

## Original Research Article

**A Study on the Spatio-Temporal evolution characteristics of green building economic competitiveness in the Guangdong-Hong Kong-Macao greater bay area***Lihong Shi, Huashan Zhang**Hainan Vocational University of Science and Technology, 571126, China*

**Abstract:** Against the backdrop of advancing the dual carbon goals, tightening resource and environmental constraints intertwine with pressures for industrial restructuring, making green development the key pathway to resolve the contradiction between economic growth and ecological conservation. With the emergence of high-quality development requirements, enhancing regional green economic competitiveness has become a core issue for achieving sustainable development. As one of China's most open and economically dynamic regions, the Greater Bay Area plays a strategic leading role in advancing national ecological civilization construction and promoting coordinated regional development through the enhancement of its green economic competitiveness.

To explore the spatiotemporal evolution of the Greater Bay Area's green economic competitiveness, this study employs spatial autocorrelation analysis, convergence characteristic assessments ( $\sigma$ -convergence and  $\beta$ -convergence), and dynamic transition pattern analysis (using methods such as continuous density curves and Markov chains). It systematically examines the distribution patterns, differential evolution, and transition characteristics of regional green economic competitiveness. Findings reveal: Spatially, green economic competitiveness exhibits pronounced agglomeration, with high-value zones concentrated in core cities like Guangzhou and Shenzhen, while low-value areas are distributed in peripheral cities. Regarding convergence characteristics, the region shows an overall  $\sigma$ -convergence trend, with the  $\sigma$ -convergence coefficient decreasing from 0.11 to 0.07 between 2002 and 2022, indicating gradually narrowing regional disparities but persistent development imbalances. Dynamic transition patterns reveal high stability in green economic competitiveness levels, with over 80% probability of maintaining initial states across all categories. Transitions between low and high levels are infrequent, while medium-level types exhibit relatively stronger mobility, indicating a gradual evolutionary process. These findings provide theoretical insights for promoting coordinated regional development and implementing differentiated policies. Future research may deepen by expanding to micro-level scales, incorporating additional influencing factors, and quantifying policy impacts.

**Keywords:** Green economic competitiveness; Spatial autocorrelation analysis; Feature evaluation

## 1. Introduction

### 1.1. Definition of the green economy

The concept of a green economy is rich in content and evolving dynamically, with varying definitions proposed by different scholars and institutions. The United Nations Environment Programme defines a green economy as an economic model that enhances human well-being and social equity while significantly reducing environmental risks and ecological scarcity. Some domestic scholars emphasize that a green economy is an economic development model constrained by ecological capacity and resource carrying capacity, treating environmental protection as a vital pillar of sustainable development. Despite varying formulations, the core principle remains achieving harmonious integration between economic growth and environmental protection, prioritizing

efficient resource utilization and ecological conservation throughout economic advancement.

## 1.2. The relationship between the green economy and related concepts

The green economy pursues low-carbon and circular development pathways, with its core essence emphasizing the coordinated advancement of economic, social, and ecological systems. The low-carbon economy focuses on reducing carbon emissions, primarily by decreasing reliance on high-carbon energy through energy technology innovation and industrial structure optimization. The circular economy emphasizes resource recycling, enhancing resource efficiency by establishing a closed-loop process of “resources-products-waste-recycled resources.” In contrast, the green economy encompasses a broader scope. It integrates the core concepts of both the low-carbon and circular economies, extending beyond carbon emission control and resource recycling to include ecosystem protection, social equity, and other multidimensional aspects. This forms a comprehensive economic development paradigm, occupying a central and overarching position within the relevant conceptual framework.

## 2. Assessment and analysis of the green economic competitiveness of the Guangdong-Hong Kong-Macao greater bay area

### 2.1. Convergence feature evaluation analysis

#### 2.1.1. Spatial autocorrelation analysis

When examining the spatial autocorrelation patterns of clustering and dispersion among research units, the global Moran’s I and local Moran’s I indices are commonly employed as analytical tools. The global Moran’s I aims to reveal the overall spatial distribution pattern—whether clustering or dispersion—across all observed units within the study area. In contrast, the local Moran’s I focuses on reflecting the spatial heterogeneity distribution characteristics among observed units, as well as the spatial clustering or dispersion status of local regional units<sup>[1]</sup>.

#### 2.1.2. Convergent change

Convergence serves as an indicator reflecting the temporal evolution of the Guangdong-Hong Kong-Macao Greater Bay Area’s green economic competitiveness, manifested through variations in dispersion levels. A lower value signifies an increasing trend in the region’s green economic competitiveness, inversely proportional to time. When differentiation diminishes over time, convergence occurs, denoted as  $\sigma$ .

