

Evolution of the Complex Network Topology of Producer Services and the Dynamic Upgrading of Manufacturing Value Chain in Guangdong-Hong Kong-Macao Greater Bay Area

Chuqi Chen^{1, a}, Sheng Liu^{2, b, *}

¹School of Economics and Trade, Guangdong University of Foreign Studies, Guangzhou City, Guangdong Province, P. R. China

²Institute of Studies for the Greater Bay Area & Center for Cantonese Merchants Research, Guangdong University of Foreign Studies, Guangzhou City, Guangdong Province, P.R. China

^ajust2525@163.com, ^{b,*}gdufsliusheng@126.com

Abstract

In the context of close integration of economic globalization and of local production networks, the network topology of producer service formed by the linkage between producer service and manufacturing industry has attracted widespread concern. Based on the research perspective of complex network theory, this paper theoretically analyzes the impact mechanism of how the evolution of network topology of producer service promotes the upgrading of manufacturing's value chain. In addition, taking the Guangdong-Hong Kong-Macao Greater Bay Area as research object, this paper further analyzes the evolution characteristics of network topology, such as the breadth, intensity and centrality of network connection of producer service, so as to identify the interactive efficiency between producer services and the upgrading of manufacturing value chain. Finally, this paper proposes the path of coordinated development of network topology of producer services and manufacturing value chain.

Keywords

Producer Services; Upgrading of Manufacturing Value Chain; Complex Network Topology.

1. Introduction

In recent years, China's producer service has developed rapidly and clustered in the eastern coastal cities and the central cities in the Midwest. The network topology of producer service has also been formed and evolved with the wide application of information technology and the connection of high-speed vehicles. As one of the important regions for the growth of producer services in China, manufacturing enterprises located in Guangdong-Hong Kong-Macao Greater Bay Area face both opportunities and challenges in the reconstruction of division of labor position in global value chain. In the context of multiple integration of intelligent manufacturing and economic transformation (Liu et al., 2017[1]; Liu et al., 2018[2]), whether and how the evolution of topological network structure of producer services affects the dynamic upgrading of global value chain of manufacturing enterprises is of great significance to emerging economies and new urban agglomerations in the world.

In the early stage, the relevant literature pays more attention to the impact of agglomeration scale of producer services on the development of manufacturing enterprises. For example, Liu et al. (2019) analyzed the impact of agglomeration scale of producer services on the upgrading of manufacturing's global value chain [3-4]. Due to the growth of producer service, the network interaction between service industry and manufacturing industry has been further discussed.

With the rise of the urban network based on producer services, more and more researches begin to focus on the relationship between the topological network organization of producer services and the production and business activities of manufacturing enterprises (Jacobs et al., 2011[5]; Bassens et al., 2020[6]).

Based on the previous studies, this article explains the impact mechanism of evolution of network topology of producer service on the upgrading of manufacturing's value chain. Also, it provides a theoretical explanation of the connection between producer service and manufacturing's global value chain through the interaction mechanism of network structure (including network connection breadth, network connection strength, network centrality, etc.).

2. Literature Review

2.1. Literature Overview

(1) Research on the Relationship between the Network of Producer Service and Industrial Development

The service industry establishes a relationship with city relying on site selection and economic activities, thereby creating an enterprise network and forming its own competitive advantage in the city. Also, the agglomeration of service industries and manufacturing industries has formed a kind of network topology in specific area, forming economies of scale, location advantages and urban networks. Producer services and manufacturing industries are interrelated and inseparable. Zhen, Wang et al. (2013) believed that the distribution of producer service has a positive effect on the development of city networks based on data from the producer service network [7]. Similarly, Zhao, Derudder et al. (2019) believes that the location information of producer service plays an important role in determining the connectivity of a city and its group [8]. Hanssens, Derudder et al. (2013) analyzed regional city networks directly based on the geographic location of Belgian's producer services procurement [9]. Correspondingly, the impact of manufacturing on urban networks has been discussed in some literatures. Krätke (2014) believes that manufacturing companies cover the world and effectively connect global cities by evidence from 120 top global companies in three manufacturing sub-industries [10]. Therefore the formation and deepening of manufacturing network will have a profound impact on the location and geographical pattern of a city. Therefore, while studying urban network, it is necessary to refine the research on network topology of producer service. The Guangdong-Hong Kong-Macao Greater Bay Area, as a city cluster with obvious location advantages, will also be closely related to the distribution of network topology of producer service.

