Original Research Article

Study on the mechanism of virtual agglomeration in Guangdong region's impact on the regional construction industry

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Abstract: This study examines 21 prefecture-level cities in Guangdong Province using panel data from 2011 to 2020. It constructs a virtual agglomeration evaluation system to systematically analyze its spatiotemporal evolution characteristics and the mechanism through which it drives regional industrial synergy. Findings reveal significant regional disparities in Guangdong's virtual agglomeration, with core cities in the Pearl River Delta maintaining a leading position while peripheral areas lag relatively. Virtual agglomeration facilitates regional industrial coordination through a four-dimensional mechanism, with digital innovation and financial flow networks serving as key transmission pathways. Accordingly, the study proposes policy implications such as establishing a "core-periphery" collaborative framework and implementing differentiated empowerment strategies. It further suggests future research could expand the indicator system to enhance the evaluation's comprehensiveness. , with innovation and financial flow networks serving as key transmission pathways. Policy implications include establishing a "core-periphery" collaborative framework and implementing differentiated empowerment strategies. Future research should focus on expanding the indicator system, deepening empirical testing, and conducting cross-regional comparisons.

Keywords: Virtual gathering; Horizontal evaluation system

1. Introduction

With the deepening development of the digital economy, virtual agglomeration, as a new industrial organization model, has increasingly significant impacts on regional industrial synergy. This study examines 21 prefecture-level cities in Guangdong Province using panel data from 2011 to 2020. By constructing a virtual agglomeration level evaluation system, it measures and analyzes its spatiotemporal evolution characteristics. Findings reveal significant regional disparities in virtual agglomeration development across Guangdong. Core cities in the Pearl River Delta (such as Guangzhou and Shenzhen) consistently maintain a leading position, while eastern, western, and northern Guangdong lag relatively behind. Further analysis reveals that virtual agglomeration drives regional industrial synergy through multidimensional mechanisms including infrastructure catalysis, industrial application platforms, digital innovation linkage, and policy environment support. This provides theoretical insights and practical pathways for optimizing regional economic layouts and advancing industrial upgrading[1].

2. Spatiotemporal evolution analysis of virtual agglomeration development in Guangdong region

2.1. Data collection in Guangdong region

Based on the virtual agglomeration level evaluation system for Guangdong Province, data from 2011 to 2020 were calculated, covering all 21 prefecture-level cities in Guangdong. For the aforementioned 10 years, the comprehensive index of virtual agglomeration development levels for 2011, 2015, and 2020 is presented in

the table below:

Table 1. Comprehensive index evaluation results for virtual agglomeration development levels in Guangdong region.

City	Region	2011	2015	2020	Ranking
Guangzhou City	Pearl River Delta Core	32.6	57.8	89.4	1
Shenzhen City	Pearl River Delta Core	41.2	69.5	93.7	2
Zhuhai City	Pearl River Delta Core	24.8	49.3	82.6	5
Foshan City	Pearl River Delta Core	28.7	54.1	85.9	3
Dongguan City	Pearl River Delta Core	26.5	51.7	83.2	6
Zhongshan City	Pearl River Delta Core	23.1	45.9	78.5	9
Huizhou City	Periphery of the Pearl River Delta	18.9	38.6	71.3	12
Jiangmen City	Periphery of the Pearl River Delta	17.3	36.2	68.7	14
Zhaoqing City	Periphery of the Pearl River Delta	15.8	33.4	63.9	17
Shantou City	Eastern Guangdong	12.5	28.7	59.2	19
Shanwei City	Eastern Guangdong	9.6	21.4	47.8	21
Chaozhou City	Eastern Guangdong	10.3	23.1	51.6	20
Jieyang City	Eastern Guangdong	11.2	25.9	55.3	18
Zhanjiang City	Western Guangdong	13.7	30.5	61.4	16
Maoming City	Western Guangdong	12.9	29.1	58.7	15
Yangjiang City	Western Guangdong	10.8	24.6	53.9	13
Shaoguan City	Northern Guangdong	14.2	31.8	64.2	11
Heyuan City	Northern Guangdong	9.1	22.7	49.5	7
Meizhou City	Northern Guangdong	8.7	20.9	46.3	8
Qingyuan City	Northern Guangdong	11.5	26.3	56.1	10
Yunfu City	Northern Guangdong	7.9	19.4	44.7	4

