Original Research Article

A study on the mechanism of virtual agglomeration's impact on the collaborative development of industrial buildings in Guangdong

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Abstract: Against the backdrop of global industrial digital transformation and coordinated regional economic development, Guangdong—As a major industrial hub in China—Faces resource constraints, barriers to factor mobility, and efficiency bottlenecks in its industrial coordination under traditional geographic agglomeration patterns. This study examines Guangdong Province, analyzing its current level of industrial synergy, its operational models (industrial chain synergy, industrial cluster synergy, regional synergy), and its outcomes (enhanced production efficiency, strengthened industrial competitiveness). It dissects the existing development challenges and constructs a theoretical analytical framework—"Virtual agglomeration—Factor flow network—industrial agglomeration—Industrial synergy"—To explore the impact mechanism of virtual agglomeration on industrial synergy.

The study finds that virtual agglomeration promotes industrial synergy through three pathways: facilitating cross-regional flows of factors such as talent, capital, and technology; deepening industrial division of labor and cluster coordination; and strengthening innovation collaboration and knowledge spillovers. Factor mobility networks and industrial agglomeration serve as key intermediary links through which virtual agglomeration influences industrial synergy. This research provides theoretical references and practical insights for Guangdong and other regions nationwide to optimize industrial synergy models and enhance industrial competitiveness through digital technologies.

Keywords: clustering model; industrial synergy

1. Introduction

Against the backdrop of accelerating global industrial digital transformation and deepening regional economic coordination, industrial synergy has emerged as a core issue driving high-quality regional economic development. It serves as a key pathway to enhance industrial competitiveness and optimize resource allocation. As China's largest economic province and industrial powerhouse, Guangdong has pioneered significant achievements in industrial synergy through its massive industrial scale, comprehensive industrial ecosystem, and leading digital infrastructure. However, as economic development enters a new phase, constraints such as resource limitations under traditional geographic agglomeration models, barriers to factor mobility, and bottlenecks in collaborative efficiency have become increasingly apparent. Overcoming spatial limitations, deepening industrial chain synergy, and enhancing innovation capabilities now represent critical challenges for Guangdong's industrial collaboration.

Virtual clustering, a novel industrial organization model driven by digital technologies, breaks geographical boundaries through internet, big data, and cloud computing. It enables resource sharing, information exchange, and collaborative innovation among enterprises, offering fresh perspectives to overcome traditional industrial collaboration challenges. This research aims to provide theoretical references and practical insights for Guangdong and other regions nationwide to optimize industrial collaboration models and enhance industrial competitiveness through digital technologies.

2. Current status and challenges of industrial synergy development in Guangdong region

2.1. Current status of industrial synergy development

2.1.1. Current level

In recent years, Guangdong has made notable progress in industrial synergy, with overall capabilities

steadily improving. In terms of industrial scale, the province hosts nearly 3 million industrial enterprises. By 2020, it had over 55,000 industrial enterprises above designated size, generating an industrial added value of 3.31 trillion yuan. This substantial industrial scale provides a solid foundation for collaborative industrial development. In terms of industrial structure, Guangdong encompasses multiple sectors including electronic information, intelligent equipment, and new energy vehicles, featuring a relatively complete industrial system. Synergistic effects among different industries are gradually emerging.

2.2. Primary modes

Industrial Chain Collaboration Model: Guangdong has developed relatively complete industrial chains in several competitive sectors, where enterprises achieve synergistic development through division of labor and cooperation. Taking the electronics industry as an example, Huaqiangbei in Shenzhen hosts over 2,000 sensor companies, accounting for 45% of China's MEMS sensor shipments. These upstream enterprises supply critical components to mid-to-downstream electronics manufacturers, forming a tightly integrated industrial chain collaboration.

Industrial Cluster Synergy Model: Industrial clusters represent a key model for coordinated industrial development in Guangdong. For instance, Dongguan's apparel industry belt leverages the industrial internet to enable rapid response to small orders, compressing delivery cycles to just 7 days. Enterprises within these clusters share resources such as infrastructure, R&D capabilities, and market intelligence, fostering collaborative innovation and mutual growth.

