

Original Research

Construction Strategy of Industrial Coordination System of Secondary Urban Agglomerations in the Context of Low Carbon Economy

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Abstract

The secondary urban agglomerations in a large city cluster can play the role of bridging the central city and the county or township, to enhance the industrial competitiveness and realize the sustainable development of the regional economy. In the context of a low carbon economy, based on the case study of a typical secondary urban agglomeration, this paper proposes that the industry chain, innovation chain, and service chain in a secondary urban agglomeration are relatively weak, which needs a complex industry collaboration system integrating industry chain, innovation chain, and service chain (IIS) to achieve low-carbon collaborative industrial development. This system can be developed by taking the real economy (industry chain) as the core and integrating innovation elements including science, technology, and knowledge (innovation chain), as well as service elements such as the material base, government policy, and financial services (service chain). The article constructs a theoretical framework for the IIS system, analyzes its operation mechanism, and finally discusses the specific construction strategy of the IIS system based on a low-carbon economy perspective.

Keywords: industry chain, science and technology innovation chain, service chain, industry collaboration

Introduction

With the increasingly serious global climate problem, a low-carbon economy characterized by low energy consumption and low pollution has attracted the attention of the international community. The realization of the low-carbon economy cannot be separated from the modernization and optimization

of industrial structure. The industrial collaborative innovation system, with modern science and technology (innovation chain) as the support, and the government and other organizations (service chain) as the guarantee, can promote the industrial structure to develop towards the direction of knowledge-technology intensive. The composition of production factors within the industry is constantly upgraded, so that the economic development is transformed from the factor-driven stage to the efficiency-driven and innovation-driven stage, and the economic development with low energy consumption and low pollution is realized. In recent

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years, China has adopted urban agglomerations as one of the vehicles for promoting regional development. It is hoped that through economic and social integration, urban agglomerations can complement each other, develop their strengths, strengthen their weaknesses, achieve overall and rapid development, and play a growing role, in driving the development of the surrounding areas. However, in the practice of urban agglomeration construction, some core cities have developed more, or because of more favorable policies or their strong ability to gather factors, but the development effect does not transmit to the small and other lower cities effectively, and there exists the phenomenon of “strong center-weak radiation”: the stronger the strong, the weaker the weak. The unbalanced development, to a certain extent, deviates from the original intention to construct an urban agglomeration. The “spillover effect” of the core city development generally radiates from the center to the periphery. The causes of “weak radiation” may include (i) insufficient spillover of the core urban development effect; and (ii) the spillover effect attenuating at the time of radiation. Some local governments are aware of the issues above, guiding the construction of secondary urban agglomerations (SUA) in larger urban areas. Local governments aim to add an effective transfer link to the radiation path and allow the spillover effect through this route, namely the core city-secondary urban agglomeration-county pathway (see Fig. 1). On the one hand, The SUA can play an intermediary and bridge role. On the other hand, the SUA can strengthen itself and become a regional center that can exert the direct spillover effect, thus driving the development of counties and even towns. The development effect of core cities is indeed transmitted to the secondary urban agglomerations, among which the industrial gradient transfer is an important measure to promote the economic development of secondary urban agglomerations. It can get rid of the environmental constraints of core cities, make better use of the resource endowment of secondary urban agglomerations, and lower labor costs and other advantages. However, industrial migration has also brought negative impacts to the secondary urban agglomerations. The industries transferred by gradient are basically traditional industries, which are often highly polluting and have low added value, bringing

greater ecological and environmental pressure to the secondary urban agglomerations.

A certain number of SUAs exist in China, such as the Xiang-Shi-Sui-Shen urban agglomeration, the Yijing Jingen urban agglomeration in the urban agglomeration of the middle reaches of the Yangtze River, and the Suzhou Wuxi Changzhou urban agglomeration in the urban agglomeration of the Yangtze River Delta, etc. The transfer function, particularly the direct radiation function of SUA, cannot be separated from its own development. The SUAs generally show the following characteristics: (i) Urban agglomerations are basically flat or fusiform [1]: there is no significant difference in the level of economic development between cities, and regional central cities are not significantly primary compared with other cities, showing a weak central-weak radiation pattern; (ii) Node cities are mostly small and medium-sized cities that are close to each other in the same province, which are connected by transportation, interlinked by the same cultures, and the economy and society are closely linked. (iii) Compared with larger urban agglomerations, the number of node cities in a SUA is small, and the economic volume of overall urban agglomeration and individual node cities is also limited. From these particularities, The SUA may not be suitable for the central-radiation construction experience generally adopted by large urban agglomerations but is more suitable for the “group” development mode of multicenter coordination.

Industry is the foundation of development, and industry collaboration is the focus of the collaborative development of SUA. It is of great significance to explore a path suitable for industry collaboration in a SUA. Based on a typical case study, this paper analyses the advantages and disadvantages of SUA in the collaborative development of industries. It is proposed that this type of urban agglomeration should integrate the industry chain, the science and technology (S&T) innovation chain, and the service chain to establish a complex industry collaboration system comprising industry, innovation, and service (IIS) to promote industrial development. This paper discusses the theoretical framework and operation mechanism of the IIS and analyzes the specific strategies to construct the system in the SUA. The innovation of this study is mainly reflected in the following aspects: Firstly,

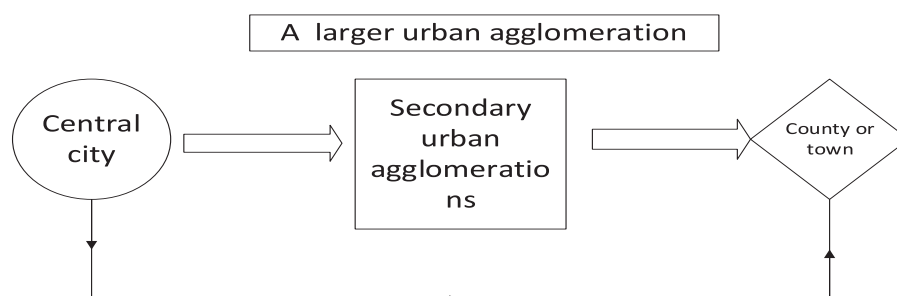


Fig. 1. Sketch map of the inheritance and transmission of spillover of SUA.

this study builds a system framework for the integrated development of industrial chain, innovation chain, and service chain to promote low-carbon collaborative industrial development. Secondly, this study expands the connotation and extension of the collaborative innovation concept. Finally, this study analyzes the construction path of industrial collaborative innovation system in urban agglomeration. In this paper, the rest of the arrangement is as follows: the second part focuses on the literature review; the third part specifically outlines the case, data, and methodology; the fourth part shows the empirical results; and, the last part completes the conclusion and policy implications.