As convergence evolves, cities with initially lower green economic competitiveness catch up to those with higher capabilities, gradually narrowing the gap until they reach comparable levels. Consequently, the catch-up effect across regions will be re-examined, with this convergence denoted as  $\beta$ . The model is expressed as:

$$\ln \left( \frac{y_{i,t+1}}{y_{i,t}} \right) = \alpha + \beta \ln y_{i,t} + \varepsilon_{it} \tag{Formula (1)}$$

In the equation: represents the growth rate of regional green economic competitiveness, with results obtained at time t+1. The term in parentheses denotes the time-dependent green economic competitiveness development index. The final term is the error term, and  $\beta$  is the convergence coefficient.

In real-world scenarios, achieving balanced regional development faces numerous challenges due to objective differences in initial conditions—such as resource distribution, economic development levels, and transportation infrastructure—and their evolutionary processes across regions. Influenced by these objective variations, each city’s green economic competitiveness index will converge toward a stable state based on its specific circumstances, introducing the concept of conditional convergence. The conditional convergence model can be

expressed as:

$$\ln\left(\frac{y_{i,t+1}}{y_{i,t}}\right) = \alpha + \beta \ln y_{i,t} + \delta X + \varepsilon_{it} \tag{Formula (2)}$$

In the equation: X represents other control variables,  $\delta$  denoted as variable coefficients. These coefficients are then used to process the variables, thereby eliminating any adverse effects they may introduce<sup>[2]</sup>.

### 2.1.3. Convergence analysis

To investigate whether the development level of green economic competitiveness in the Guangdong-Hong Kong-Macao Greater Bay Area exhibits consistent trends, this study calculated the coefficient of variation for the region’s green economic competitiveness development from 2002 to 2022. If the coefficient of variation exhibits a year-on-year decreasing trend, it indicates that the green economic competitiveness level of the Greater Bay Area is gradually converging toward  $\sigma$ ; conversely, a year-on-year increasing trend suggests that the competitiveness level is progressively diverging, implying the emergence of dispersion phenomena.

**Table 1.** Coefficient of variation for green economic competitiveness.

	2005	2007	2012	2017	2022
Guangzhou	0.11	0.12	0.11	0.12	0.07
Shenzhen	0.12	0.12	0.13	0.12	0.07
Hong Kong	0.11	0.11	0.11	0.12	0.07
Dongguan	0.13	0.13	0.12	0.13	0.06
Foshan	0.11	0.11	0.09	0.09	0.07
Zhuhai	0.10	0.11	0.09	0.08	0.06
Zhongshan	0.11	0.12	0.10	0.12	0.06
Huizhou	0.12	0.12	0.12	0.09	0.07
Macao	0.13	0.11	0.12	0.11	0.08
Jiangmen	0.11	0.11	0.11	0.11	0.09
Zhaoqing	0.12	0.12	0.11	0.12	0.08

**Table 1** reveals the trend in the  $\sigma$  convergence coefficient of the Guangdong-Hong Kong-Macao Greater Bay Area’s green economic competitiveness. Observing the  $\sigma$  convergence pattern, it is evident that regional inconsistencies exist within the Greater Bay Area, indicating uneven development. Simultaneously, the downward trend suggests that the overall level of green economic competitiveness in the Greater Bay Area is converging, with disparities between regions gradually narrowing<sup>[3]</sup>.

From a city-specific perspective, Guangzhou’s  $\sigma$  convergence coefficient stood at 0.11 in 2002, declining to 0.07 by 2025. While showing a downward trend in most years, it also exhibited increases in certain years. Shenzhen’s  $\sigma$  coefficient was 0.12 in 2005, falling to 0.07 by 2022, reflecting an overall fluctuating downward trajectory. Hong Kong’s  $\sigma$  convergence coefficient was 0.11 in 2005, falling to 0.07 by 2022, also exhibiting an overall fluctuating downward trend. It is evident that despite brief increases in some cities, the overall trend is downward, indicating that the coordinated development of the Guangdong-Hong Kong-Macao Greater Bay Area is yielding results. Overall, development disparities persist, necessitating further efforts to narrow regional gaps and promote a balanced enhancement of green economic competitiveness across the entire urban cluster.

### 3. Assessment and analysis of dynamic transfer patterns

#### 3.1. Research methods

The findings indicate that while regional disparities are narrowing, they are unlikely to disappear in the short term, necessitating further policy interventions. This study employs continuous density curves and density estimation methods to conduct an in-depth analysis of the distribution dynamics of green economic competitiveness within the Guangdong-Hong Kong-Macao Greater Bay Area. It reveals the uneven characteristics among cities and their evolutionary trends. Additionally, by integrating traditional and spatial analytical approaches, the research explores the specific evolution patterns of green economic competitiveness levels in the Greater Bay Area and elucidates regional disparities and polarization phenomena in green economic competitiveness.