In a practical study of producer service companies in urban networks, Van Meeteren, Neal et al. (2016) applied the latest two-way network prediction model to analyze the statistical relationships between intra-city and inter-city companies by simulating corporate entry behaviors and building urban network effects [11]. Zhang and Kloosterman (2016) detailed statistics on the number of advanced producer services (APS) in major cities of Pearl River Delta and used the "chain network model" to analyze the internal and external service networks of cities and regions in Pearl River Delta [12]. Also, the network evolution of group producer service was predicted. They believe that the growth of enterprises in the Pearl River Delta region is not only a result of market logic, but also the result of an institutional environment. In the future, the formation of network topology will continue to be the hub of Guangzhou-Shenzhen spreading to other places.

(2) Research on the Upgrading of Manufacturing Industry Driven by Producer Service Network

The relationship between producer services and manufacturing enterprises has always been the focus of economic research. Hansen (1993) denied the negative relationship between the

two in traditional cognition and agreed that the complex interaction played a role in improving productivity by explaining the relationship between producer services and manufacturing industry [13]. Chunbin (2011) believes that producer service is highly related to manufacturing value chain, and the integration of them is conducive to enhancing industrial competitiveness and promoting industrial upgrading [14]. Guerrieri and Meliciani (2005) believed that a country's ability to develop a competitive service economy depends on the structure of its manufacturing industry. The optimization of manufacturing structure effectively affects the development of the overall economy, so every country requires to layout and configure producer services which separate from manufacturing industry specifically [15]. Therefore, the formation of a reasonable topological network structure of producer services plays an important role in economic growth.

What about the mechanism that producer service network specifically affects the upgrading of manufacturing industry? Lia (2011) established a two-sector model and analyzed that producer service can provide information capital, differentiated services and reduced production costs, thereby improving manufacturing's capacity and production efficiency [16]. It can be seen that specialization, competition and external effects brought by producer service will exert great influence on the upgrading of manufacturing industry. From the perspective of network topology's visual description, the deepening of breadth, intensity and centrality of network will also directly increase the number of connected entities, transaction volume, and service dominance, thereby accelerating spillover of technological knowledge and transformation and upgrading of manufacturing. Some literatures have previously described the network parameters through the ability of nodes to diffuse in complex networks. Newman (2001) used network centrality measures, including compactness and intermediateness, to build collaborative networks among scientists in various disciplines [17]. Kinne (2012) studies the relationship between multilateral trade conflicts using three measurement methods: the breadth of trade links, the depth of trade links, and the commercial distance between non-partners [18]. In addition to the application of the theory, Gao et al. (2014) proposed a local structure center metric and enriched parameters based on the original node diffusion theory, fully considering the number of node neighbors and topological connections [19].

2.2. Literature Comments

In summary, the evolution of the producer service network promotes the construction of urban networks and the formation of geographical advantages through the collection of independent enterprise networks. Also, the dominant position of urban networks promotes the upgrading of manufacturing industries and the integration of more production and service companies. They complement each other. Based on the existing literature, this article focuses on the Guangdong-Hong Kong-Macao Greater Bay Area. This article mainly provides supplementary research from the following aspects.