Literature Review

Industry Chain, Innovation Chain, Service Chain, and Multi-Chain Integration

The three-chain integration of industry, innovation, and service refers to the situation or the process by which the industry, science, and technology innovation, and service chains form a value chain, promoting the efficient and innovative development of industries through interaction and integration. In existing studies, scholars have discussed the definitions of industry, science and technology innovation, and service chains, the relationship between the chains, and their significance in industrial development. The collaborative relationship among enterprises formed in the process of producing services and products and providing the same to consumers is called an industry chain. An industry chain may be described as an industrial system comprising interconnected industries [2]. It can also refer to an organization that connects upstream and downstream businesses, which further connect various enterprises, with supply and demand as the links [3]. Marshall [4] advanced the concept of the innovation chain in 1992, maintaining that the innovation process is the interaction process of different innovation subjects. Hansen and his colleagues [5] first offered the concept of the innovation value chain, arguing that innovation is a value-added process that includes three stages: idea generation, idea development, and the diffusion of developed concepts. A science and technology innovation chain can simply be identified as the chain of organization in which innovation-related achievements are disseminated between the industries and innovation entities, such as higher education institutions, research institutes, and R&D centers of enterprises, in both directions. The essence of this chain is the collaborative research and development among innovation entities guided by the industry chain [6-8]. Its purpose is to serve and promote the development and growth of the industry chain. A service chain is the supply chain formed by service units through tight or loose connections [9], which supplies the various service factors required for

industrial development [10-12]. The nodes [13] of a service chain include the end-point of the service chain – the customer – as well as enterprises and institutions with specific service capabilities.

The relationship between the industry chain and the science and technology innovation chain has attracted considerable academic attention. The precise connection between the two chains produces an endogenous impetus for the efficient operation of the innovation system [14]. The science and technology innovation chain has a dynamic effect on the industry chain, and the industry chain has a pulling effect on the science and technology innovation chain [15]. Some scholars [16] have also discussed the relationship among the industry, science and technology innovation, and service chains and believe that innovative factors can be integrated through the integration and interaction of the chains.

Urban Agglomeration Coordination and Industry Collaboration

The significance of the construction of urban agglomerations lies in that each node city can form a resultant force to coordinate the development. Industrial synergy is the most important aspect of urban agglomeration coordination, which has been a concern of the academic community. Synergetics, game theory, dissipative structure theory, and catastrophe theory are usually cited in the discussion of urban agglomeration coordination [17]. Li & Liu [18] suggest that the collaborative innovation system of urban agglomerations is a self-organizing process. Various innovation subjects take the city as the carrier and innovation ability as the foundation, linking and integrating diverse innovation elements to produce a spatial spillover effect. Finally, urban agglomeration can achieve the overall benefit of “1+1 > 2.” Meanwhile, Serrano and Fischer [19] offer that the full flow of stimulus factors and the acceleration of knowledge diffusion are conducive to the realization of regional innovation system optimization. Xia, et al. [20-22] maintain that industrial collaboration has a significant spatial spillover effect, which is a positive effect on the rationalization of the industrial structure and on the economy and innovation as well.

In the study of the coordinated development of industries in the Beijing-Tianjin-Hebei region, Zhang & Shu [23] found that when gradients exist within industries or the differentiation between industrial structures is large, the collaboration between industries is made smoother. However, high degrees of industry similarity, improper industrial layout, and an unreasonable industry chain negatively impact industrial collaboration [24]. Moreover, factors affecting industrial collaboration include the inability to share benefits, regional blockages, administrative barriers, lagging management, and an over-reliance on the top-level design and administrative power of the government [25]. Some scholars have measured the degree of industrial collaboration and the development level of certain urban agglomerations and

proposed indicators for the measurement of industrial collaboration. Summarizing the measured data, many of China's urban agglomerations under construction have industrial collaborations close to the primary stage [26]. The difficulties, strategic positioning, and methods of development of industrial collaboration have garnered attention from academics. Some propose that a balanced, efficient, and sustainable system for the division of labor and cooperation is necessary for the development of industrial collaboration [27, 28]. The construction of a scientific industrial system and reasonable profit distribution mechanism – under the two hands of the government and market – would help form an integrated market landscape to achieve industrial collaboration [29-31].

By examining the research on the industrial collaboration of urban agglomerations, the following can be observed. On the one hand, most existing studies focus on big urban agglomerations and pay less attention to smaller ones. On the other hand, little is known about the specific methods of the construction of the industrial collaboration system.

Methodology

Methodology

This paper adopts a case study method to explore the path of industry synergy in a secondary small urban agglomeration. The main reasons are as follows: firstly, the path of industry synergy in a secondary small urban agglomeration belongs to a typical “How” type problem, which has inductive and exploratory characteristics and is suitable for case study methods for interpretable mechanism or process research problems; secondly, industry synergy is a complex and dynamic process, involving the interaction of various factors of industrial chain, innovation chain and service chain, and the case study method is not only helpful to summarize and present the interrelationship between poly-constructs, but also helps to present the particularity of industrial collaboration in secondary small city agglomerations according to detailed evidence, and excavate the hidden theoretical logic behind it.

Case Collection

The process of case study should be aimed at a theoretical framework [32], following the principle of analytical generalize rather than statistical generalize, so the case is not a sampling unit or sample, but the basis for revealing the source of theoretical concepts, then the sample selection of the case study should conform to the principle of matching the case object and the research question, highlighting the essential attributes and key characteristics of the research problem. This study not only examines the current status of industrial collaboration in SUAs, but also reveals the

mechanism of interaction of various factors in the process of industrial synergy, and sets the following sample selection principles for the selected cases according to the essential attributes and key characteristics of the research problem: first, the case should be SUAs and have strong representativeness; secondly, the case urban agglomeration has certain construction experience, and can provide comprehensive and complete data on the current situation of industrial synergy in secondary small city agglomerations. The research team conducted preliminary research on three urban agglomerations (“Chang-Zhu-Tan” urban agglomeration in the middle reaches of the Yangtze River, “Su-Xi-Chang” urban agglomeration in the Yangtze River Delta, and “Yijing Jingen” urban agglomeration in the middle reaches of the Yangtze River), and comprehensively compared and analyzed according to the factors of case typicality, traceability and data availability, the “Yijing Jingen” urban agglomeration (the following text is referred to as case urban agglomeration or Yijing Jingen) is selected as the research object.

