Original Research Article

A study on the collaborative development of the construction industry in Guangdong province from the perspective of virtual agglomeration

Dan Wang, Haixiang Xiong

Hainan Vocational University of Science and Technology, Haikou City, Hainan Province, 571126, China

Abstract: This study examines industrial synergy in Guangdong Province, focusing on virtual agglomeration as a novel industrial organization model. It systematically explores its impact mechanisms and practical pathways on regional industrial collaboration. Research indicates that despite possessing a comprehensive industrial system and cluster advantages, Guangdong—a major manufacturing province—faces challenges such as limitations of traditional geographic agglomeration and lagging digital transformation. Virtual agglomeration overcomes spatial constraints through information technology, optimizing resource allocation and collaborative innovation to offer new solutions for industrial synergy. Theoretically, this paper constructs an analytical framework based on industrial agglomeration theory, network economy theory, transaction cost theory, and innovation theory. Empirical evidence reveals the mechanism through which virtual agglomeration promotes industrial synergy by reducing transaction costs and strengthening network externalities. Findings indicate that virtual agglomeration effectively compensates for the shortcomings of traditional models, empowers enterprises in digital transformation, and provides scientific basis for government policy formulation. It holds significant implications for strengthening industrial chain integration and narrowing regional disparities. Future research directions include deepening studies on new technology integration, cross-regional collaboration, policy adaptability, and SME participation strategies. This study enriches the theoretical framework of industrial collaborative development, offering theoretical and practical references for Guangdong's industrial transformation toward "high-end, intelligent, and green" development.

Keywords: Virtual aggregation; Theoretical framework for industrial collaborative development

1. Research background and significance

1.1. Research background

Guangdong, as China's major manufacturing province, holds a pivotal position in the nation's industrial development landscape. In recent years, Guangdong's industrial sector has achieved remarkable progress, boasting nearly 3 million industrial enterprises. By 2020, the province had over 55,000 industrial enterprises above designated size, with industrial added value reaching 3.31 trillion yuan. Its comprehensive industrial system spans multiple sectors including electronic information, intelligent equipment, and new energy vehicles, fostering robust industrial cluster effects.

In the electronics and information sector, companies like Huawei and Tencent lead industry innovation, propelling Guangdong into a globally significant electronics hub. Within intelligent equipment, firms such as Guangzhou CNC continuously advance core technologies, enhancing the market competitiveness of domestic equipment. The new energy vehicle industry also shows vigorous growth, with companies like Xpeng and BYD achieving notable successes in R&D and market expansion.

However, with the deepening of economic globalization and the acceleration of technological revolution, Guangdong's industrial development faces numerous challenges. Industrial growth has slowed, the proportion

of manufacturing has declined, and the industrial structure requires further optimization. Simultaneously, the limitations of traditional geographic clustering models in resource allocation and collaborative innovation have become apparent, creating obstacles to coordinated development among enterprises.

Against this backdrop, the virtual clustering model has emerged as a response to these challenges. Virtual clustering refers to a new industrial organization model where enterprises leverage information technologies such as the internet, big data, and cloud computing to transcend geographical constraints, enabling resource sharing, information exchange, and collaborative innovation. With the rapid advancement and widespread adoption of information technology, the application of virtual clustering in the industrial sector has become increasingly prevalent. It provides enterprises with broader development opportunities, effectively integrates upstream and downstream resources within industrial chains, enhances industrial synergy efficiency, and reduces operational costs.

Currently, Guangdong's industrial synergy faces several pressing issues. On one hand, collaboration among enterprises under the geographic agglomeration model primarily relies on physical proximity, lacking deep industrial division of labor and collaborative innovation, resulting in low industrial value-added. On the other hand, enterprises encounter multiple challenges in digital transformation, including technological, financial, and talent constraints, leading to uneven digitalization levels that hinder the overall progress of industrial synergy. Furthermore, insufficient coordination in industrial policies has also impacted the effectiveness of industrial synergy to some extent. Therefore, conducting in-depth research on industrial synergy in Guangdong from the perspective of virtual agglomeration holds significant practical significance.

1.2. Analysis of research significance

This study focuses on the coordinated industrial development in Guangdong Province from the perspective of virtual agglomeration, holding significant theoretical and practical implications while also playing a substantial role in promoting regional economic growth.

From a theoretical standpoint, current research on coordinated industrial development predominantly centers on traditional geographic agglomeration models, with relatively limited theoretical exploration of coordinated industrial development under virtual agglomeration. This study delves into the impact mechanisms of virtual agglomeration on industrial synergy in Guangdong, constructing a theoretical analytical framework that enriches and expands the theoretical system of industrial synergy. By examining the relationships between virtual agglomeration, factor flow networks, and industrial clustering, it offers new theoretical perspectives and research approaches for regional industrial synergy, filling a gap in this field[1].