$$P = \begin{bmatrix} p_{11} & \cdots & p_{1k} \\ \vdots & \ddots & \vdots \\ p_{k1} & \cdots & p_{kk} \end{bmatrix} \tag{Formula (3)}$$

In the formula: The level of a city in year  $t$  is denoted as  $X_t$ , the past time period is denoted as  $X_s$ , and a future time period is denoted as  $X_w$ . The formula is as follows:

$$P\{X_t = j | X_{t-1} = i, X_{t-2} = i_{t-2}, \dots, X_0 = i_0\} = P\{X_t = j | X_{t-1} = i\} = P_{ij}$$

$$P_{ij} = n_{ij} / n_i \tag{Formula (4)}$$

In the formula:  $P_{ij}$  denotes the probability of transfer of green economic competitiveness within the region;  $n_{ij}$  represents the sum of green economic competitiveness levels within the region;  $n_i$  indicates the sum of green economic competitiveness across regions under scenario  $i$ .

#### 3.2. Feature analysis

To better analyze the dynamics of the Guangdong-Hong Kong-Macao Greater Bay Area, a Markov chain was employed to analyze the characteristics. The regional green economic competitiveness was categorized using quartiles, with the results presented in **Table 2**.

**Table 2.** Markov transition matrix.

Spatial Lag Type	t/t+1	Low	Slightly lower	Slightly higher	High	Observed values
lag-free	Low	0.819	0.213	0	0	311
	slightly lower	0.011	0.801	0.241	0	300
	slightly higher	0	0.021	0.811	0.199	269
	High	0	0	0.006	0.991	251

As shown in **Table 2**, the diagonal elements of the four state transition probability matrices are significantly higher than the off-diagonal elements, with probability values ranging from 0.801 to 0.991. This phenomenon indicates that during the study period, the probability of maintaining the initial state was at least 0.801, while the probability of regions retaining their existing development types exceeded 0.8 across all regions—far higher than the probability of state changes. This reveals a high degree of stability in regional green economic competitiveness. Further analysis shows that the stability of the low and slightly low types (0.819 and 0.801, respectively) is significantly lower than that of the slightly high and high types (0.811 and 0.991, respectively). The probability values on both sides of the off-diagonal are smaller than those on the diagonal. This result indicates that the growth of the Guangdong-Hong Kong-Macao Greater Bay Area’s green economic competitiveness is a

gradual and continuous process, making it difficult to achieve rapid leaps in the short term<sup>[4]</sup>.

## 4. Conclusions and outlook

### 4.1. Research findings

This study systematically examines the spatiotemporal evolution of the Guangdong-Hong Kong-Macao Greater Bay Area's green economic competitiveness through spatial autocorrelation analysis, convergence characteristic assessment, and dynamic transfer pattern analysis. Findings reveal:

Spatially, the green economic competitiveness of the Guangdong-Hong Kong-Macao Greater Bay Area exhibits pronounced spatial clustering. High-value areas are concentrated in core cities like Guangzhou and Shenzhen, while low-value areas are distributed in peripheral cities. The global Moran's I index confirms the region's overall positive spatial correlation.

Regarding convergence characteristics, the region's green economic competitiveness exhibits an overall  $\sigma$ -convergence trend. Between 2002 and 2025, the  $\sigma$ -convergence coefficient decreased from 0.11 to 0.07, indicating a gradual narrowing of regional disparities. However, development imbalances between core and peripheral cities remain unresolved.

Dynamic transition patterns reveal high stability in green economic competitiveness levels. Markov chain analysis indicates that the probability of maintaining the initial state exceeds 0.8 for all categories. Transition probabilities are low between low-level and high-level types, while medium-level types exhibit relatively stronger mobility. The evolution process demonstrates gradual characteristics.

### 4.2. Policy implications

Based on the research findings, the following policy recommendations are proposed:

1. Strengthen regional coordination mechanisms by establishing cross-city green economy cooperation platforms. Facilitate the diffusion of core cities' technological and capital resources to surrounding areas to narrow regional development gaps.

2. Implement differentiated policies for cities at varying development stages: Increase ecological compensation and industrial support for low-level regions; prioritize cultivating green industrial clusters in medium-level regions; and reinforce innovation leadership in high-level regions to explore new green economy paradigms.

3. Refine the green economy evaluation system by incorporating indicators such as ecological conservation and social equity into local government performance assessments, thereby establishing a long-term incentive mechanism.

### 4.3. Research outlook

Future research can be deepened in three areas:

1. Expand the research scale by integrating county-level or industrial park data to reveal the evolution patterns of green economic competitiveness at the micro level.

2. Introduce more influencing factors for analysis, such as the role of variables like the digital economy and carbon trading policies in shaping green economic competitiveness.

3. Employ spatial econometric models to quantify the effects of policy interventions, providing stronger empirical support for formulating targeted regional coordination policies.

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