Established in 2021, the case urban agglomeration consists of four cities, namely Yichang, Jingmen, Jingzhou, and Enshi, and is in the greater urban agglomeration in the middle reaches of the Yangtze River. The urban agglomeration in the middle reaches of the Yangtze River is composed of three SUAs, including the Wuhan Metropolitan Area (with Wuhan as the core), the Poyang Lake urban agglomeration (with Nanchang as the core), and the Changsha-Zhuzhou-Xiangtan urban agglomeration (with Changsha as the core), for a total of 26 cities, all of which are in Hubei, Hunan, and Jiangxi provinces in central China. Wuhan is the central city of the urban agglomeration in the middle reaches of the Yangtze River. Around the Wuhan Metropolitan Area, the government of Hubei Province established two SUAs: Xiang-Shi-Sui-Shen urban agglomeration and this case – Yijing Jingen urban agglomeration. The urban agglomeration in the middle reaches of the Yangtze River can be regarded as a large first-level structure, the three secondary urban agglomerations such as the Wuhan metropolitan area can be regarded as the secondary structure of this urban agglomeration, and the case urban agglomeration is the third-level structure (see Fig. 2). Most urban agglomerations in China are organized in accordance with such multi-level spatial nesting structures, partly to fully undertake and transmit the radiation effect of central cities.

The case urban agglomeration covers an area of about 61,400 square kilometers and has a population of about 17 million. The four node cities are in the middle of metropolis, county, and rural areas, and each has jurisdiction over more than 10 counties, districts, and dozens of towns and townships. It can be used as a typical case when studying the secondary small urban agglomeration. First, it is representative of the secondary small urban agglomeration and has the general characteristics of the secondary small urban

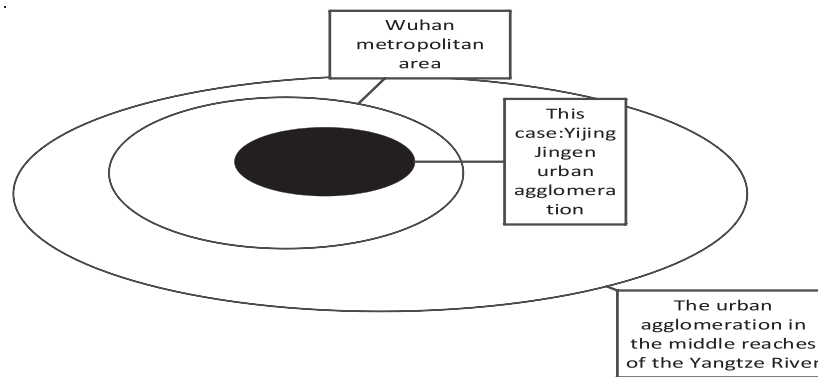


Fig. 2. Location of the case in the structure of Chinese urban agglomerations.

agglomeration: it is composed of prefecture-level cities. The economic development of node cities is relatively balanced, showing the characteristics of flatness and non-centrality. Second, the main part of the urban agglomeration has been constructed for many years and has accumulated rich materials, which is convenient for research.

Data Collection and Processing

This study strictly followed the case study “triangle validation” method, combined with primary and secondary data, complementing each other and cross-validation, to ensure reliability and validity. Data sources include primary data such as in-depth interviews and field observations, as well as secondary data such as internal and public data, news reports, and seminar data. Aiming at the research problem of industry collaboration path of SUAs, it is determined that the following data of case urban agglomerations should be collected: (i) the current situations of industry development and industry collaboration among the node cities; (ii) the data on industry structure; (iii) the existing foundation and problems faced by the industry collaboration; and (iv) other factors that may affect the industry collaboration among the cities, such as the innovation chain and the service chain of urban agglomerations.

From October 2021 to April 2022, the research team surveyed relevant units in the case urban agglomeration and collected firsthand data. In particular, the team (i) interviewed the person in charge of Yichang Development and Reform Commission four times online, (Development and Reform Commission, [NDRC], is the main department that formulates urban construction planning), and each time lasting about 30 minutes to understand the basic situation, the completed and unfinished projects of urban agglomerations, and the status of industrial development, industry collaboration, and government support in the four cities, (ii) visited the Yichang Biomedical Incubation Center, the representative S&T incubation center of Yichang city, and had a face-to-face interview with the person in charge for about 60 minutes, mainly to understand the

construction and operation of S&T transformation units and intermediary units in the urban agglomeration; (iii) telephone interviewed the person in charge of Yichang Science and Technology Bureau for about 30 minutes to learn about the construction of innovation chains such as scientific research institutions and science laboratories in urban agglomeration; (iv) telephone interviewed loan officers of two comprehensive banks (Industrial and Commercial Bank of Yichang, Construction Bank of Yichang) and one commercial bank (China Merchants Bank of Yichang) for 30 minutes each to identify the status of S&T finance in the urban agglomeration; (v) participated in two 240-minute seminars on the construction of the case urban agglomeration, which were attended by the four governments, scientific research units, enterprises and other personnel. At the end of each interview, the interview notes were sorted out and about 50,000 words of text data were collected, which became the firsthand data of the study. The main sources of secondhand data are (i) fifteen news items selected by mainstream newspapers in four cities; (ii) four policy texts collected from field research; (iii) one research product obtained from a seminar; (iv) ten pieces of public information obtained from the websites of relevant departments; (v) the statistical yearbook data of the four cities in 2022 obtained from the official website; and (vi) the list of university majors, about 100,000 words, collected from official websites of universities in cases of urban agglomeration.

