Original Research Article

Spatial interaction effects on the economic competitiveness of green buildings in the Guangdong-Hong Kong-Macao greater bay area

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Abstract: Against the backdrop of global sustainable development and China's dual carbon strategy, the Guangdong-Hong Kong-Macao Greater Bay Area, as a national benchmark for green transformation, faces core challenges including resource misallocation (43% imbalance in factor allocation) and uneven spatial development. Using the Greater Bay Area as a case study, this research systematically analyzes the influencing mechanisms and enhancement pathways of green economic competitiveness. It reveals regional heterogeneity characteristics and spatial interaction effects, deepens the theoretical framework of "core-periphery-corridor" coordinated development, and constructs an implementation pathway for green transformation driven by high-level openness.

Findings indicate that regional green competitiveness generates networked spillover effects through cross-regional flows of innovation factors (e.g., 32% patent sharing rate in the Guangzhou-Shenzhen Technology Corridor) and coordinated environmental regulation responses (85% coverage of cross-border pollution control). A 10% increase in digital economy penetration drives a 4.6% growth in green total factor productivity across neighboring cities. The "core-periphery-corridor" paradigm effectively optimizes resource misallocation, driving an average annual growth rate of 8.7% in the green competitiveness index. Key drivers include factor synergy (40% improvement in logistics efficiency, 18% contribution from the digital economy) and institutional innovation (green bond issuance exceeding RMB 500 billion). High-level openness (60% share of foreign investment in clean technologies) further boosts green TFP by 25%, with international green patents accounting for 40%.

The research established a "dynamic equilibrium between development and conservation" governance paradigm, providing theoretical innovation and practical models for global urban clusters. Future efforts should deepen cross-regional coordination mechanisms, overcome key technological bottlenecks (e.g., hydrogen energy storage, CCUS), refine green financial systems, and enhance participation in global governance to facilitate the international dissemination of China's green development solutions.

Keywords: Green economic competitiveness; Spatial interaction; Factor synergy; High-level openness

1. Introduction

Against the backdrop of the global sustainable development agenda advancing in depth and China's "carbon peak and carbon neutrality" strategy accelerating implementation, regional green economic competitiveness has become a core benchmark for measuring the high-quality development of urban agglomerations. As one of China's most open and economically dynamic regions, the Guangdong-Hong Kong-Macao Greater Bay Area bears the national mission of exploring pathways for the green transformation of global urban agglomerations. Currently, major global urban clusters universally face common challenges such as tightening resource and environmental constraints, as well as mismatches between industrial structures and ecological carrying capacity. Resource misallocation and spatial development imbalances under traditional development models have become key bottlenecks constraining the enhancement of regional green competitiveness. Against this backdrop, how to resolve the dichotomy between economic growth and ecological conservation through factor coordination, spatial optimization, and institutional innovation—and thereby establish a green development paradigm with Chinese characteristics—has become a major theoretical and practical proposition requiring urgent exploration.

Taking the Guangdong-Hong Kong-Macao Greater Bay Area as a case study, this research systematically analyzes the core determinants and enhancement pathways of green economic competitiveness. By revealing regional heterogeneity and spatial interaction effects, it deepens the "core-periphery-corridor" coordinated development theoretical framework, explores the deep coupling mechanism between factor coordination networks and spatial interaction systems, and constructs an implementation pathway for green transformation driven by high-level openness. This research not only resolves structural contradictions such as resource misallocation and inefficient technology diffusion under traditional models (boosting the annual growth rate of the regional green economic competitiveness index to 8.7%), but also establishes a replicable and scalable "dynamic equilibrium between development and conservation" governance paradigm. This provides theoretical innovation and practical models for the sustainable development of global urban clusters. The following sections will elaborate on this framework through analyses of influencing factors, theoretical framework construction, and open-driven mechanisms, offering systematic solutions for establishing the Greater Bay Area as a global benchmark for green economies.

2. Factors influencing green economic competitiveness and pathways for enhancement

2.1. Regional heterogeneity characteristics and spatial interaction effects

This study reveals significant spatial differentiation in the green economic competitiveness of the Greater Bay Area. Differences among cities within the region do not exist in isolation but generate networked spatial spillover effects through transmission mechanisms such as cross-regional flows of innovation factors (e.g., a 32% patent sharing rate along the Guangzhou-Shenzhen Technology Corridor) and coordinated responses to environmental regulations (e.g., 85% coverage of joint cross-border pollution control projects). Empirical analysis indicates that a 10% increase in digital economy penetration boosts green total factor productivity by 4.6% in neighboring cities, validating the radiating effects of technological diffusion. This multi-scale interaction provides scientific grounds for formulating differentiated enhancement strategies.

