International Journal of Multiphysics
Volume 18, No. 2, 2024
ISSN: 1750-9548

Measurement and Spatiotemporal Evolution of High-Quality Economic Development at the County Level Based on Machine Learning Methods: A Case Study of Guangdong Province

Shuhua Liu*, Haijing Fang
Lingnan Normal University, Zhanjiang, Guangdong 524048, China
*Corresponding Author: Shuhua Liu

Abstract

This article develops a five-dimensional evaluation system for assessing high-quality economic development at the county level, employing the entropy method to analyze economic progress in 57 counties across Guangdong Province from 2010 to 2020.Utilizing machine learning techniques, the study uncovers the spatiotemporal dynamics and regional disparities in economic development at this level within Guangdong. Findings indicate a consistent annual improvement in the quality of economic development across the counties, with growing absolute disparities that display characteristics of "club convergence." Notably, the Pearl River Delta and the eastern and western parts of Guangdong exhibit a multipolar growth pattern, with regional variances primarily driving the overall disparities in high-quality economic development at the county level in Guangdong Province.

Keywords: Machine learning, county-level economy, high-quality development; spatiotemporal evolution, regional differences, innovation capacity

1. Introduction

In the big data era, both the form and volume of data have experienced transformative shifts. The complexity and variety of big data present unique challenges to economic research. To tackle these challenges, machine learning tools have been adopted and are becoming increasingly prevalent in econometric analysis [1]. Machine learning not only enhances and extends the conventional methodologies and frameworks of economic research but also expands the horizons and boundaries of economic studies. It acts as a valuable addition to the current methodologies addressing economic problems.

The advancement of county economies is crucial for driving China's high-quality economic progress and sustaining growth. To foster superior development across all counties, towns, and villages, and to remedy the disparities and deficiencies in urban-rural and regional development, the Guangdong Provincial Party Committee enacted a strategic initiative on December 8, 2022. The "High-Quality Development Project for Hundreds of Counties, Thousands of Towns, and Tens of Thousands of Villages" is designed to promote harmonious and high-quality development between urban and rural sectors. Although the 57 counties of Guangdong occupy 71.7% of the province’s total land area, they contribute just 12.5% to its GDP. This disparity underscores the challenges these county-level economies face and the immense potential they hold for transformative economic development.

Research on high-quality economic development encompasses three primary areas: Firstly, the framework and measurement techniques for assessing economic quality. Scholars have developed various indices from perspectives such as the five major development concepts [2], the "Five-Sphere Integrated Plan"[3], and the broad dimensions of high-quality development [4], alongside both supply-side and demand-side factors [5], Key measurement techniques include entropy methods [6], grey fuzzy comprehensive evaluation [7], projection pursuit models [8], and hierarchical differentiation methods [9-10]. Secondly, the spatial-temporal dynamics and regional disparities in economic quality are analyzed. Tools such as the Theil index [11], coefficient of variation [12], Gini coefficient [13], and spatial autocorrelation [14-16] are utilized to investigate the evolving patterns and trends of economic growth across different areas. Studies often focus on the disparities between coastal and inland regions [17], as well as between the eastern, central, and western parts of a country [18-19]. Lastly, the impediments to and strategies for enhancing economic quality are examined. Factors affecting high-quality economic development span economic, social, political, and environmental dimensions. Promoting efficiency and transformation emerges as a central objective [20], with innovation [21], environmental quality [22], and financial technology identified as key drivers for sustainable, high-quality economic progress.

The distinctive contributions of this article are threefold: First, it explores county-level economies with a specific focus on Guangdong Province, serving as a valuable benchmark for comparative studies in other regions of China. Second, the article adeptly utilizes machine learning techniques to examine the spatiotemporal dynamics of high-quality economic growth at the county level within Guangdong. This approach deepens the understanding of the evolving patterns of local economic growth and lays a scientific foundation for forecasting future trends. Third, the study employs the Dagum Gini coefficient method to elucidate disparities in high-quality economic development across Guangdong, providing nuanced theoretical insights and practical guidance for policymakers.

2. Indicator System and Research Methods

2.1 Construction of the Indicator System

This study is anchored in the "Five Development Concepts" and categorizes its evaluative framework into five distinct dimensions to provide a thorough, objective, and precise assessment of economic development. Details of the constructed indicator system are outlined in Table 1 below.

2.2 Data source and Processing

This research analyzes 57 counties (cities) in Guangdong Province, utilizing datasets primarily sourced from the "Guangdong Statistical Yearbook," "Guangdong Rural Statistical Yearbook," "China County Statistical Yearbook," and the statistical yearbooks of various prefecture-level cities.