In this paper, the quality of the case study is ensured from four aspects. (i) Conceptual validity. Through the mutual support of the three methods, the credibility of the measurement of the research topic is improved. First, the reliability and usefulness of data sources are increased through the complementarity and cross-corroboration of data from different sources, such as data acquisition, in-depth interviews, public data materials, and key sector material archival records; Secondly, based on the construction of a complete data and evidence chain, multiple coherent data evidence from different sources and different levels is used to support the exploration and summary of the industrial collaboration system of secondary small city

agglomerations in this paper, so as to meet the internal logical consistency. Finally, strictly control all kinds of oral information, such as information expounded by key interviewers and important information providers, to ensure that the case investigation report presents the research results based on authenticity and reliability, and avoid the one-sided view of the narrator. (ii) Internal validity. On the basis of the previous research results and theoretical knowledge reserve, the theoretical association is established with the existing theoretical basis and data, and a preliminary theoretical framework of the industrial collaboration system of the secondary small city agglomeration is formed, and through the mutual confirmation and repeated iteration between data, relationships and frameworks, it verifies whether the internal logic of the expected theoretical framework and the empirical data research conclusion is consistent, so as to improve the internal validity of the case study. (iii) External validity. In the case design stage, through the summary and collation of existing literature and theories, the relevant theories are used to guide, analyze and explain the summarized relationships and frameworks, the differences between the summarized results and the conclusions of existing research are compared, and the conclusions of the case studies are committed to summarizing the industrial synergy mechanism of the secondary small city agglomeration based on the integration of industrial chain, innovation chain and service chain from the case study conclusions, constructing a theoretical model with general characteristics that conforms to the current situation, strengthens the reproducibility of the interpretation of important phenomena, and forms a dialogue, comparison and confirmation with existing theories, to clarify the rationality and innovation of the IIS of SUAs, so as to improve the external validity of this case study. (iv) Reliability. Through the establishment of a rich database of case city clusters, data from various sources are preserved, including audio recordings, conference minutes, interview manuscripts, news reports, audio and video interviews, and journal articles, to facilitate the mutual verification of materials in the later stage and improve the credibility of research results.

The research team sorted out and numbered the collected data, conducted text research and quantitative

analysis according to the data types, and finally obtained the analysis results.

Results

The Industry Chain of the Case Urban Agglomeration

(1) Certain gradients exist within industrial development. The economic development of the urban agglomeration, in this case, does not have a significant difference and shows flatness overall, there exist certain gradients in the development of the four industries, which act as a driving force and facilitate regional industrial cooperation. Fig. 3 and 4 reveal that as the regional central city, the economic development of Yichang is better than that of the other three regions. Barring the primary industry, all indicators of Yichang are almost twice those of Jingzhou, which ranks second. The GDP of the Enshi region significantly lags that of the other three regions, with the secondary industry lagging the most. From the perspective of the proportions of the primary, secondary, and tertiary industries, compared with the other two regions, Enshi and Yichang are relatively more advanced. The proportion of the tertiary industry in Enshi is considerably higher than that of the primary and secondary industries, while that of the primary industry in Yichang has decreased to single digits.

(2) The industries exhibit an overall high similarity. The regional specialization index can be adopted to measure the differences in the industrial structures among regions. The following formula can be used to calculate the relative specialization index of industries between regions [33]:

$$K_{ij} = \sum_k |s_i^k - s_j^k| s \tag{1}$$

$$\text{Here, } \bar{s}_i^k = \sum_{j \neq i} E_j^k / \sum_k \sum_{j \neq i} E_j^k, s_i^k = E_i^k / \sum_k E_i^k,$$

$i, j,$ and $k,$ respectively, denote region $i,$ region $j,$ and industry $k,$ while E_i^k is the gross industrial output value of industry k in region $i.$ The value threshold of k_{ij} is ully between 0 and 2. A larger value threshold represents a larger difference between the industry structures

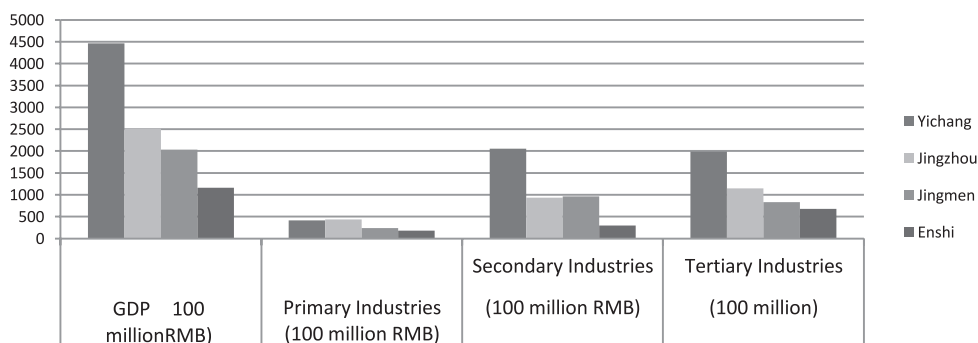


Fig. 3. Comparison of the economic indicators of the case urban agglomeration in 2021.

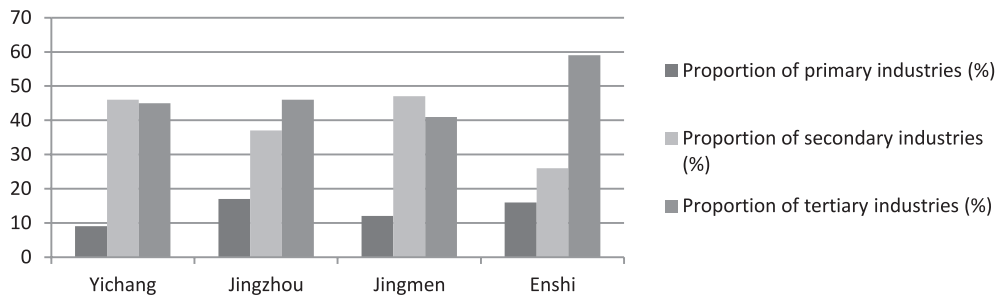


Fig. 4. Comparison of the economic indicators of the case urban agglomeration in 2021.

across regions. A total of 36 industries have been analyzed, and the results show that 8 industries, including the manufacture of raw chemical materials and chemical products of Yichang, have more significant degrees of relative specialization.