Practically, this research provides Guangdong's industrial enterprises with actionable development pathways and strategic recommendations. By evaluating their level of virtual agglomeration development, enterprises can clearly understand their strengths and weaknesses within the virtual agglomeration environment, enabling targeted digital transformation and collaborative development. Simultaneously, the proposed countermeasures to accelerate virtual agglomeration development and measures to promote industrial collaborative development—such as strengthening industrial division of labor and collaboration, and improving factor flow networks—can help enterprises overcome the limitations of traditional geographic agglomeration models. This enhances resource allocation efficiency, reduces operational costs, and boosts market competitiveness.

For government departments, this research provides a scientific basis for formulating relevant industrial policies. Based on the findings, governments can introduce more precise and effective policy measures to guide enterprises in actively participating in virtual agglomeration and promoting industrial synergy. For instance, in terms of policy support, investments in R&D and application of virtual agglomeration-related technologies can be increased. Regarding talent development, targeted talent policies can be established to attract and cultivate more professionals suited for virtual agglomeration development.

From a regional economic development perspective, enhancing industrial synergy in Guangdong will drive overall regional economic growth. As a vital pillar of Guangdong's economy, industrial synergy promotes industrial upgrading and structural optimization, elevating the region's comprehensive competitiveness. Industrial synergy under the virtual clustering model can also strengthen cooperation and exchange among enterprises within the region, forming tighter industrial chains and clusters that advance regional economic integration. Furthermore, industrial synergy will create more employment opportunities, raise residents' income levels, and promote social stability and prosperity.

2. Core concepts and theoretical foundations

2.1. Definition of the concept of virtual agglomeration

Virtual clustering is a novel industrial organization model emerging against the backdrop of rapid information technology advancement. It refers to enterprises leveraging advanced information technologies such as the internet, big data, and cloud computing to transcend geographical constraints, enabling resource sharing, information exchange, and collaborative innovation within virtual spaces. Unlike traditional geographic clustering, virtual clustering does not rely on the physical proximity of enterprises. Instead, it connects dispersed businesses, institutions, and individuals across different regions through digital platforms and network technologies, forming a highly collaborative and innovative industrial ecosystem.

Virtual clustering exhibits the following distinct characteristics. First, it overcomes geographical constraints. Enterprises need not physically co-locate, enabling them to transcend regional boundaries and integrate global resources and factors for broader collaboration and exchange. This allows companies to select the most advantageous partners for collaborative innovation based on their specific needs, enhancing resource allocation efficiency. Second, it facilitates information sharing and real-time interaction. Within virtual clusters, enterprises can share information in real time through digital platforms, enabling swift responses to market shifts. This efficient information flow mechanism helps businesses adjust production strategies promptly and mitigate market risks. Third, dynamic adaptability and flexibility. Members of virtual clusters can join or exit the network at any time based on market demands and their own development strategies, endowing industrial organizations with greater adaptability and flexibility. Enterprises can rapidly assemble teams according to project requirements and dissolve them flexibly upon task completion, thereby enhancing operational efficiency.

The formation mechanisms of virtual clusters primarily encompass the following aspects. First, advancements in information technology form the foundation for virtual clusters. Continuous progress in technologies like the internet, big data, and cloud computing provides enterprises with convenient platforms for information exchange and resource sharing. Second, shifting market demands serve as the driving force behind virtual clusters. As consumer needs become increasingly diverse and personalized, enterprises require more flexible and efficient production models to meet market expectations. The virtual cluster model integrates resources across the industrial chain, enabling rapid response and customized production to enhance corporate competitiveness. Finally, the inherent corporate pursuit of cost reduction and efficiency improvement is another crucial factor. Through virtual clusters, enterprises can share infrastructure, R&D outcomes, and market channels, thereby lowering production costs and boosting efficiency. Simultaneously, virtual clusters foster knowledge spillovers and collaborative innovation among businesses, elevating the overall innovation capacity of the industry.

2.2. Regional industrial synergy concept

Regional industrial synergy refers to an economic development model where industrial enterprises and sectors within a defined region achieve mutual development and maximize overall benefits through resource sharing, complementary strengths, and division of labor. It emphasizes collaboration and coordination among

regional industrial entities to enhance the collective competitiveness and sustainable development capacity of the regional industrial sector.

The objectives of regional industrial synergy are primarily reflected in the following aspects. First, optimizing resource allocation. Through coordinated development, it breaks down the fragmented and compartmentalized state of industrial resources within the region, enabling rational resource flow and efficient utilization to improve allocation efficiency. Second, enhancing industrial competitiveness. It promotes specialized division of labor and collaboration among industries within the region, forming complete industrial chains and clusters. This amplifies economies of scale and synergistic effects, strengthening the market competitiveness of industries. Third, driving industrial upgrading. Encourage enterprises to increase investment in technological innovation and R&D, promote the application of new technologies, processes, and materials, and drive regional industry toward high-end, intelligent, and green development. Fourth, promote coordinated regional economic development. Narrow the industrial development gap between different areas within the region, achieve balanced regional economic growth, and enhance the overall strength and stability of the regional economy.

