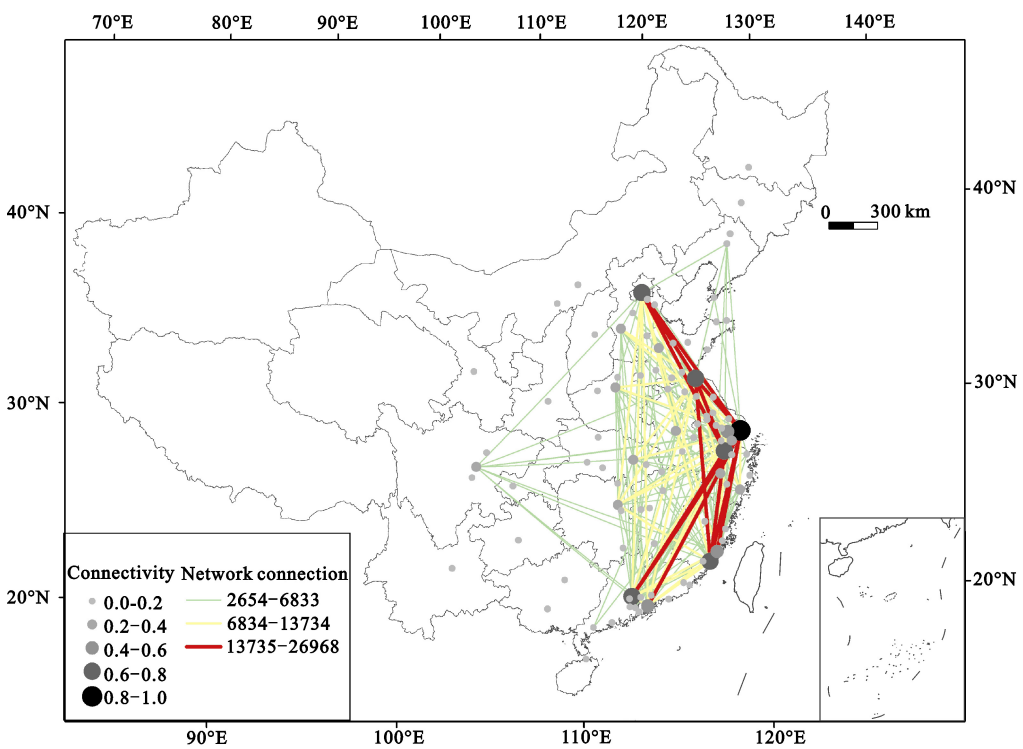

Fig. 3 China's intercity networks based on the online clothing commodity services of international brands

Table 4 Intercity network connection matrix based on online clothing commodity of Chinese brands

	Shanghai	Suzhou	Hangzhou	Guangzhou	Quanzhou	Beijing	Xiamen	Hefei	Jinan	Wuhan	Zhengzhou	Jiaxing	Nanjing	Jinhua	Wuxi
Shanghai	0														
Suzhou	19245	0													
Hangzhou	12782	11010	0												
Guangzhou	10569	7252	8502	0											
Quanzhou	9359	8513	5203	10560	0										
Beijing	10122	11155	7417	7498	6341	0									
Xiamen	8861	7085	5596	6289	9445	6696	0								
Hefei	8808	8762	6243	2167	2092	4269	3001	0							
Jinan	7883	7304	4608	2913	6007	3986	5819	4139	0						
Wuhan	7941	7903	4285	2557	4364	4758	4493	4102	3717	0					
Zhengzhou	6395	6394	3399	6714	4964	4464	3708	2309	2411	2809	0				
Jiaxing	6556	6217	4626	2999	1199	2810	1395	3258	2208	1805	980	0			
Nanjing	4333	5529	3162	3832	4279	3454	3467	1938	2275	2388	2140	1232	0		
Jinhua	5441	5500	3458	1818	1462	3242	3121	2796	2257	2775	1704	1630	1614	0	
Wuxi	4827	6073	3705	1438	1785	2027	1650	2684	1918	2097	1329	1875	1462	1594	0