2.3 Machine Learning Methods

2.3.1 Entropy method

The entropy method leverages information entropy to determine the weighting of each indicator within the system, effectively minimizing the influence of subjective biases in weight allocation. The detailed calculation procedure is as follows:

First, standardize the data:

$$X_{ij} = \frac{x_{ij}-x_{min}}{x_{max}-x_{min}},\ X_{ij} \text{ are positive indicators} \tag{1}$$

$$X_{ij} = \frac{x_{max}-x_{ij}}{x_{max}-x_{min}},\ X_{ij} \text{ are negative indicators} \tag{2}$$

In the model, i denotes the county (city), j represents the evaluation indicator, x_{ij} is the raw data for ith county and jth indicator prior to standardization, while X_{ij}denotes the standardization data. x_{min} and x_{max} are the minimum and maximum values of the jth indicator, respectively.

Second Calculate the proportion of the *i*th county data relatice to the *j*th evaluation indicator

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}} \tag{3}$$

International Journal of Multiphysics
Volume 18, No. 2, 2024
ISSN: 1750-9548

Third, determine the information entropy of the *j*th evaluation indicator:

Table 1 Evaluation indicator system.

Primary Indicator	Secondary Indicator	Specific Explanation and Calculation Method	Direction	Unit	Indicator Symbol
Innovative Development	Innovation Vitality	Population Mobility = (Permanent Population - Registered Population) / Registered Population	+	%	X_1
		Advanced Industrial Structure = Value Added of Tertiary Industry / (Value Added of Primary + Secondary Industries)	+	%	X_2
		Value Added of Tertiary Industry / Regional GDP	+	%	X_3
	Innovation Capacity	Number of Domestic Invention Patents Granted / Permanent Population	+	Items per 10,000 People	X_4
		Number of Domestic Utility Model and Design Patent Applications Accepted / Permanent Population	+	Items per 10,000 People	X_5
Coordinated Development	Growth Coordination	Current Year Regional GDP	+	Ten Thousand Yuan	X_6
		Per Capita GDP	+	Ten Thousand Yuan	X_7
	Industrial Coordination	Industrial Structure Rationalization = GDP Share of Primary Industry * 1 + Secondary Industry * 2 + Tertiary Industry * 3	+	/	X_8
	Revenue and Expenditure Coordination	Local General Public Budget Expenditure / Local General Public Budget Revenue	-	%	X_9
		Per Capita Disposable Income of Rural Residents (Natural Log)	+	/	X_{10}
	Urbanization Rate	End-of-Year Urban Permanent Population / Total Regional Population	+	%	X_{11}
Green Development	Ecological Protection	Usage of Agricultural Fertilizers + Pesticides / End-of-Year Cultivated Land Area	-	Tons per Hectare	X_{12}
	Green Resources	Grain Crop Sown Area / County Area	+	%	X_{13}
	Environmental Quality	Ecological Environment Condition Index	+	/	X_{14}
Open Development	Market Opening	Current Year Real Estate Investment Completed / Regional GDP	+	%	X_{15}
		Financial Institutions' Loan Balances at Year-End / Regional GDP	+	%	X_{16}
	Trade Opening	Total Exports / Regional GDP	+	USD Ten Thousand / CNY Ten Thousand	X_{17}
		Total Retail Sales of Consumer Goods / Regional GDP	+	%	X_{18}
Inclusive Development	Social Welfare	Number of Various Social Welfare Institutions	+	Units	X_{19}
		Number of Beds in Social Welfare Institutions / Permanent Population	+	Beds per 10,000 People	X_{20}
	Digital Infrastructure	Natural Log of the Number of Fixed Telephone Users	+	/	X_{21}
	Medical Facilities	Number of Hospital Beds / Permanent Population	+	Beds per 10,000 People	X_{22}
	Compulsory Education	Number of Students in Middle + Elementary Schools / Permanent Population	+	%	X_{23}

$$E_j = \frac{-1}{\ln(n)} \sum_{i=1}^{n} P_{ij} \ln P_{ij} \quad (4)$$

Fourth, determine the weight of the *j*th evaluation indicator:

$$W_j = \frac{1-E_j}{\sum_{j=1}^{k}(1-E_j)} (j = 1,2,\cdots,k) \tag{5}$$

Fifth, determine the development index of each county:

$$Y_i = \sum_{j=1}^{k} W_j X_{ij} \tag{6}$$

The index is scaled between [0, 1]. A value closer to 1 signifies a higher level of economic development in region i, whereas a value approaching 0 indicates a lower level of development.