Regional Synergy Model: Industrial coordination is also strengthening across Guangdong's diverse regions. As the core industrial area, the Pearl River Delta drives industrial development in Eastern, Western, and Northern Guangdong through industrial transfer and regional cooperation. For instance, some Guangzhou-based enterprises have relocated production segments to surrounding areas, achieving inter-regional industrial synergy and optimized resource allocation[1].

2.3. Achievements

Table 1. Level of industrial synergy development.

Effect Type	Specific manifestations	Case Study
Production Efficiency Enhancement	Through industrial synergy, enterprises have achieved significant improvements in production efficiency.	Midea Microwave Oven's “5G + AI Quality Inspection” System Boosts Efficiency by 300% and Reduces Unit Costs by 25%.
Enhanced industrial competitiveness	Industrial synergy has promoted the specialization and collaboration of industries, enhancing the scale effect and synergy effect of industries, and strengthening the market competitiveness of industries.	The Guangzhou CNC Industrial Internet platform has connected over 100,000 devices, with a fault prediction accuracy rate of 92%, enhancing the market competitiveness of domestic equipment.
Enhanced innovation capability	The increase in collaborative innovation cooperation between enterprises has promoted the application of new technologies, new processes, and new materials, enhancing the innovation capabilities of the industry.	Huawei's ‘Huawei Cloud Industrial Intelligence' serves over 50 automakers, improving production line efficiency by 18%, and has promoted the innovative development of the automotive industry.
Growth in economic benefits	The coordinated development of industry has driven regional economic growth and improved the economic benefits of enterprises.	Shenzhen Power Supply Bureau's ‘Digital Twin Power Grid' reduces line loss by 12%, saving over 500 million kilowatt-hours of electricity annually, achieving a win-win situation for economic and social benefits.

Overall, Guangdong's industrial synergy has achieved certain results in terms of current levels, models, and effectiveness, yet some issues and challenges remain. The following section will delve into the impact mechanism of virtual agglomeration on industrial synergy from a virtual agglomeration perspective.

3. Mechanism of virtual agglomeration's impact on idustrial synergistic development in Guangdong region

3.1. Theoretical analytical framework for impact analysis

To gain a deeper understanding of the impact of virtual agglomeration on industrial synergy in Guangdong, the following theoretical analytical framework is constructed. This framework primarily encompasses four core elements: virtual agglomeration, factor flow networks, industrial agglomeration, and industrial synergy. These

elements are interconnected and mutually influence one another.

Table 2. Element relationships and specific content.

Factor	Translated content
Virtual Agglomeration	Enterprises leverage internet, big data, cloud computing, and other information technologies to break through geographical constraints and achieve resource sharing, information exchange, and collaborative innovation in the virtual space as an industrial organization model.
Factor Flow Network	A network of mobility composed of talents, capital, technology, and other elements promotes the efficient allocation of these elements between enterprises and industries.
Industrial Agglomeration	Including types such as specialized agglomeration and collaborative agglomeration, the concentration of enterprises in geographical or virtual spaces brings about economies of scale and synergistic effects.
Industrial Synergy Development	Industrial enterprises within a region achieve common development and maximize overall benefits through resource sharing and division of labor cooperation.

The relationships among the various elements are as follows:

Virtual Agglomeration and Factor Mobility Networks: Virtual agglomeration provides the platform and technological support for the formation and development of factor mobility networks. Through digital platforms, enterprises can more readily access factors such as talent, capital, and technology, breaking geographical constraints and facilitating cross-regional factor mobility. For instance, companies can recruit specialized talent globally via online recruitment, secure funding through digital financial platforms, and share R&D outcomes with other enterprises. Simultaneously, the refinement of factor mobility networks also contributes to the advancement of virtual agglomeration. The free flow of factors enables enterprises to better integrate resources, enhance innovation capabilities and competitiveness, and attract more businesses to join the virtual agglomeration network[2].