The manufacture of automobiles, computers, communications, and other electronic equipment has more significant degrees of relative specialization. Coal exploitation and washing, the manufacture of tobacco, and the production and supply of gas are more significant in the case of Enshi. Jingmen has a more significant degree of relative specialization in four industries, including the comprehensive utilization of waste resources. Other industries do not have significant degrees of regional specialization. From a regional perspective, the industrial degree of differentiation between Jingzhou and Jingmen is relatively low, with regional specialization indices of approximately 0.49 each. The differentiation degree of Yichang is slightly higher at approximately 0.56. Additionally, Enshi has the highest degree of industrial differentiation compared to the other three regions, at approximately 0.93 (see Fig. 5).

This study included the analysis of the industries with the top ten industrial output values in Yichang,

Jingzhou, and Jingmen (the top ten industries contribute approximately 80% of the gross industrial output value of each city) and the top seven industrial output values in Enshi (as the overall industrial volume of Enshi is relatively small, only the top seven industries are selected). The results showed that part of the industries with advantages in the four regions of Yijing Jingen overlap. For example, the processing of agricultural byproducts and the manufacture of nonmetallic mineral products are common industries with advantages in the four regions. The manufacture of raw chemical materials and chemical products has advantages in Yichang, Jingzhou, and Jingmen, while wine, beverages, and refined tea have advantages in Yichang, Jingzhou, and Enshi (see Fig. 6). Common industries with advantages in the regions show even development across regions. For example, the processing of agricultural byproducts in Jingmen has the highest relative specialization index of 0.89. Moreover, the manufacture of raw chemical materials and chemical products in Yichang has the highest relative specialization index of 1.05, showing significant differences when compared to the other three regions. The similarity of industries in the four cities is greater than the differences. This situation makes the

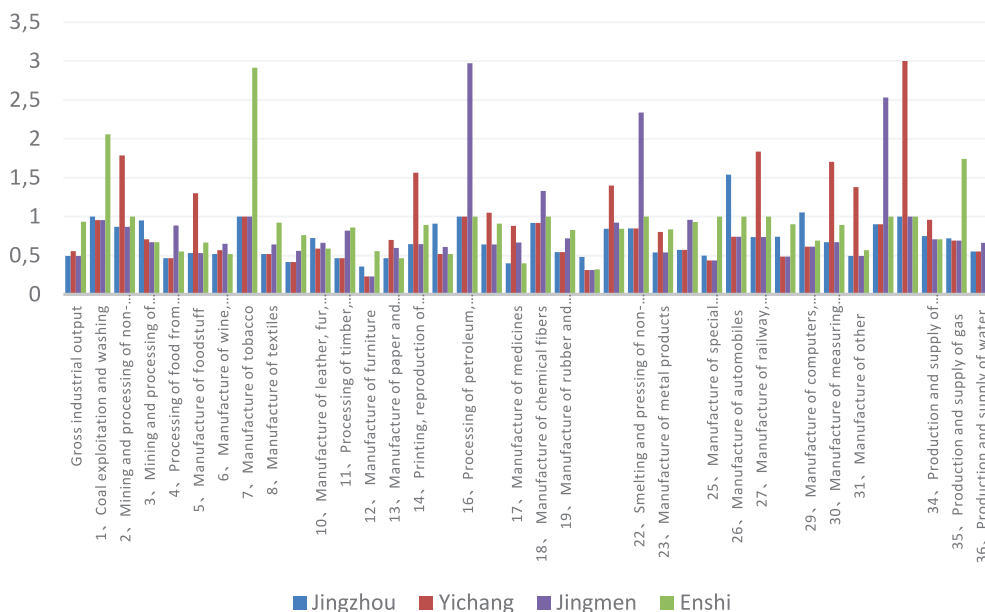


Fig. 5. Relative specialization index of industries in the case urban agglomeration.

intercity industry more a competition than cooperation. The situation can be illustrated by the example of the phosphorus chemical industry. The phosphorus chemical industry of Yichang, Jingzhou, and Jingmen enjoys an eminent position in Hubei and at the national level. The number of enterprises engaged in the manufacture of chemical raw materials and products in the three cities accounts for 30% of the total industry in Hubei Province. In addition, the gross industrial output and income from primary businesses account for 40% of Hubei Province. Moreover, the average annual number of employees in the industry accounts for 43% of Hubei Province, and the phosphate fertilizers produced by the three cities comprises approximately 15% of the national total. In particular, the phosphate fertilizers produced by Yichang are more than 10% of the national total. However, in the low-end industry chain, the phosphorus chemical industry is engaged in a low-level competition that mainly relies on low-end products. Almost all production of the phosphorus chemical industry in the three cities involves the entire industry chain, produces comparable products, and has no division of labor between regions. The low-end products mainly involve fertilizers with low added value; they create considerable pollution and are insufficient for the deep processing and comprehensive utilization of phosphate products. The SUA faces abundant challenges in adjusting the industrial planning to rationalize the division of labor and upgrade the industry chain.

It is most conducive to collaborative development if the industries in urban agglomeration have ladders and differences. The gradient and difference make the industries complementary and facilitate the docking of industrial chains. On the contrary, urban agglomerations with high similarity and isomorphism between industries will face challenges in industrial synergy. Only by abandoning vicious competition can we achieve synergy. The industrial chain of the case urban agglomeration has a certain degree of ladder, which makes collaborative development possible. However, the high homogeneity of industries affects the effect of industrial synergy. It also needs the regulation and guidance of the government and other service chains to finally realize the collaborative development of industries in integrated regions.

The Innovation Chain of the Case Urban Agglomeration

(1) The S&T innovation chain is relatively weak overall. The development of the S&T innovation chain in the case urban agglomeration is uneven. According to related research, Yichang has scored higher than the national average on the following: technological innovation development and innovation resource indices (innovative talents, R&D funding); innovation performance index (S&T output, economic development, eco-development, spillovers, and leadership); innovation service index (startup services, financial services) [34].

However, the scores of the other three cities in the three indices are lower than the national average. Judging from the number of patent applications, which reflect innovation performance, Yichang obtained a total of 7,093 patents in 2021, approximately equal to that of the other three regions combined. Jingzhou City obtained 3,674 patents, Jingmen City obtained 2,607, and Enshi Prefecture obtained only 762, less than a quarter of Jingzhou City. Simultaneously, the region scores lower than the national average in the innovation environment index, revealing a relatively backward condition in terms of policy support, as well as investment in education and informatization.