On the one hand, this article tries to analyze the fundamental changes in industrial organization brought about by the evolution of the producer service's network topology. Different from some of the existing literature which focuses on the relationship between the scale of producer services and the development of manufacturing enterprises, this article attempts to investigate the co-evolution relationship and mechanism between network topology (including network connection breadth, network connection strength, network centrality, etc.) of producer services and manufacturing's global value chain.

On the other hand, previous studies have paid more attention to the urban networks of developed countries and transnational corporations based on producer services. However, new urban agglomerations in developing countries have special economic and social structural conditions, and the existing research conclusions and countermeasures may not be applicable. Based on the theoretical framework of urban network, this article focuses on the area of

Guangdong-Hong Kong-Macao Greater Bay Area because the urban network based on producer services in this area has made great progress, but its relationship and interaction mechanism with the local manufacturing industry foundation has not been studied in depth. Based on the analysis of the bottleneck constraints and driving factors of the interactive relationship between the network topology of producer service and the global value chain of manufacturing industry, this article further proposes relevant industrial governance strategies to provide inspiration for more emerging cities in developing countries to realize the industrial upgrading process.

3. Impact Mechanism

The service industry, as a supporting industry directly related to the manufacturing industry, is separated by virtue of its specialized production, regional exogenous comparative advantages, and high transaction efficiency. The manufacturing and service industries of the Guangdong-Hong Kong-Macao Greater Bay Area constitute local producer service network.

From the perspective of the value chain, for enterprises that enter the global value chain from the low end of value chain, their industrial upgrades generally follow the process of production flow upgrade to product upgrade, then function upgrade, and finally chain upgrade (Gereffi et al., 2001[20]). During this upgrade process, it will generate heterogeneous demands on the types and quality of service industries in different spatial scales and networks. When the positive evolution of producer service network in the Greater Bay Area starts, it will also play a positive role in promoting the upgrading of the manufacturing industry. The specific manifestation is the deeper the positive evolution of the producer service network is, the more significant the improvement of manufacturing production efficiency is. After the process, the manufacturing value chain is upgraded.