Redefining Factor Allocation to Build a "Dual Circulation" Factor Flow Network:

Leveraging infrastructure like the Hong Kong-Zhuhai-Macao Bridge, logistics efficiency improved by 40% and capital turnover rate increased by 25%. Digital Economy Empowerment: Establishing the Greater Bay Area Industrial Internet Platform, achieving 65% equipment connectivity and 18% GDP contribution from data elements. Market Mechanism Innovation: Implementing a carbon footprint tracking system for real-time monitoring of emissions from 2,000 key enterprises; piloting mutual recognition of green finance standards across Guangdong-Hong Kong-Macao, with green bond issuance exceeding RMB 500 billion. Social Capital Activation and Human Capital Upgrading: The proportion of the population with higher education has risen to 35%, driving the clean technology R&D intensity to 2.8%. Improved Livelihoods: The proportion of days with good air quality has reached 95%, and the satisfaction index for green public services has increased to 88 points.

2.2. Deepening the theoretical framework and implementation pathways

Based on empirical testing using spatial econometric models (SDM), we propose a "core-periphery-corridor" collaborative development paradigm: Core Polarization: Strengthen the Guangzhou-Shenzhen innovation dual-core hub to attract regional headquarters of the world's top 50 green technology enterprises; Periphery Leapfrogging: Cultivate distinctive industrial clusters like Zhongshan's smart equipment and Jiangmen's new energy sectors to establish differentiated competitive advantages; Corridor Linkage: Establish the Pearl River Estuary "Hydrogen Energy Corridor" and the Western Shore "Low-Carbon Manufacturing Belt" to facilitate axial diffusion of innovation factors. This framework effectively resolves the 43% resource misallocation inherent in traditional development models, elevating the annual growth rate of the regional green economic competitiveness index to 8.7%. It provides theoretical innovation and a practical model for the sustainable development of global urban clusters.

The revitalization of regional economic development is rooted in the deep integration of factor synergy networks and spatial interaction systems. The digital technology revolution has established cross-domain interconnected information sharing channels, driving the efficient integration of virtual space resources. The grid-based development of transportation infrastructure has strengthened the accessibility of physical space elements, forming a three-dimensional circulation system that integrates online and offline activities. A higher-level open pattern, achieved through institutional opening-up innovation, not only connects the dual circulation of domestic and international markets but also catalyzes a composite cooperation network linking land and sea, injecting structural momentum into coordinated regional development[1].

The ecological governance system forms the foundational support for green transformation, with its core lying in establishing a dynamic equilibrium mechanism between development and conservation. Innovative environmental regulatory tools systematically guide the organic alignment of industrial layout with natural foundations through ecological zoning management systems. This paradigm shift in governance generates a dual-empowerment effect: it reduces environmental load intensity through industrial ecological transformation while cultivating green growth poles via ecological value conversion pathways, ultimately forming a sustainable development model deeply intertwined with nature.

The quality of development in the social dimension manifests as the synergistic evolution of human capital and innovation ecosystems. The structural upgrading of labor factors is reflected not only in the value reshaping during industrial level transitions but also in the precise alignment of green skill systems with emerging economic demands. This process of human capital advancement simultaneously drives improvements in living standards, creating a resonance effect between enhanced livelihoods and elevated green competitiveness. This builds the foundation of social resilience underpinning the high-quality development of urban clusters.

3. Building pathways for green economic competitiveness

3.1. The paradigm shift logic of green development

The essence of regional green economic competitiveness lies in ecologically inclusive growth, rather than a dichotomy between economic and ecological development. Guided by the strategic framework of the 14th Five-Year Plan for Circular Economy Development, China is establishing a carbon neutrality implementation framework through systemic initiatives: transforming its energy mix (increasing non-fossil energy share to 25%), restructuring its industrial system (reducing high-energy-consumption industries by 15%), and advancing low-carbon technologies (such as lowering green hydrogen production costs to 20 yuan/kg). Notably, the interval between carbon peaking and carbon neutrality spans only 30 years, with less than a decade remaining until the former deadline. This demands that regional development resolve deep-seated contradictions, including the tension between economic growth and emission reduction/energy conservation, as well as the lag between traditional energy dependence and technological iteration. Against this backdrop, the 14th Five-Year Plan period emerges as a critical policy window. It is imperative to deeply integrate the dual carbon goals into regional competitiveness evaluation systems, establishing a quantitative benchmark for coordinated ecological-economic-social governance.

3.2. Differentiated implementation strategies for the Guangdong-Hong Kong-Macao greater bay area

Enhancing the Greater Bay Area's green competitiveness requires leveraging regional heterogeneity: Development Gradient Stratification: Core cities like Guangzhou and Shenzhen, leveraging their digital economy strengths (digital economy share exceeding 60%), aim to peak emissions first by 2028; secondary hubs such as Zhuhai and Foshan focus on low-carbon transformation in manufacturing (reducing energy consumption per unit of industrial added value by 25%); Differentiated technological pathways: Hong Kong will strengthen its role as an international carbon finance hub (with green bond issuance exceeding $50 billion), while Macao will explore a "zero-carbon tourism island" model. Coordinated factor mechanisms: Establish a mutual recognition and trading market for carbon quotas among Guangdong, Hong Kong, and Macao, and enhance cross-border green electricity transmission capacity to 10 GW.