The primary manifestations of regional industrial synergy include the following. Industrial division of labor and collaboration represent the core form of regional industrial synergy. Enterprises within a region leverage their respective strengths and characteristics to specialize in specific segments or domains of the industrial chain, forming a pattern of specialized division of labor. Through this division and collaboration, enterprises can enhance production efficiency, reduce costs, and improve product quality. Industrial cluster development is another significant manifestation of regional industrial synergy. Related industries aggregate within a defined area to form industrial clusters. Enterprises within these clusters achieve collaborative innovation and shared growth by pooling resources such as infrastructure, R&D capabilities, and market intelligence. Industrial parks and industrial bases within a region are typical examples of industrial clusters. Collaborative alliances among enterprises are also common forms of regional industrial synergy. By establishing strategic partnerships, joint ventures, and technology transfers, enterprises achieve resource sharing, complementary advantages, and jointly undertake production and business activities. Such collaborative alliances can be horizontal cooperation among enterprises in the same industry or vertical cooperation between upstream and downstream enterprises in the industrial chain.

2.3. Relevant theoretical foundations

When studying virtual agglomeration and regional industrial synergy, several important theoretical foundations come into play, providing robust support for in-depth understanding and analysis of related phenomena.

Industrial agglomeration theory serves as a crucial cornerstone for studying regional industrial synergy. This theory posits that the geographical concentration of industries yields numerous advantages. First, industrial agglomeration enables resource sharing, allowing enterprises to jointly utilize infrastructure, labor markets, and other resources, thereby reducing production costs. For instance, within certain industrial parks in Guangdong, numerous enterprises share infrastructure such as water, electricity, and transportation, lowering individual construction costs. Second, industrial agglomeration facilitates knowledge spillovers and technological innovation. Close proximity among enterprises allows rapid dissemination of information and technology, fostering mutual learning and imitation while stimulating innovation. Take Guangdong's electronics and information technology cluster: frequent technical exchanges among enterprises drive technological upgrading across the entire industry. Furthermore, industrial agglomeration generates economies of scale and scope, enhancing industrial competitiveness[2].

Network economy theory is also closely linked to virtual agglomeration. Within a network economy environment, information dissemination and sharing become more convenient and efficient. Virtual agglomeration leverages information technologies like the internet to connect dispersed enterprises into a network. Network

economy theory emphasizes network externalities—The value a user derives from a network increases as the number of other users grows. Within a virtual agglomeration network, the greater the number of enterprises, the richer the sharing of information and resources, and the greater the benefits enterprises gain. Simultaneously, the network economy exhibits diminishing marginal costs, where operational expenses gradually decrease as the network expands. For instance, when businesses exchange information and collaborate through digital platforms, their marginal costs become nearly negligible.

Transaction cost theory also holds significant relevance for understanding virtual agglomeration and regional industrial synergy. This theory posits that enterprises exist to reduce market transaction costs. Under traditional geographic agglomeration models, transaction costs between enterprises are influenced by factors such as geographical location and information asymmetry. Virtual agglomeration, however, utilizes information technology to reduce transaction costs associated with information search, negotiation, and supervision. Enterprises can swiftly identify suitable partners in the virtual space and conduct efficient transactions. Furthermore, virtual agglomeration can lower organizational costs and enhance operational efficiency[3].

Innovation theory emphasizes the central role of innovation in economic development. Virtual agglomeration provides enterprises with an innovation platform, fostering collaborative innovation among businesses. Within this environment, enterprises can integrate innovation resources from different regions and engage in cross-disciplinary innovation activities. For instance, some enterprises in Guangdong have leveraged virtual agglomeration platforms to collaborate with universities and research institutions on joint technology R&D, thereby enhancing their innovation capabilities. These theories are interconnected, collectively providing a robust theoretical foundation for studying the coordinated industrial development of the Guangdong region from the perspective of virtual agglomeration.

3. Conclusions and outlook

3.1. Research findings

This study examines the coordinated industrial development in Guangdong Province from the perspective of virtual agglomeration, yielding the following key conclusions: First, as a new industrial organization model driven by information technology, virtual agglomeration effectively addresses the limitations of traditional geographic agglomeration in terms of depth of industrial division and digital collaboration. By overcoming geographical constraints, optimizing resource allocation efficiency, and fostering collaborative innovation, it offers a novel pathway for coordinated industrial development in Guangdong. Second, the theoretical foundation of this research integrates industrial agglomeration theory, network economy theory, transaction cost theory, and innovation theory. Among these, network externalities and diminishing marginal costs provide an economic rationale for the efficient collaboration inherent in virtual agglomeration, while reduced transaction costs serve as the core motivator for enterprises to participate in such virtual clusters.

3.2. Future outlook

Future research can be deepened in the following directions: First, explore the deep integration mechanisms between virtual clustering and industrial digital transformation, focusing on application scenarios of new technologies such as artificial intelligence and blockchain in resource sharing and collaborative innovation. Second, expand research on cross-regional virtual clustering collaboration models, analyzing networked integration pathways for industrial resources within the Guangdong-Hong Kong-Macao Greater Bay Area and across the nation. Third, strengthen research on dynamic policy adaptability, building a flexible policy support system that aligns with technological iteration and industrial transformation needs. Fourth, examine participation barriers and breakthrough strategies for small and medium-sized enterprises within virtual clusters to promote inclusive

development of industrial collaboration.

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