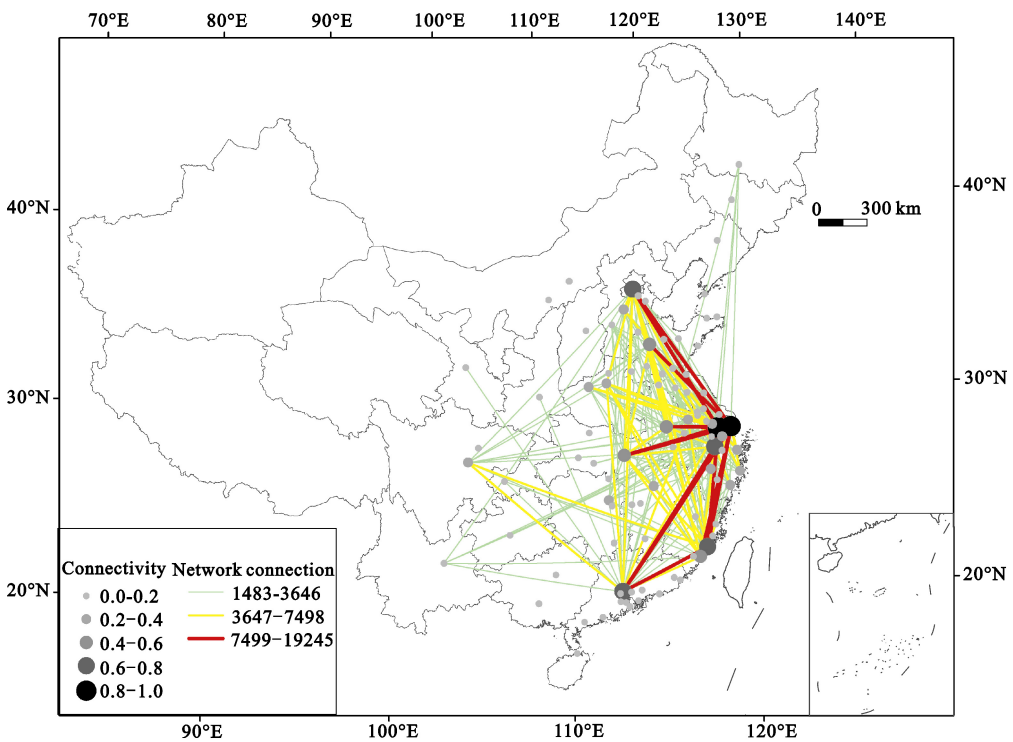

Fig. 4 China's intercity network based on the online clothing commodity services of Chinese brands

lowest linkages and node degrees. In general, online clothing commodity networks of Chinese brands are closely linked between eastern and central cities.

With the network of online electronic commodity, Table 5 shows 7 pairs of cities with a linkage of more than 50 000, including those of Shenzhen-Shanghai (122 467), Shenzhen-Beijing (99 496), Shenzhen-Guangzhou (74 254), Shenzhen-Dongguan (60 190), Beijing-Shanghai (59 105), Shenzhen-Hangzhou (58 414), and Shenzhen-Wuhan (51 282). Among these top linkages, the connection between Shenzhen and Shanghai is strongest, then that between Shenzhen and Beijing, which indicate that these cities share highly similar and dominate online retailing services of electronic products. Besides these top cities, the value of other linkages decreases significantly.