Virtual Agglomeration and Industrial Agglomeration: Virtual agglomeration and industrial agglomeration mutually reinforce each other. Virtual agglomeration transcends geographical constraints, connecting enterprises scattered across different regions to form virtual industrial clusters. Such virtual clusters integrate resources across the industrial chain, enabling synergistic industrial development. For instance, through virtual platforms, enterprises in diverse locations can jointly undertake R&D, production, and sales activities, enhancing overall industrial efficiency. Concurrently, traditional industrial clusters can leverage virtual agglomeration to boost their collaborative innovation capabilities and competitiveness[3].Enterprises within industrial clusters can leverage digital platforms to share information, collaborate, and expand their market reach.

Factor Mobility Networks and Industrial Agglomeration: Factor mobility networks serve as a crucial foundation for the formation and development of industrial agglomeration. The flow of factors enables enterprises within agglomeration zones to access necessary resources, achieve specialized division of labor and collaboration, and enhance industrial competitiveness. For instance, talent mobility facilitates knowledge exchange and technological innovation among enterprises, while capital mobility supports enterprises' expanded reproduction and technological upgrading. Simultaneously, industrial agglomeration attracts further inflow of factors. Enterprises within industrial clusters benefit from economies of scale and synergistic effects, offering better development opportunities and returns for factors of production. This, in turn, attracts the concentration of factors such as talent, capital, and technology.

Virtual Agglomeration, Factor Mobility Networks, Industrial Agglomeration, and Industrial Synergy: Virtual agglomeration ultimately drives industrial synergy by facilitating the formation of factor mobility networks and the development of industrial agglomeration. The efficient flow of factors and coordinated industrial clustering enable optimal resource allocation, enhance corporate productivity and innovation capabilities, and facilitate industrial upgrading and transformation. Simultaneously, industrial synergy provides a better development environment and market demand for virtual clustering, factor flow networks, and industrial agglomeration, creating a virtuous cycle[4].

Through the theoretical analytical framework outlined above, the mechanism by which virtual agglomeration influences the coordinated industrial development in Guangdong becomes clearly discernible. The interplay and mutual reinforcement among various factors collectively propel Guangdong's industrial coordination to new heights.

3.2. Specific mechanisms through which virtual agglomeration promotes industrial synergy

Virtual agglomeration promotes coordinated industrial development in Guangdong through multiple mechanisms, playing a vital role in facilitating factor mobility, industrial division of labor, and innovation collaboration.

Regarding factor mobility, virtual agglomeration breaks geographical barriers, significantly enhancing the efficient flow of factors such as talent, capital, and technology. In terms of talent, enterprises can recruit specialized professionals globally via digital platforms, overcoming geographical constraints on talent acquisition. For instance, some high-tech enterprises in Guangdong have attracted top-tier domestic and international research talents and technical experts through online recruitment channels, injecting new vitality into corporate innovation and development. These professionals can remotely participate in project R&D and production management, enabling the sharing of knowledge and expertise. Regarding capital, virtual agglomeration provides enterprises with more accessible financing channels. The development of online financial platforms allows companies to quickly secure funding support, reducing both financing costs and time expenditures. Small and medium-sized enterprises can obtain microloans through internet finance platforms, resolving cash flow challenges and enabling greater participation in industrial synergy. Regarding technological resources, enterprises can share R&D outcomes and collaborate on technology through virtual platforms. Companies across regions can jointly tackle technical challenges and overcome bottlenecks. For instance, Guangdong's electronics firms share chip development technologies via virtual clustering platforms, elevating the industry's overall technical capabilities[5].