There are no first-class universities in the region; furthermore, the number of higher education institutions and high-standard scientific research institutions is relatively low. The weakness in terms of the quantity and quality of innovation institutions affects the innovation capabilities of the region. Even Yichang, with the highest technological innovation capability in the region, mainly relies on creation based on imitation and has a smaller proportion of original innovation.

(2) The matching degrees of the S&T innovation chain and the industry chain must be strengthened. The ability to link industries, universities, and research is an indicator that measures the collaboration efficiency of the industry and S&T innovation chains. The interaction between enterprises and universities or research institutions, based on project cooperation, can reflect the ability to link industries, universities, and research [35] while matching university majors and industries with advantages. This interaction forms the basis for enterprises to cooperate with universities on projects. By comparing the industries in Yijing Jingen and the university or junior college major programs open for application in 2022 in the region we find a basis for cooperation between the higher education institutions and industries in the Yijing Jingen regions, along with challenges. First, the major programs offered by higher education institutions in the regions are essentially in line with the development of industries with advantages. The chemical industry has advantages in Yichang, Jingzhou, and Jingmen; half of the higher education institutions in the urban agglomeration offer relevant programs. Tourism is an industry with advantages in Yichang and Enshi; five out of the six universities in the two regions offer tourism-related major programs. In Yichang, where the Three Gorges Dam is located, the "production and supply of electric power and heat power" is an industry with advantages. Two higher education institutions offer relevant major programs, one of which is a national key discipline. Second, some higher education institutions in Jingzhou emphasize emerging industries such as new energy vehicles and the big health industry, aiming at the future development of the region. However, the universities in other regions need to pay closer attention to the future development of regional industries. For example,



Fig. 6. Analysis of industries with advantages in the case urban agglomeration.

fields such as the integrated circuit industry, intelligent manufacturing industry, bio pharmacy, new energy, and new materials are poised to become the prime focus of industrial development in Yichang. However, few higher education institutions in Yichang provide programs relevant to such industries. Finally, the training for high-level talent is insufficient. Higher education institutions that can award master’s degrees are lacking, and those that can award doctoral degrees are relatively scarce. Training high-level talent cannot satisfy the needs of the industries. For example, the phosphorus chemical industry of Yichang mainly relies on outsourcing high-level talent from other places.

The Service Chain of the Urban Agglomeration

(1) Intergovernmental interaction has been actively conducted, while its effectiveness remains to be observed. Consensus among governments and unified plans for urban agglomerations is essential to guaranteeing the construction of an industrial collaboration system for urban agglomerations. Currently, the four regions have taken positive action, such as signing cooperation agreements and constituting institutional achievements, preliminarily constructing cooperation platforms, and beginning to plan major projects. Of course, as the construction of the urban agglomeration is still in the initial stage, many policies are confined to the exploratory stage, and their effectiveness remains to be observed.

(2) Some innovative service-oriented social organizations have been reduced to a formality. Although

Yijing Jingen's innovative service-oriented organizations are in the process of establishment, their benefits are yet to be maximized. Consider Yichang as an example – the city with the highest score on the innovation service index. Currently, there are seven national-level technology business incubators in Yichang, with a total of 54 incubators at various levels. Some incubators have close connections with institutions such as technology intermediaries, investment funds, and finance companies. They have multiple roles, including public technology platforms, small- and medium-sized testing workshops, and technology trading platforms. However, only two technology business incubators have begun to form innovative industrial parks for specific industries. Most incubators only act as property management companies and are primarily engaged in renting office space.

(3) Financing for technological development is still mainly provided by the government, and financial investments in technology need to be strengthened. Financial support is a prerequisite for enhancing technological innovation capability. As a small urban agglomeration at a lower level, the private financial investment in the technology of Yijing Jingen is inadequate, like most other prefecture-level cities. Currently, the financial investment in technology in this region is mainly provided by local governments, followed by loans designated for innovation and startup businesses, provided by state-owned banks, or the investment of enterprises' own funds, with fewer funds from private venture capital invested in the field.

Conclusion and Discussion

Conclusion

By analyzing the current situation, we found a certain foundation for industry collaboration in the case urban agglomeration. For example, a certain gradient of intercity economic development is present, some industrial transfers and division of labor occur between cities, and nationally acclaimed industries have advantages in urban agglomeration. Furthermore, industries and university majors match to a certain degree, and the government pays considerable attention to the construction of the urban agglomeration. However, the challenges faced by the construction prevail: (i) the industry chain exhibits high similarity, the competition among cities is more than collaboration at present; (ii) the overall innovation chain is weak, and the innovation output and transformation are insufficient, which is not conducive to the advanced industrial chain of urban agglomeration; (iii) there are weak links serving innovation transformation, and the financing methods supporting industrial innovation and development are relatively few, which cannot meet the needs of industrial development. These challenges make the current situation of industry collaboration

in urban agglomerations fragmented, local, and even non-synergistic. On the one hand, the industrial chain between node cities is not fully coordinated: there is also a lack of overall planning for industrial development based on the integration of urban agglomerations. On the other hand, the integration of the industrial chain, innovation chain, and service chains, which are of great significance to industry development, is not enough. This situation is reflected not only in a single industrial chain or a single city but also in entire urban agglomerations.

The degree of industry collaboration reflects the degree of integrated industrial development of urban agglomerations. The current situation of fragmentation, local and even non-coordination in industrial collaboration in the secondary small urban agglomeration represented by the case is not conducive to industrial development. According to Porter's [36] competitive advantage theory, to transform the factors of production in a region into competitive advantages, in addition to labor, capital, material resources, and other factors of production, it is also necessary to have a strong integration ability of factors of production.

Discussion

The economic volume of the secondary small urban agglomeration is small and the factors of production are relatively scarce; therefore, appropriate paths are needed to integrate the factors of production and maximize the utilization efficiency of limited resources. Establishing a systematic system to realize the industry collaboration should be an effective way to fully integrate the production factors and realize the industrial development of the SUA. Based on the idea of integration, the SUA can integrate service elements (service chain) such as the material base, labor force, and financial capital, and innovation elements (innovation chain) such as science, technology, and knowledge, while keeping the real economy (industry chain) at the core. This constructs a complex industry collaboration system (IIS) that features the close integration of the industry, service, and S&T innovation chains, as well as a high level of collaboration among cities, to promote industrial development.