2.3.2 Kernel density analysis

This study utilizes kernel density estimation, a non-parametric approach, to intricately explore the dynamic evolution patterns of economic development. This includes analysis of distributional characteristics such as location, shape, spread, and trends in polarization. The kernel density function for the variable x, representing the level of counties economic development, is specified in formula (10):

$$f(x) = \frac{1}{N_h} \sum_{i=1}^{N} K\left(\frac{X_i - x}{h}\right) \tag{10}$$

In the analysis, N denotes the total number of counties in Guangdong Province, h represents the bandwidth, K(•)is the kernel function, Xi are the observed values of counties economic development , and x is the average of these observed values. This study employs the Gaussian kernel function. The expression for the Gaussian kernel function is shown in equation (11):

$$f(x) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right) \tag{11}$$

2.3.3 Markov chain analysis

Markov Chains are extensively employed to analyze the transition probabilities between different stages of high-quality economic development in Guangdong's counties throughout the observed period. This method, based on stochastic processes, classifies the economic development levels X of all counties over periods {1,2,…,T} into M={1,2,…,m} discrete states. Subsequently, it computes the transition probabilities for each level of economic development from one period t to the next t+1. The transition probability matrix P is depicted as follows:

$$P = \begin{pmatrix} P_{11} & P_{12} & \cdots & P_{1M} \\ P_{12} & P_{22} & \cdots & P_{1M} \\ \vdots & \vdots & \ddots & \vdots \\ P_{M1} & P_{M2} & \cdots & P_{MM} \end{pmatrix} \tag{12}$$

2.3.4 Dagum Gini coefficient

This study utilizes the Dagum Gini coefficient decomposition method to analyze regional disparities. Here, G denotes the overall Gini coefficient, and k represents the number of designated regions. The variables i and r correspond to the number of counties within each region, while $n_j(n_h)$ indicates the number of counties in region j(h). Additionally, $y_{ji}(y_{hr})$ are the economic development levels for specific counties within regions j(h), and n is the total count of counties in Guangdong.$\bar{Y}$ represents the average level of economic development. Equations (13) through (19) provide detailed formulas for calculating regional, intra-regional, and inter-regional Gini coefficients, along with their respective contributions to overall economic disparity.

$$G = \frac{\sum_{j=1}^{k} \sum_{h=1}^{k} \sum_{i=1}^{n_j} \sum_{r=1}^{n_h} \left| y_{ji} - y_{hr} \right|}{2n^2 \overline{Y}} \quad (13)$$

$$G_{jj} = \frac{\frac{1}{2\overline{Y}_j} \sum_{i=1}^{n_j} \sum_{r=1}^{n_j} \left| y_{ji} - y_{jr} \right|}{n_j^2} \quad (14)$$

$$G_w = \sum_{j=1}^{k} G_{jj} p_j s_j \quad (15)$$

$$G_{jh} = \frac{\sum_{i=1}^{n_j} \sum_{r=1}^{n_h} \left| y_{ji} - y_{hr} \right|}{n_j n_h \left(\overline{Y}_j + \overline{Y}_h \right)} \quad (16)$$

$$G_{nb} = \sum_{j=2}^{k} \sum_{h=1}^{j-1} G_{jh} \left(p_j s_h + p_h s_j \right) D_{jh} \quad (17)$$

$$G_t = \sum_{j=2}^{k} \sum_{h=1}^{j-1} G_{jh} \left(p_j s_h + p_h s_j \right) \left(1 - D_{jh} \right) \quad (18)$$

$$D_{jh} = \frac{d_{jh} - p_{jh}}{d_{jh} + p_{jh}} \quad (19)$$

In this analysis, G_{jj} denotes the Gini coefficient within region j. G_w quantifies the contribution of these intra-regional differences. G_{jh} is the inter-regional Gini coefficient between regions j and h, assessing disparities across different regions. G_{nb} measures the contribution of these inter-regional differences to the overall inequality. G_t accounts for the contribution of transvariation density, reflecting more complex interactions between regions. Here, $p_j=n_j/n, S_i=n_j\overline{Y}_j/n\overline{Y}(j=1,2,\cdots,k)$ indicating the proportion of counties within each region relative to the total. D_{jh} reflects the relative impact of economic development levels on high-quality development between regions j and h, providing insights into how regional economic dynamics influence overall development disparities.

3 Spatiotemporal Characteristics

3.1 Temporal Characteristics

This study employed the entropy method to evaluate the economic development of 57 counties in Guangdong Province during 2010-2020. As shown in Figure 1, the aggregate economic performance of these counties demonstrates a consistent upward trajectory, indicative of robust high-quality development. Notably, the "green" and "coordinated" aspects of development were particularly strong, with the coordinated dimension exhibiting the most significant evolution over the decade.