Table 5 Intercity network connection matrix based on online electronic commodity services

	Shenzhen	Shanghai	Beijing	Guang-zhou	Dong-guan	Hang-zhou	Wuhan	Nanjing	Fuzhou	Chengdu	Suzhou	Hefei	Quan-zhou	Jinan	Zheng-zhou
Shenzhen	0														
Shanghai	122467	0													
Beijing	99496	59105	0												
Guangzhou	74254	44625	36717	0											
Dongguan	60190	35106	29296	21726	0										
Hangzhou	58414	34958	28841	21223	16650	0									
Wuhan	51282	28905	22757	17350	13852	13931	0								
Nanjing	46352	30459	22782	17059	12697	13330	10902	0							
Fuzhou	36500	21258	15937	11868	9617	9756	9417	8261	0						
Chengdu	26192	16015	12770	9345	7688	7638	6333	6101	4710	0					
Suzhou	28343	16031	12582	9378	7023	8042	7416	6215	5296	3375	0				
Hefei	20540	12189	9675	7633	6217	5574	4872	4576	3395	2628	2330	0			
Quanzhou	20479	11749	9386	7840	6713	5191	4777	4198	3134	2546	1794	2694	0		
Jinan	18299	10981	8904	6521	5395	5332	4353	4247	3211	2564	2348	1870	1801	0	
Zhengzhou	17820	10665	8924	6496	4994	5361	4370	4118	3098	2381	2542	1643	1405	1626	0

Fig. 5 further shows that the network structure of online electronic commodity is extremely unbalanced between different regions. The core cities with highest connections and hierarchy are located in the eastern coastal areas, such as Shenzhen, Shanghai and Beijing, while most cities in central and western China are at the fringes of the network with their weak connections. In the linking process of online commodity service, core cities with the greater number of online commodities possibly own more regional agents and wholesalers, which can contact sub-agents or retailers operating in the fringe cities.

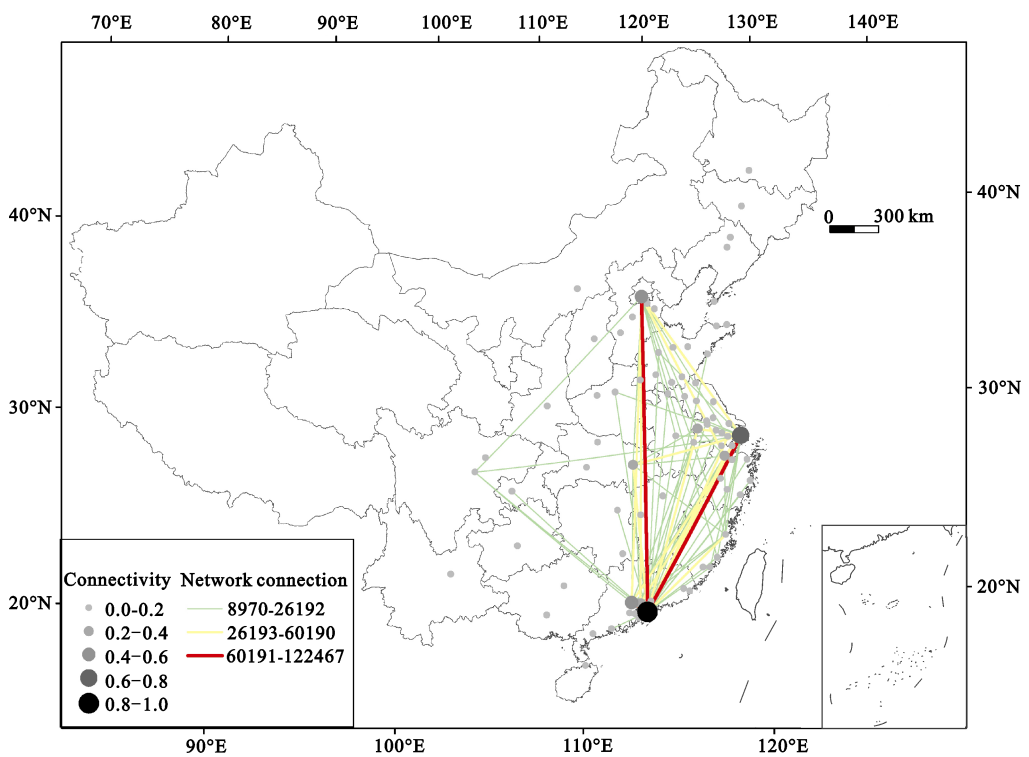

Fig. 5 China's intercity network based on the online electronic commodity services