(1) IIS: a feasible path for the industrial development of secondary small urban agglomeration.

IIS is a complex system made up of multiple subsystems. The industrial chain, innovation chain, and service chain are subsystems of the IIS. In the system, the industrial chain is the core. The innovation chain provides power for the industry chain, and the service chain supports the industry chain. The close interaction between the industrial and innovation chains forms a new important chain: the industry-innovation chain. The service chain interacts with the industry-innovation chain (the service chain not only interacts with the overall innovation-industry chain, but also interacts with the innovation chain and industry chain, respectively,

and can form an industry-service chain, service-innovation chain, and other double-chain integration chains), together to form a complete IIS.

(i) The core of the IIS: the industry chain. Raw material suppliers, manufacturers, distributors, and terminal markets join to become key nodes of the industry chain from top to bottom. The relationships and the “combinations” of the nodes [37] and the nodes themselves constitute the primary ecological environment within the industry. The industrial chain with a certain development basis is the premise of industry collaboration and the core component of the IIS. As an idealized industry chain of IIS, on the one hand, there should be modern infrastructure and advanced structure; on the other hand, there is a certain degree of gradients and differences between the industries in node cities, which allow industries across urban agglomerations to complement each other. Urban agglomerations with industries that exhibit considerable similarity and a high degree of isomorphism will face challenges in industrial collaboration. In this situation, collaboration can be achieved only by abandoning vicious competition and adopting a rational division of labor between regions.

(ii) The dynamics of the IIS: the S&T innovation chain. The innovation chain, composed of research institutes, universities, enterprise R&D institutions, and other institutions, runs through the overall process of industrialization of innovation achievements, such as R&D, commercialization, and marketization. In addition, the innovation chain should have a two-way information exchange with each node of the industrial chain and the overall industrial chain to form a synergistic relationship of mutual integration and mutual motivation. The innovation chain provides intellectual support for the upgrading of the industrial chain and can timely respond to the needs of the industrial chain, which plays a positive role in the growth of the overall benefits of the industrial chain. The practices and demands of the industry chain can also be quickly fed back to the innovation chain, providing the source and power for the development of the innovation chain, and facilitating the relatively free nodes in the science and technology innovation chain to exert greater momentum of innovation.

The innovation chain and the industry chain are integrated into a chain that creates value together, that is, the innovation – industrial chain. Various innovation – industry chains or the same innovation – industry chains across cities will interact with each other. These chains and their interactions become the endogenous driving force for the healthy and efficient operation of the industry. The role of the innovation-industry chain depends on three aspects: First, an urban agglomeration should have a relatively complete science and technology innovation chain or be able to introduce external resources to strengthen the chain so that the urban agglomeration can produce continuous scientific and technological breakthroughs. Second,

the exchange of information between the science and technology innovation chain and the industry chain should be smooth. This exchange would ensure that the latest scientific and technological achievements can be promptly adopted by the industry while the technological bottlenecks are expeditiously resolved by the innovation institutions. Thus, the system and organization of the innovation transformation should be sound. Finally, The layout of the innovation chain is carried out around the industrial chain, and the output of the innovation chain can connect with the demand of the industrial chain accurately.

(iii) The support of the IIS: the service chain. The service chain consists of government, financial institutions (banks, insurance companies, etc.), consulting agencies, intermediaries, service agencies, and others. Each node provides support for a link or the overall process of the innovation-industry chain. The government plays a central role, and the functioning of other service providers is directly or indirectly affected by the government. The nodes of the service chain separately or jointly provide policy support, financial support, support for scientific and technological achievement transformation, talent support, infrastructure, and environmental support to the innovation – industry chain. The service chain acts on the entire process of the innovation – industry chain. It offers a guarantee to the science and technology innovation chain and the industry chain and serves as the glue that binds the two chains. Simultaneously, it coordinates the relationship among the innovation – industry chains of different cities. Some studies [38] state that the regional differences in industrial collaboration are closely related to factors such as systems and policies, regional information transmission capabilities, economic development levels, labor supply, and levels of transportation facilities in the service chain. The evolution of the industry chain – science and technology innovation chain – three chain integration of industry, innovation, and service has gradually realized the close integration among these elements. Moreover, the complex industry collaboration system (IIS) of urban agglomerations has completed its construction.

(iv) The essence and operation mechanism of the IIS. As a complex system with the industrial chain as the core, the IIS aims to achieve the high-quality development of the industry in an integrated region such as an urban agglomeration. The IIS consists of people or institutions on the industrial chain, innovation chain, and service chain, production factors such as resources, capital, and information, and other visible or potential, tangible, or intangible components surrounding industrial development. The IIS has the following general system characteristics. (i) Dynamism. Within the system, there is a positive interaction between the large and small systems, and the dynamic equilibrium is maintained. The change of one component will lead to the change of other components, and then to a new equilibrium.

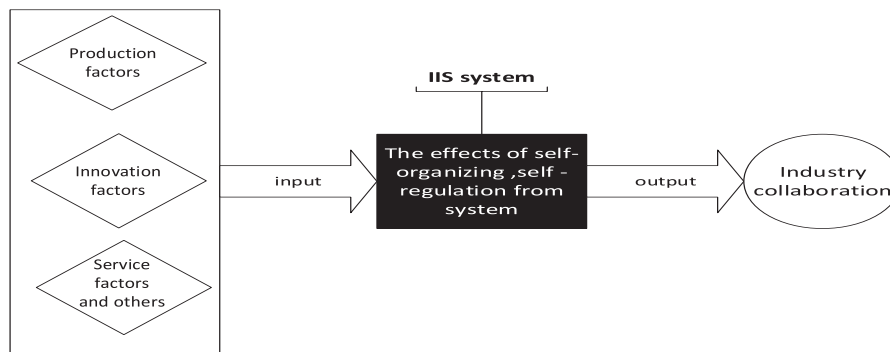


Fig. 7. The operation mechanism of IIS.