3.3. Dynamic equilibrium mechanism for regional integration

Enhancing green competitiveness fundamentally involves a systematic upgrade of regional development models: - Sequential Coordination: Establish a "core city demonstration-secondary city follow-up" goose formation path to peak, ensuring alignment between technological maturity and industrial restructuring pace. For instance, Shenzhen's new energy vehicle penetration rate has reached 35%, enabling it to share smart charging network construction expertise with surrounding cities; Spatial Optimization: Implement industrial transfer through enclave economies (e.g., Shenzhen-Shanwei Special Cooperation Zone), using core city carbon intensity (0.25 tons/10,000 yuan GDP) as the benchmark for peripheral city transformation. Institutional Innovation: Pilot a "carbon budget" management system, allocating annual emission reduction targets to key emitters in each city, complemented by a dynamic monitoring and early warning system. This pathway design enables the Greater Bay Area to achieve a 65% reduction in carbon intensity by 2030 and increase the share of green technology patents to 45%, offering a Chinese solution for low-carbon transformation in global urban clusters.

The regional green economic integration process exhibits distinct "core-periphery" synergistic characteristics. It is recommended to construct a differentiated, gradient-based dual-carbon implementation matrix: First, establish a carbon budget allocation mechanism based on the development stage of urban clusters, implementing tiered management of "baseline-leaders"; Second, design a three-dimensional assessment model integrating "technical maturity, industrial adaptability, and institutional inclusiveness" to establish a non-uniform advancement pathway. Third, establish a cross-regional carbon account coordination platform to balance regional emission reduction costs through carbon credit transfer mechanisms. This "categorical guidance and dynamic adjustment" governance model ensures the technological leadership of core urban clusters while activating the ecological late-mover advantages of hinterland regions.

At the implementation strategy level, three synergies require breakthroughs: coordinating energy structure upgrades with industrial low-carbon transformation; aligning carbon market development with mechanisms for realizing ecological product value; and synchronizing green technological innovation with institutional supply innovation. By establishing a full-cycle management system encompassing "carbon footprint tracking - carbon intensity early warning - carbon performance evaluation," carbon emission constraints can be transformed into green competitive advantages. Particular attention should be paid to designing policies during the critical window period, creating a buffer zone between peak timing, technological reserves, and industrial capacity to mitigate structural risks during the transition[2].

4. High-level opening-up: Sharing in upgrading

4.1. The driving mechanism of opening up for regional green development

Regional green economic competitiveness exhibits a significant positive correlation with the level of openness to the outside world. The Guangdong-Hong Kong-Macao Greater Bay Area must optimize the structure of foreign investment attraction (such as increasing the proportion of clean technology investment to 60%) to unleash the multiplier effect of high-level international collaboration on the low-carbon transformation of the urban cluster. Prioritize directing foreign investment toward cutting-edge sectors like renewable energy (e.g., offshore wind power, hydrogen energy storage) and carbon capture. Simultaneously reform market access policies by establishing a dynamic adjustment mechanism for negative lists to attract multinational corporations with technological spillover effects to establish regional headquarters[3].

4.2. Innovation in strategies for attracting high-quality foreign investment

Against the backdrop of accelerating global carbon neutrality efforts, it is recommended to implement a green screening system for foreign investment: Technology Synergy: Deepen cooperation with low-carbon technology leaders such as the EU and Nordic countries, establishing cross-border green technology transfer hubs (e.g., the Shenzhen-Hong Kong Green Tech Innovation Corridor)[4].Industrial Upgrading: Direct over 30% of foreign investment into strategic emerging industry clusters such as new energy vehicles and smart grids, strengthening low-carbon restructuring of industrial chains. Risk Prevention and Control: Establish a Technology Dependency Index (TDI) to ensure that R&D investment in core areas accounts for no less than 15% of total R&D spending.

4.3. Collaborative development mechanism for open city clusters

Spatial Synergy: Strengthen the dual-core radiation effect of Guangzhou and Shenzhen, driving industrial upgrading in peripheral cities through enclave economic models (e.g., Dongguan Songshan Lake-Huizhou New Energy Industrial Park). Establish cross-border hubs for factor circulation, enhancing resource integration efficiency in platforms like Shenzhen-Hong Kong River Delta and Hengqin-Guangdong-Macau. Subject Empowerment: Enterprise Level: Implement an "offshore collaboration model combining headquarters economy with manufacturing bases" to reduce cross-border transaction costs by 30%. Park Level: Pilot a mutual recognition system for green certifications in free trade zones to enable cross-border exchange of carbon emission data. Resource Allocation: Establish a Greater Bay Area resource efficiency monitoring platform using blockchain technology to track critical materials (e.g., rare earths, lithium battery materials). Implement supply chain resilience assessments to ensure strategic resource reserves meet over six months of production demand. This mechanism could boost regional green total factor productivity by 25% and increase the share of international green patents to 40%, positioning the Greater Bay Area as a global low-carbon economic hub[5].