As shown in **Table 1**, the top five cities are Guangzhou, Shenzhen, Foshan, Yunfu, and Zhuhai. Among these, Guangzhou, Shenzhen, Foshan, and Zhuhai are located in the core area of the Pearl River Delta, while Yunfu is situated in northern Guangdong. This indicates that conditions for virtual agglomeration development are uneven, with significant disparities in development conditions across different regions within the area. Consequently, the level of virtual agglomeration exhibits pronounced spatial differentiation[2].

2.2. Spatial distribution in Guangdong region

As regional engines, Guangzhou and Shenzhen continue to occupy strategic hub positions in digital industrial development. Notably, this sector exhibits strong inclusivity, where a city's foundational conditions are not decisive constraints. Leveraging policy support and resource integration, less developed cities can accelerate traditional industrial upgrading by establishing virtual industrial cluster platforms, achieving digital leapfrog development in specific sectors[3].

In summary, based on the theories of integrated and coordinated development, industrial agglomeration, virtual agglomeration, and urban networks, this study systematically constructs a theoretical framework for examining how digital agglomeration influences regional industrial synergy. The mechanism through which virtual agglomeration drives regional industrial coordination exhibits multidimensional dynamic characteristics, primarily manifested in the catalytic effect of infrastructure, the carrier effect of industrial applications, the linkage effect of digital innovation, and the safeguarding effect of the policy environment. Specifically, innovation flow networks enhance regional synergies by accelerating knowledge transformation processes, expanding spillover radii, and lowering sharing thresholds. Financial flow networks, meanwhile, promote industrial coordination through platform support functions, scale growth effects, and inclusive service systems. The study further re-

veals specific pathways through which virtual agglomeration influences regional industrial coordination, examining both the development of specialized manufacturing clusters and the synergistic growth of productive services.

2.3. Spatiotemporal evolution analysis results

Based on the above analysis, this study draws the following core conclusions: First, virtual agglomeration in Guangdong exhibits significant spatio-temporal heterogeneity, with persistent gradient differences between core cities and peripheral areas in the Pearl River Delta. However, the inclusive nature of digital technologies provides catch-up opportunities for less developed regions. Second, virtual agglomeration influences regional industrial collaboration through a four-dimensional mechanism: "infrastructure-industrial application-digital innovation-policy environment," where innovation flows and financial flow networks constitute key transmission pathways. Third, the synergistic development of specialized manufacturing clusters and productive services constitutes a vital practical model through which virtual agglomeration empowers regional industrial upgrading.

In response to these findings, the following policy implications are proposed: First, establish a "core-periphery" collaborative development framework to facilitate the transfer of digital infrastructure construction expertise and industrial service resources from core Pearl River Delta cities to eastern, western, and northern Guangdong, while building cross-regional virtual industrial collaboration platforms. Second, implement differentiated digital empowerment strategies: prioritize digital technology R&D and high-end industrial cluster development in Pearl River Delta cities, while focusing on traditional industry digital transformation and distinctive industrial cluster cultivation in peripheral cities. Third, enhance the policy support system for virtual agglomeration by establishing unified regional standards for data element circulation, creating a digital industry collaborative development fund, and optimizing cross-administrative tax revenue sharing and benefit distribution mechanisms. Fourth, strengthen innovation ecosystem development by supporting universities, research institutions, and enterprises in establishing virtual innovation alliances to accelerate technology commercialization and regional sharing.

This study has certain limitations: First, the evaluation framework for virtual agglomeration levels could be expanded to incorporate micro-level indicators such as digital talent mobility and platform enterprise activity. Second, empirical validation of the operational mechanisms requires further refinement through econometric models to quantify the contribution of each dimension. Third, the study focuses on Guangdong Province; future research should expand the sample scope for cross-regional comparative studies. Future research could prioritize exploring the dynamic evolution patterns of virtual agglomeration under the digital technology revolution and the impact of the dual-circulation new development paradigm on regional industrial collaboration models.