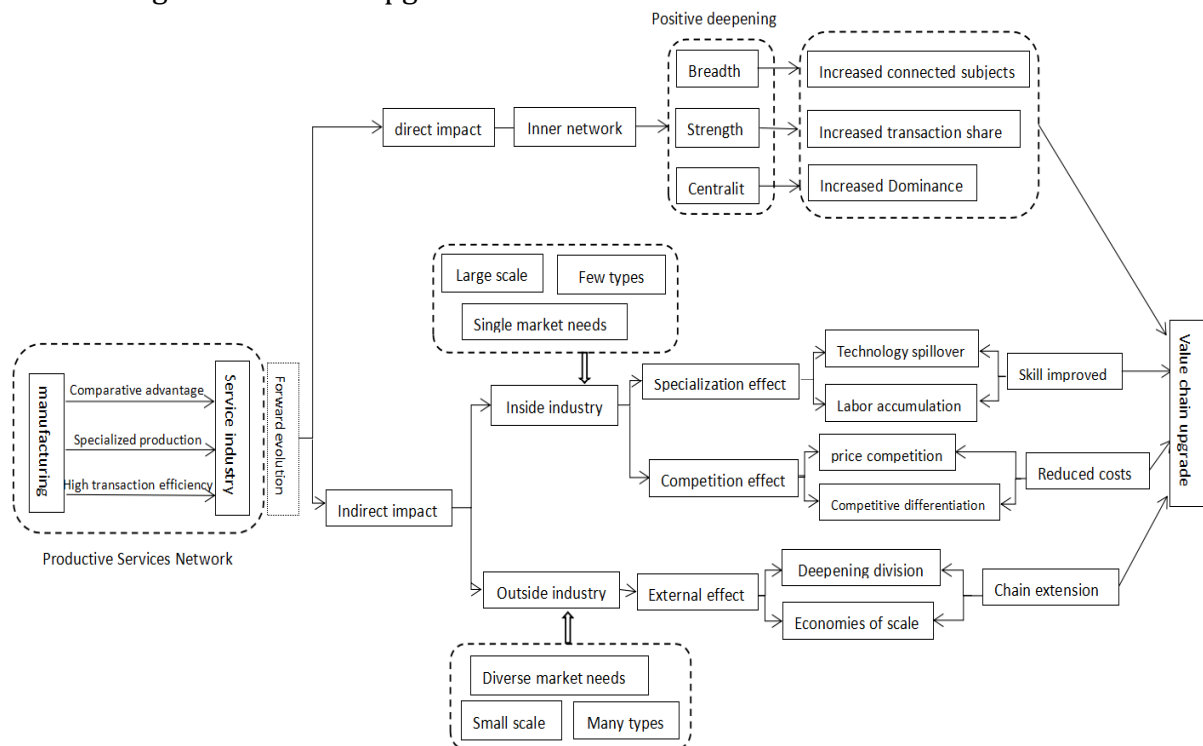


Fig 1. The Influence Mechanism of the Evolution of Producer Services Network on the Upgrade of Manufacturing Value Chain

Different from the fragmentation of producer service network, when it evolves forward, the advantages such as technological innovation and knowledge spillover can better promote the

manufacturing's efficiency. In addition, high degree of evolution and relatively fierce competition can better promote the formation of differentiated services. In terms of direct variables, when the breadth, strength, and centrality of the network are deepening, this network structure will be continuously optimized. That means the increase in the number of connected entities, transaction shares and dominant position will lead to the transformation of the entire industry organization. As Figure 1 shows, this will all drive the upgrading of the manufacturing value chain.

Specifically, it can be elaborated from the following aspects.

3.1. Indirect Influence Channels

The evolution of producer service network mainly indirectly affects the upgrading of manufacturing value chain through specialization effects, competition effects, and external effects inside and outside the industry. When it evolves forward, the service industry and manufacturing industry in the network make technological progress, reduce transaction costs and extend the industrial chain through three major effects.

When the specialized industry gathers in the network structure, it will promote the sharing and circulation of technology, capital and human capital, thereby promoting the industry's innovation ability and technological level. The technical knowledge spillover and human capital accumulation brought about by the development of the service industry in this industry will effectively promote the improvement of the corresponding manufacturing production efficiency and drive the industrial upgrade. In addition, the industry's specialized concentration has also brought greater competition. On one hand, service industry has eliminated downstream manufacturing companies by improving service quality and reducing service prices, so that manufacturing enterprises can concentrate on the comparative advantage and continue to improve innovation capacity, thereby promoting industrial upgrading. On the other hand, manufacturing industries are competing with each other to obtain more production opportunities through higher production efficiency and lower transaction costs. In addition to promoting the inner industry, industrial agglomeration also has a positive effect outside the industry. When industry types and market demands are diverse, it will bring a highly competitive market environment, which can further promote knowledge spillover and technological progress, thereby reducing transaction costs and promoting upgrading of the manufacturing value chain.

It is worth noting that the leading effects of specialization, competition and external effects brought by agglomeration are affected by industry size, industry type and market demand. In the early stages of the development of the Guangdong-Hong Kong-Macao Greater Bay Area, there were few types of industries and the market demand was characterized by a "big and single" characteristic, which easily made the industry form a specialized agglomeration in a given space. It is mainly influenced by professional effect and competition effect. In the later stages of development, when the types of industries are diverse, the market demand is characterized by "large and diverse" characteristics. It mainly exerts external effects to promote the extension of the producer service network and continuously deepen the division of labor, thereby promoting the upgrading of manufacturing global value chain.

3.2. Directly Influence Channels

In addition to the indirect effects, changes in the direct variables of the producer services network have promoted changes in organizational network between the two industries, which in turn has promoted the upgrading of manufacturing value chain.