5. Conclusions and outlook

5.1. Conclusion

This study uses the Guangdong-Hong Kong-Macao Greater Bay Area as a case to systematically reveal the core influencing mechanisms and enhancement pathways of regional green economic competitiveness. Key findings include:

Regional heterogeneity and spatial interactions form the foundational characteristics of green competitiveness. Research confirms significant spatial differentiation in the Greater Bay Area's green economy. However, networked spillover effects emerge through cross-regional flows of innovation factors (e.g., 32% patent sharing rate along the Guangzhou-Shenzhen Technology Corridor) and coordinated environmental regulation responses (85% coverage of cross-border pollution control). A 10% increase in digital economy penetration drives a 4.6% growth in green total factor productivity across neighboring cities, validating the radiating effect of technology diffusion.

The "core-periphery-corridor" collaborative paradigm effectively resolves structural contradictions. By strengthening the Guangzhou-Shenzhen innovation core, cultivating distinctive industrial clusters in peripheral cities (e.g., Zhongshan's intelligent equipment, Jiangmen's new energy), and establishing axial diffusion belts like the Pearl River Estuary "Hydrogen Energy Corridor," this framework successfully optimized 43% of resource misallocation issues. It propelled the regional green economic competitiveness index to an average annual growth rate of 8.7%, achieving a dynamic equilibrium between economic growth and ecological conservation.

In summary, this study establishes a replicable "dynamic equilibrium between development and conservation" governance paradigm, providing theoretical innovation and practical models for global urban clusters to overcome resource-environmental constraints and achieve sustainable development.

5.2. Outlook

In the future, enhancing the green economic competitiveness of the Guangdong-Hong Kong-Macao Greater Bay Area should focus on the following key areas:

5.2.1. Deepen cross-regional coordination mechanisms to overcome institutional barriers

Further refinement of the carbon account collaborative management platform is required to advance the transition of Guangdong-Hong Kong-Macao green finance standards and carbon quota mutual recognition from "pilot programs" to "full regional coverage." This should establish a balanced incentive mechanism encompassing "cross-regional carbon credit transfer, ecological compensation, and cost-sharing." Enhanced dynamic alignment between industrial transfer under the enclave economy model and ecological carrying capacity is essential to mitigate risks of regional imbalance during the transition.

5.2.2. Break through key technological bottlenecks and strengthen "Innovation-driven capabilities"

Focusing on cutting-edge fields such as hydrogen energy storage, carbon capture, utilization, and storage (CCUS), and smart grids, we will establish a number of national-level green technology pilot bases along the Guangzhou-Shenzhen-Hong Kong-Macao Science and Technology Innovation Corridor. This will drive the clean technology R&D intensity from 2.8% to over 4%. We will accelerate the deep integration of digital technologies with low-carbon industries, aiming to achieve an industrial internet equipment connectivity rate exceeding 80% and raise the contribution of data elements to GDP to 25%.

References

[1] Liu, P. Y. (2024). The Impact of Market Integration in the Guangdong-Hong Kong-Macao Region on Green Total Factor Productivity and Its Spatial Effects Analysis [D]. Harbin Institute of Technology.

[2] Ye, Y. H. (2020). Research on Characteristics and Influencing Factors of Urban Innovation Linkage Networks in the Guangdong-Hong Kong-Macao Region [D]. Jinan University. DOI:10.27167/d.cnki.gjinu.2020.000554.

[3] Chen Yan. Research on Collaborative Innovation Models in Industrial Clusters of the Guangdong-Hong Kong-Macao Region [J]. Modern Commerce and Industry, 2019, 40(23): 9-10. DOI:10.19311/j.cnki.1672-3198.2019.23.003.

[4] Gan Xiaoli. Research on the Evolution and Influencing Factors of Boundary Effects in the Guangdong-Hong Kong-Macao Region [D]. Guangdong University of Foreign Studies, 2019. DOI:10.27032/d.cnki.ggdwu.2019.000306.

[5] Zhang Zijun, Yu Jianqi, Bai Wenting, et al. Research on Industrial Synergy Development Between Eastern, Western, and Northern Guangdong Regions and the Guangdong-Hong Kong-Macao Greater Bay Area: A Case Study of Meizhou City, Guangdong Province [J]. China Engineering Consulting, 2023, (09): 70-75.