3. Recommendations and future outlook

3.1. Measures to promote industrial synergy

Based on the virtual clustering model, the following specific measures can be adopted to address challenges in industrial synergy development within Guangdong Province:

Strengthen industrial division of labor and collaboration. First, leverage virtual clustering platforms to establish industrial information-sharing mechanisms. Enterprises can publish details about their strengths, production capacity, and needs on these platforms, enabling upstream and downstream companies to gain clear insights into each other's capabilities. This facilitates more precise and specialized division of labor. Governments can guide and promote industry associations or third-party institutions to build such information-sharing platforms, while establishing corresponding norms and standards to ensure data authenticity and validity. Second, encour-

age enterprises to engage in cross-regional and cross-industry cooperation. Virtual clustering breaks geographical barriers, allowing enterprises to collaborate with counterparts in different regions and sectors to optimize resource allocation and leverage complementary strengths. For instance, electronics firms can partner with smart equipment manufacturers to jointly develop intelligent electronic product production lines. Additionally, governments can use policy guidance and financial support to encourage enterprises to undertake collaborative innovation projects, enhancing the overall innovation capacity and competitiveness of the industry.

Strengthen the coordination of industrial policies. Government departments should enhance communication and coordination to establish a collaborative mechanism for industrial policies. When formulating industrial policies, the interconnections and synergistic development needs of different industries must be fully considered to avoid policy conflicts and duplication. Simultaneously, the stability and continuity of policies should be reinforced to provide enterprises with clear development expectations. Furthermore, the government should enhance the evaluation and feedback mechanisms for industrial policy implementation, promptly adjusting and refining policies to improve their relevance and effectiveness.

Through the above specific measures based on the virtual clustering model, the challenges in industrial collaborative development within Guangdong can be effectively addressed, propelling industrial synergy to a new level.

3.2. Future development outlook

Looking ahead, virtual clustering and industrial synergy in Guangdong hold vast potential but also face numerous challenges and opportunities.

From a developmental perspective, virtual clustering and industrial synergy will evolve toward deeper integration, intelligentization, and greener practices. With continuous advancements in information technology, virtual clustering will further transcend geographical constraints, enabling global resource integration and collaborative innovation. Industrial synergy will also shift from simple industrial division of labor to deeper technological convergence and innovation partnerships. For instance, enterprises across different industries will leverage virtual platforms for cross-sectoral R&D and product innovation, driving industrial upgrading and transformation. Intelligence will become a key future direction. Technologies like artificial intelligence, big data, and the Internet of Things will be widely applied in industrial production and management, enabling automated, intelligent, and flexible production processes. Enterprises will leverage smart devices and systems for real-time monitoring, precise decision-making, and efficient operations, thereby enhancing production efficiency and product quality. Green development will also become an inevitable trend. With heightened environmental awareness and sustainable development requirements, Guangdong's industrial sector will increasingly prioritize energy conservation, emission reduction, and environmental protection. Virtual clustering and industrial collaboration will help advance the R&D and application of green technologies, facilitating the industry's green transformation.

Despite challenges, virtual clustering and industrial collaboration in Guangdong present significant opportunities. Policy support continues to strengthen. National and local governments have introduced a series of policy measures supporting industrial digital transformation and collaborative development, creating a favorable policy environment for virtual clustering and industrial synergy. Market demand remains robust. As consumer preferences grow increasingly diverse and personalized, enterprises require more flexible and efficient production models to meet market needs. Virtual clustering and industrial synergy enable rapid response and customized production, addressing this demand for diversity. The industrial ecosystem is steadily improving. Guangdong has established relatively complete industrial chains and clusters, providing a solid foundation for virtual clustering and industrial synergy. Increasing collaboration and exchange among enterprises, coupled with an optimized industrial ecosystem, will further propel the advancement of virtual clustering and industrial synergy.

The prospects for virtual clustering and industrial synergy in Guangdong are promising. However, it requires concerted efforts from governments, enterprises, and society at large to address challenges, seize opportunities, and drive high-quality industrial development in the region.

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