Comparing the networks of different online commodities, the results demonstrate that similarities of spatial pattern in intercity networks exist. It can be summarized as the spatial polarization and obvious layer structure of connections in the networks, showing significant descending trends from the centers in eastern China to periphery cities in central and western China. The center cities and top tiers in different commodity networks consist of Beijing, Shanghai, Guangzhou, and Shenzhen. It suggests that these cities have the strongest flows of information, technology, capital and even innovation in internet economic era. Even connections and hierarchies between cities have been expected to be more flattened in the information and Internet economy age (Zhen et al., 2016). Nevertheless, the intercity links of commodity networks still present great imbalance mainly due to path dependence. That is to say, the spatial patterns of online commodity networks are mainly determined by the economic, transportation, and information infrastructure networks.

Differences between intercity networks of online clothing commodity and electronic products also exist. With the hierarchy of city connectivity, high and middle grade cities in the network of online clothing commodity are more than those in the network of online electronic commodity. In terms of network connections, the link ranges in online clothing commodity networks are more than those in the online electronic commodity network. Even more cities can be better connected into the networks of online clothing commodity, especially for the online clothing commodity of Chinese brands, while the cities incorporated into the network of online electronic commodity are fewer. In general, intercity networks based on different kinds of online commodity have different levels of control over urban systems.

4.3 Global connection networks

Due to most of online electronic commodities are provided by Chinese retailers on Tmall platform, so we use the online clothing brands from different countries to calculate global specialization rate, reflecting the connection characteristics of online commodity network between Chinese cities and other countries in the world. We also selected representative cities from different areas in China to analyze their global connection networks with countries that have more than two clothing brands (Table 6). The result shows that the global specialization rates of Shanghai, Xiamen, and Suzhou are more than one with the online clothing brands from the US, indicating strong global connections between these cities and the US. At the same time, Guangzhou and Hangzhou are closely linked with brands from Italy, while Shanghai and Shenzhen are closely linked with those of France. Despite the specialization on these countries, Wuhan and Zhengzhou show low rates, but Chengdu in western China has a high specialization rate (3.592) with the clothing brands from Denmark.

Thus, online commodity connections between different Chinese cities and countries in the world present complex characteristics. Shanghai, Hangzhou, and Guangzhou dominate the online clothing commodity networks of international brands, but these cities are not highly specialized with the commodity brands originated from other countries. Unlike traditional global

Table 6 Specialization rates of representative cities with different countries

Ctiy	US	Germany	Italy	France	Denmark	Japan
Beijing	0.736	1.235	0.045	0.271	0.021	0.177
Shanghai	1.247	0.559	0.080	2.256	0.013	3.536
Guangzhou	0.647	1.421	4.612	0.468	0.042	0.156
Hangzhou	0.698	0.700	2.207	0.185	0.217	0.206
Xiamen	1.114	1.503	0.015	0.051	0.000	0.010
Lianyungang	0.566	0.952	0.000	0.004	0.000	0.000
Quanzhou	0.910	0.080	0.029	0.037	0.015	0.031
Suzhou	1.589	1.649	0.151	0.012	0.000	0.168
Shenzhen	0.376	0.734	0.869	3.268	0.002	0.021
Wuhan	0.354	0.446	0.101	0.112	0.000	0.089
Zhengzhou	0.637	0.540	0.012	0.055	0.008	0.000
Chengdu	0.662	0.570	0.109	0.132	3.592	0.337

commodity distribution networks, Internet and online retailing increases the spatial uncertainty of commodity supply and distribution. Although some are disadvantaged in the global city network, they might have obvious advantages on the online connection of certain commodity and obtain new opportunity for globalization development.

5 Discussion and Conclusions

In the context of globalization and informatization, the Internet economy has increasing control on urban functions and connections, thereby reshaping city network (Zhen et al., 2015). Using the commodity data of Tmall clothing and electronic product retailers as basis, this study explores the Chinese city network in the age of Internet economy by analyzing online commodity service networks with interlocking network model and specialization rate of global commodity connections. Different city networks are also compared between the online clothing commodity of international and Chinese brands and online electronic commodity.