In terms of industrial division of labor, virtual clustering helps deepen specialization and enhance collaborative efficiency. It enables enterprises to gain clearer insights into supply and demand across the entire industrial chain, thereby achieving more precise division of labor. Companies can leverage their strengths and expertise to focus on specific segments of the chain, improving production efficiency and product quality. For instance, within Guangdong's intelligent equipment industry, some enterprises concentrate on R&D and manufacturing of core components, while others specialize in assembling and marketing complete systems. Through this specialized division of labor, enterprises form close cooperative relationships, enhancing the competitiveness of the entire industry. Virtual agglomeration also promotes the development of industrial clusters, enabling enterprises within these clusters to achieve better coordinated development. Enterprises within industrial clusters can share resources such as infrastructure and logistics distribution through virtual platforms, reducing production costs. Simultaneously, more frequent information exchange between enterprises allows for timely adjustments to production plans to adapt to changes in market demand.

Regarding innovation collaboration, virtual clustering provides an open innovation platform that fosters cooperation among enterprises. Companies can engage in industry-academia-research partnerships with universities and research institutions through virtual platforms, integrating diverse innovation resources. For instance, some enterprises in Guangdong have established virtual R&D centers in collaboration with universities to jointly pursue technological development and talent cultivation. This model not only enhances corporate innovation capabilities but also offers practical platforms for universities and research institutions, accelerating the commercialization of scientific achievements. Virtual clustering also accelerates knowledge spillovers and innovation diffusion among enterprises. Within this environment, information exchange becomes more efficient, enabling rapid dissemination of new knowledge and technologies. Innovations developed by one enterprise can be swiftly adopted and applied by others, driving industry-wide innovation. For instance, successful business model innovations by some Guangdong-based internet companies spread rapidly through virtual platforms, catalyzing innovation upgrades across the entire sector.

Virtual clustering also fosters trust and cooperative relationships among enterprises. Within this environment, collaboration becomes more frequent and profound. Through sustained cooperation and exchange, enterprises gradually build trust. This trust reduces transaction costs and enhances cooperation efficiency. Simultaneously, virtual clustering provides a level playing field for fair competition, compelling enterprises to continuously improve their competitiveness and thereby driving coordinated industrial development.

Virtual clustering has powerfully propelled industrial synergy in Guangdong through mechanisms that facilitate factor mobility, deepen industrial division of labor, and strengthen innovation collaboration. Moreover,

sustained interactions on virtual platforms help build trust between enterprises, further reducing transaction costs.

4. Conclusions and outlook

4.1. Conclusion

This study systematically examines the impact mechanism of virtual agglomeration on industrial synergy in Guangdong Province, with the following key findings:

Guangdong has achieved remarkable results in industrial synergy but faces bottlenecks. Leveraging its massive industrial scale, comprehensive industrial system, and diverse synergy models (industrial chain synergy, industrial cluster synergy, regional synergy), Guangdong has significantly enhanced production efficiency, strengthened industrial competitiveness, boosted innovation capabilities, and increased economic benefits. However, resource constraints, barriers to factor mobility, and bottlenecks in synergy efficiency under traditional geographic agglomeration models continue to hinder further development.

Factor mobility and industrial agglomeration serve as critical intermediary links. Virtual agglomeration provides technological support for factor mobility networks, which in turn underpin the formation and upgrading of industrial agglomeration. Together, these three elements form a virtuous cycle that drives industrial synergy, ultimately achieving optimal resource allocation and enhanced industrial competitiveness.

4.2. Outlook

Expand research on industrial heterogeneity in virtual agglomeration. Future studies may conduct comparative analyses of virtual agglomeration characteristics across different industries (e.g., high-end manufacturing, services), exploring differences in collaborative mechanisms between technology-intensive and labor-intensive sectors.

Deepen research on dynamic evolutionary mechanisms. Utilizing long-term panel data, analyze the dynamic impact of virtual agglomeration on industrial collaboration and its varying effects across different phases of the economic cycle.

Explore the moderating effects of policy interventions. Further research should examine how policy tools—Such as digital infrastructure development and data security regulations—Can optimize the synergistic outcomes of virtual agglomeration, providing more precise theoretical support for policy formulation.

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