For example, the increased investment of financial institutions in the service chain to the transformation stage of the innovation chain will encourage labor input from the upper and lower nodes of the innovation chain, which may lead to a change in product supply in the industrial chain and then positive feedback to the service chain to form a benign interaction. Of course, if the feedback is negative, the dynamics will also make the system tend to self-adjust to a new equilibrium and in time “stop” and correct. (ii) Openness. The IIS is not a closed system but instead keeps an active exchange of material, energy, and information with external systems, constantly adjusting its operation to maintain vigor and vitality. This openness also enables the secondary urban agglomeration to timely undertake the spatial spillover effect of the upper-level region and further transmit it to the lower-level region. (iii) Integrity. As an organic whole, the IIS is composed of various parts. However, its function is not the simple addition of each component or the function of each element. That is, the interaction of each component is a benign connection that often makes the overall meaning greater than the sum of each element. This type of integral effect is the basic mechanism and intrinsic power of the IIS’s operation (see Fig. 7).

The properties of dynamism, openness, and integration of the IIS make it a self-organizing and continuous internal equilibrium. However, to keep the equilibrium of the IIS, which is beneficial to the development of the industry, as well as achieve the system goal, a suitable external environment is necessary. This external environment, in addition to the necessary material basis and natural conditions, mainly depends on the interaction of market regulation and government regulation.

(2) Strategies for building IIS systems in sub-cities based on the low carbon economy.

(i) Collaboration and innovation in policy: building the support system of the IIS. Policy collaboration is at the top of regional collaboration and is a necessary condition that supports industrial collaboration. The creation of an industrial collaboration system can be possible only when governments have reached a consensus to emancipate minds and innovate

institutions when generating top-level design. First, co-formulation of plans. The overall development plan of the secondary urban agglomeration should be co-formulated by all regions to consummate the supporting policies. It is also essential to guide the entire region to realize a high degree of integration that involves the co-formulation of plans, division of labor along the same chain, transportation within the same network, and the sharing of public services. By allocating development factors scientifically and reducing low-level competition, the region’s resource utilization efficiency can be improved. Second, providing public services together. Governments will work together with the proper division of labor in the areas of land use and major infrastructure construction, especially for the construction of a complex transportation system and social welfare system. This would help jointly guarantee the quantity and quality of public goods and services provided by the urban agglomeration. Third, integrated administration. The barriers between administrative divisions would be broken down, and the industries may be served adequately using a creative approach. For example, important departments can establish a joint office or an online one-stop office to simplify the work process and remotely conduct administrative examinations and approvals. This can help support the development of industries by utilizing the power of modern technology fully. Finally, policy innovation. The upgrading of the industry chain should be guided through the innovation of regulatory means, such as fiscal, financial, taxation, and talent policies. On the one hand, strategic emerging industries must be developed for the future growth of the region. On the other hand, advantageous industries, which are currently growing extensively, wasting resources, or creating pollution, must be advised to transform into refined, energy-saving, and eco-friendly industries, thus, the goal of low-carbon economic development can be achieved.

(ii) Innovation chain around the industrial chain: building the dynamic system of the IIS. Investment

should be increased in funds and talents for innovation institutions such as local higher education institutions and research institutes; moreover, the levels and standards of innovative institutions should be promoted. Moreover, talent should be attracted to the region, and the agglomeration of scientific research personnel would be realized. Furthermore, innovation capabilities should be enhanced, especially to enhance the operations of local industries in urgent need of upgrading, to realize key technological breakthroughs. The local innovation system will strengthen the exchange of information with the external innovation system and actively undertake knowledge spillovers from other regions with strong innovation capabilities [39]. Additionally, relevant preferential policies will be rolled out to attract external aid, attracting well-known scientific research institutions to build “technical enclaves” locally and laboratories, together with experts from within and outside of the district. The free flow of scientific research personnel between scientific research institutions and enterprises across urban agglomerations should be realized. To this end, personnel should be encouraged to take projects with them when they resign and start up new businesses. Moreover, a secondment mechanism for employees of public institutions should be consummated, and the problems of social insurance premiums, which arise when working for multiple entities, should be resolved. Additionally, an exchange platform should be built actively for scientific research personnel in the regions, thus allowing the timely sharing of knowledge and information among the regions. Unblocking the paths for innovative achievements to transform them into production. The situation of institutions that specialize in the transformation of scientific research achievements in the regions, such as incubators, medium-sized testing workshops, and patent agencies, should be evaluated. In addition, whether the quantity and quality of the institutions meet the needs of transforming scientific research achievements should be determined. Moreover, new institutions should be built if there is an insufficient number that engages in transformation, and the situation should be rectified if the quality of existing institutions is poor, thus, the goal of low-carbon economic development can be achieved.

(iii) Division of labor and cooperation: building the core system of the IIS. Industrial transfer for the realization of co-opetition collaboration among regional industries. The economic development in a secondary urban agglomeration is uneven, with varying industrial land and labor prices. Gradient transfer can be performed on some of the industries or some links on the industry chain so that the industries across regions can complement each other and promote the optimization of the local economic structure and coordinated economic development. Division of labor between regions for the realization of complementary collaboration between regional industries. As the node cities must participate in performance evaluations based

on economic and social development, a certain degree of competition exists among them. As they have certain common industries with advantages, there are many disputes due to competition for resources, policies, and markets. For such industries in competition with each other, the regions can reasonably compromise and divide labor, establish their own “spheres of influence,” and collaborate to create common brands in the region. In addition, regions can expand the influence of regional industries, and realize the breakthroughs of regional industries’ industry chains from the lower end (assembly and packaging, etc.) to the higher end (R&D and brands, etc.), achieving win-win results and obtaining complementary collaboration. Thus, a pattern of the division of labor that features “outstanding principals and distinctive characteristics” within the urban agglomeration can be formed. This pattern can include an overall and highly competitive industry chain in which each region has its own key positions in the links of the industry chain. Multicenter spillovers for the realization of factor synergy between regional industries. No qualitative difference is seen in the level of development in the secondary urban agglomeration, and there is no clear division between the center and non-center cities. Therefore, the cities can constitute a multicenter network that allows spillovers among one another. This network will help achieve factor collaboration and promote the industrial development level of the entire integrated region through the sharing and exchange of funds, talent, and information, thus, the goal of low-carbon economic development can be achieved.

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Conflict of Interest

The authors declare no conflict of interest.

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