Results show that online commodity service network presents many new features compared with the traditional Chinese urban system. The connections of different commodity networks show similar descending trends from eastern cities to central and western cities in China. Although megacities in the eastern coastal areas maintain high levels of control and functions in intercity network, smaller cities such as Quanzhou, Lianyungang, Jiaxing, and Wenzhou enjoy a fairly high hierarchy in the urban system of online clothing commodity networks. By contrast, traditional regional central cities, such as Xi'an, Chongqing, Kunming, and Lanzhou, are of lower hierarchy. In general, Beijing, Shanghai, Guangzhou, and Shenzhen are the core and top tier cities in different online commodity networks. However, Shanghai occupies the status of primate city in online clothing commodity network, but the primate city in online electronic commodity network is Shenzhen. Furthermore, the hierarchy and connection of online clothing commodity network are more concentrated than that in online electronic commodity network. Unlike traditional global commodity chain, the online commodity services of different cities show obvious differences and uncertainties in terms of their specialization rates of international connection, presenting a tendency of diversification. Cities that are not the core in the global connection networks can be offered with new opportunities of development to a certain extent, forming themselves to be a certain functional center in the global commodity supply chain (Wang and Cheng, 2010).

The comparison of online commodity services of international and Chinese brands shows that core cities of international brands are highly concentrated in the eastern coastal areas, while cores of Chinese brands are mainly located in eastern and central China. Such is the case because the traditional urban system is geographically dependent, where urban population and transportation infrastructure serve as the key determiners in locational conditions, agglomeration of factors, and spatial interaction. However, the application of the Internet and popularization of online commodity services weaken the isolation of geographic spaces and lead to time-space compression, while information location factors alter the socio-economic linkages between cities and reshape the traditional city network. On the one hand, although industrially developed cities (e.g., Quanzhou, a city famous for clothing production) remain at lower levels in the traditional urban system, their control and function have been increasing due to their significantly improving commodity services with e-commerce platforms. On the other hand, economically central cities in the middle and western areas are being marginalized in terms of Internet economy and online commodity services; consequently, their influence is decreasing in Chinese intercity networks.

Unlike traditional urban network whose major measuring indexes are population sizes and entity enterprises, online commodity service network can reflect well the impact of emerging economies, especially the Internet economy, on city networks. In traditional economy, population and enterprises represent the control of city on physical goods and services. In the age of Internet economy, online commodity service networks not only associates with the capacities of goods production, supply, and consumption in physical space but is also closely associated with virtual information, capital, and technology flows. In addition, the range of their services is no longer limited to a certain space. As a result, the analysis on online commodity networks can reflect the interaction between the spaces of flows and places and their effects on city connection and network. Such an analysis is also helpful for describing the hierarchies and

connections of Chinese intercity network.

The ability of online commodity services is closely related to the city's internet penetration rate and logistics system (Du et al., 2016). The regional differences of Internet application remain substantial in developing countries. For example, the Internet penetration rate of western China is 16%, less than that of eastern China (CINNC, 2015), which determines the functional level of different cities in online commodity service network. The regional differences of third party logistics companies lead to different express prices, causing various costs of online goods express in different regions (Xi et al., 2015). These factors, including retail and manufacturing industries and social consumption and economic development levels, also affect the functions of city online commodity services (Du et al., 2016). Future studies should attempt to measure and understand the reshaping of city networks under the interaction between online commodity services and traditional socio-economic factors.

This study confirms that online commodity services lead to the polarization of cores and fringes in China's intercity networks as well as the flattening of the internal network connection in the developed coastal areas. Nevertheless, insufficiencies exist in this work due to the limitations of accessibility of data and representation of commodity types. The online commodity networks should be more precisely reflected by different indexes, such as commodity supplies, demands, and distribution. In addition, the dependency of online commodity services on the physical economy and commodity supply chain, as well as how a city network is altered, need to be further explored.

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