(1) Network Breadth and the Upgrading of Manufacturing Value Chain

The breadth of producer service network refers to the number of connected entities in a network. When the network evolves forward, that means the breadth of a network deeper, the

number of connecting entities in the network larger, indicating that the service industry has established links with more manufacturing industries. In addition to the increase in the number, it faces more different types of manufacturing companies, which can fully mobilize business to improve production efficiency and form economies of scale. Correspondingly, the manufacturing industry serving as targets for technology spillovers and human capital transfer has established links with more service industry systems, thereby reducing transaction costs and promoting the upgrading of manufacturing global value chain.

(2) Network Strength and the Upgrading of Manufacturing Value Chain

Network connection strength is a comprehensive reflection of the "interaction time, emotional strength, intimacy, and reciprocity service" between network nodes, which also presents the strength of the relationship between network nodes (Granovetter, 1973[21]). Relatively, the strength of the producer service network refers to the strength and degree of the connection between the service industry and the manufacturing industry. A higher intensity of the producer service means that the service industry has strengthened its relationship with the manufacturing industry and increased its transaction share. As a result, its market dynamics are stronger and the added value of products is higher, thus the manufacturing value chain is upgraded.

(3) Network Centrality and the Upgrading of Manufacturing Value Chain

Network centrality is used to measure the degree to which a node is located in the middle of other nodes in a social network, reflecting the degree of control and centrality of the node in the network resources (Freeman, 1979[22]). Relatively, the centrality of the producer service network reflects the degree and central position of the producer service in controlling resources. When the centrality continues to deepen and the producer service's ability to control resources is strengthened, it will effectively mobilize innovative elements (talent, capital, technology) to optimize technical knowledge, thereby increasing overall production added value. In addition, knowledge spillovers and talent flow in the service industry will also increase. It will promote the upgrading of the manufacturing industry structure and the value chain.

4. Regional Status Analysis

The Guangdong-Hong Kong-Macao Greater Bay Area is one of the most important urban agglomerations in China. Based on its good geographical location and urban network, its economy has developed steadily, which has also promoted the development of manufacturing and service industries and formed network topology of producer service. At present, this area has gathered a large number of service industries and continuously promoted the development model of regional coordinated division of labor. It treats Guangzhou and Shenzhen as the central cities and organically spreads to peripheral cities, forming the market hinterland. However, judging from the degree of industrial synergy and the evolution of network communities, there is still huge development potential and space for the industrial transformation. With the continuous introduction and development of the service industry, problems gradually appear: insufficient network coverage; overcrowding in central cities; low connection and lacking high-quality innovation elements. There exists urgent need for a more complete top-level design.

Firstly, the evolution of producer service network in the Greater Bay Area is fragmented, and its network breadth is not large. With the exception of Guangzhou and Shenzhen, the development of producer services in other parts of the Greater Bay Area is more fragmented, and there is a lack of targeted technical research to address the lack of core product technology. That means the manufacturing industries in various regions are dominated by "imitating" processing trade and the corresponding service industry is characterized by single type and less intensive technology. It is separated from the development mode of the Guangzhou and

Shenzhen's high-tech industry and it isn't conducive to the expansion of network. According to the survey, at present, some inland cities in the Greater Bay Area not only have insufficient supply, but also have low quality development. In 2017, the proportion of producer services in Foshan, Zhongshan, Jiangmen, and Zhaoqing accounted for 15.4%, 17.9%, 16.2%, and 17.9% of GDP, respectively lower than the national average of 12.5, 10, 11.7, and 10 percentage points. In addition, there is a lack of targeted measures for network's community structures. With the dynamic development of the network, various regions are also continuously strengthening the technology integration model, but the corresponding policy measures during the development process have not been amended and followed up in a timely manner, making the gap of Shenzhen, Guangzhou and other regional network communities widen.

Secondly, the network strength is not strong enough and it lacks matching high-quality innovation elements. High-quality coordinated development of the service industry and manufacturing industry is closely related to the development of urbanization. But at present, the level of joint development of the two in the Greater Bay Area still has inadequacies, which are specifically manifested in the following. On one hand, the insufficient resource integration capabilities will simultaneously restrict the development of the service industry and manufacturing industry, thereby limiting the expansion of the network topology. According to the survey, the R&D investment intensity of Guangdong Province in 2018 was 2.78% and 3.19%, lower than that of Beijing and Shanghai. In addition, the proportion of higher education talents in the resident population is 25.19% in Shenzhen and only 15.74% in Dongguan, below the national average. On the other hand, while the support of the service industry has been strengthened, the development of the manufacturing industry has been uneven, which has restricted the promotion of the breadth and depth of urban service network. The current upgrading of the manufacturing industry is facing difficulties. Although Shenzhen, Huizhou, Dongguan and other cities have rapidly developed manufacturing industries, the radiation effect on surrounding cities is not obvious. From 2011 to 2018, the annual compound growth rates of Shenzhen, Huizhou, and Dongguan were 8.3%, 8.0% and 11.7%, higher than the national average of 1.7, 1.4, and 5.1 percentage points, but negatively Foshan, Jiangmen, and Zhaoqing are 2.1%, -0.6% and 2.5%. Therefore, the development of manufacturing industry is not balanced across cities and the service network extension is limited.

Finally, the positive evolution of the producer service network in the Guangdong-Hong Kong-Macao Greater Bay Area is not strongly coupled with the upgrading of the manufacturing value chain. The coupling between a system and another system needs the following requirements: heterogeneity, specific internal connections, system rules and overall functions. The value chain upgrade depends on the positive evolution of the network, but there is no inevitability between the two. Specifically, the various entities involved in the evolution of the network, such as enterprises, research and development institutions, intermediary institutions, financial institutions, governments and markets, cover the various entities involved in the upgrading of the manufacturing value chain. Furthermore, the internal connections of system interaction and continuous transformation depend largely on the evolution of the producer service network. Therefore, the local governments of Guangdong-Hong Kong-Macao Greater Bay Area need to formulate policies that conform to market rules according to the producer service network and the manufacturing mechanism coupling mechanism. Any mandatory system and non-rational mechanism must be continuously revised and improved according to the requirements of the mechanism in the coupling process.

5. Conclusion

In view of the impact on the upgrading of manufacturing value chain, it is necessary to deepen the coupling relationship between the network topology of producer services and the

upgrading of value chain of manufacturing enterprises. Due to the unique topological network structure of producer service and coupling relationship with the upgrading of manufacturing value chain, the improvement measures for its evolution have unique specific conditions that are consistent with its own actuality. Therefore, this article is based on the inherent mechanism of the producer service's network topology. The in-depth interpretation of the strategy is as follows.

Firstly, the additive expansion of the network topology needs the improvement of the capacity of integrating innovating resources. Also, it needs enhancement of the level of coupling with upgrading of manufacturing value chain. Therefore, on one hand, manufacturing companies require to accelerate the integration of innovative resources, optimize their production methods and promote the transformation into high-end manufacturing companies. Furthermore, producer service companies require to promote the integration of talent capital and knowledge spillovers, and to build a coupling form between various entities. Secondly, the expansion of the network topology requires the establishment of supporting public service platforms. In order to expand the breadth of the network, it is necessary to accelerate the construction of supporting platforms, such as research and development innovation platforms, financial financing platforms, and public information platforms, thereby effectively connecting the service industry and manufacturing enterprises. Thirdly, the construction of producer service's network topology cannot be separated from the construction of a well-defined urban network. It is necessary to coordinate the overall interests of the metropolitan area and the comparative advantages of each city, strengthen specialized division and cooperation among cities, promote complementary urban functions, industrial dislocation layout, infrastructure and public services, and achieve the mutual benefit and win-win in deepening the cooperation network.

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