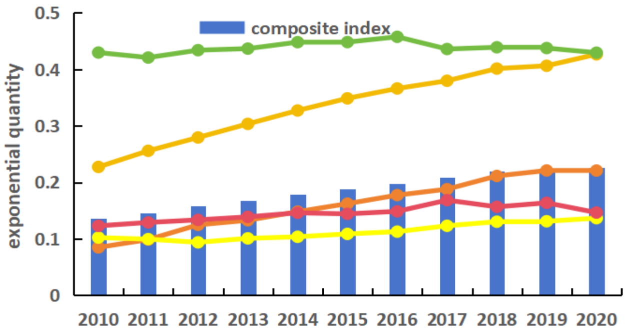

Figure 1 Trends in the average level of high-quality economic development and its dimensions in Guangdong province's counties, 2010—2020

3.2 Spatial Characteristics

To further investigate the spatial distribution patterns of counties economic development, this study employed ArcGIS software for enhanced spatial visualization. Spatial distribution maps for the years 2010, 2014, 2018, and 2020 were generated, as depicted in Figure 2.

From the analysis of Figure 2, two principal insights emerge: Firstly, the spatial distribution of counties economic development in Guangdong Province predominantly displays a pattern characterized by higher values in the central areas and lower values on the periphery, highlighting significant regional disparities. Secondly, while the comprehensive indices of the counties in the eastern, western, and northern parts of Guangdong relative to the central Pearl River Delta area are lower, these regions have demonstrated notable improvements over the analyzed period. This trend underscores the growing potential for economic development in these peripheral areas of Guangdong Province.

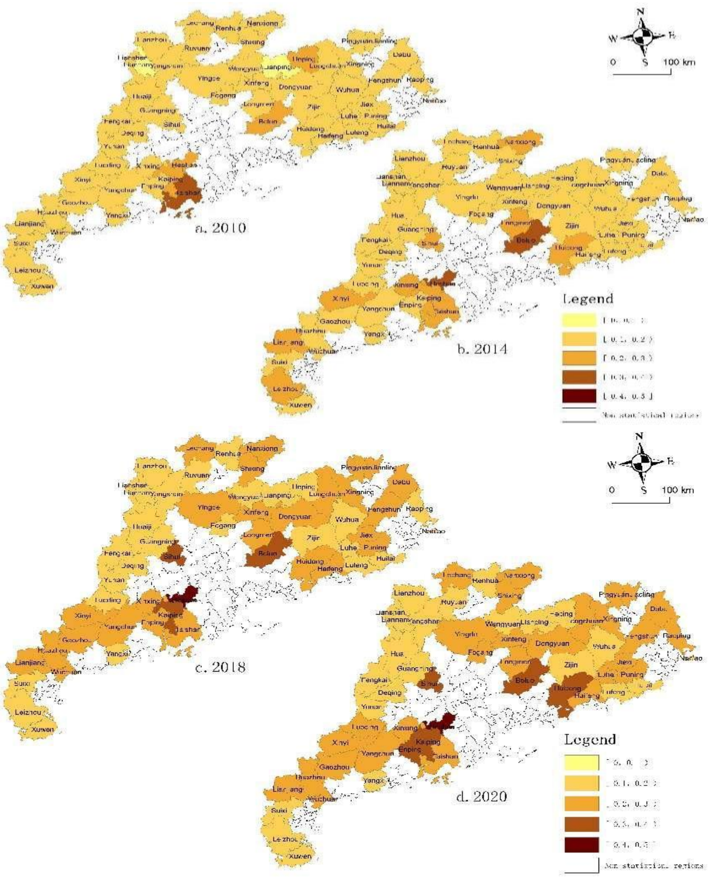

Figure 2 Spatial distribution

Note: The maps utilized in this study were created using the standard map service provided by the Ministry of Natural Resources, authorized under the designation Yue S (2019) No. 031.

4. Distribution Evolution

4.1 Temporal Evolution Trend Based on Kernel Density Estimation

Figure 3 illustrates the overall characteristics of the counties economic development levels across the Guangdong Province as follows: Regarding distribution location, the central point of the overall density function curve exhibits a noticeable rightward shift during the sample period, signaling a consistent rise in the economic growth levels throughout the region. Concerning distribution shape, the principal peak of the density function transitions from a decline to a moderate increase in height, with the peak's width moving from widening to narrowing, suggesting an overall expanding trend. This pattern indicates that the absolute differences in economic growth levels among the counties are intensifying. With respect to distribution spread, the density functions of economic development levels in the counties demonstrate right-tail dragging, undergoing a broadening evolutionary process, which points to an increasing disparity between counties with higher economic development levels and the average. As for polarization trends, the density function curve features a single main peak accompanied by several smaller side peaks, depicting a mild multi-polar differentiation in the overall counties economic development levels within Guangdong Province.

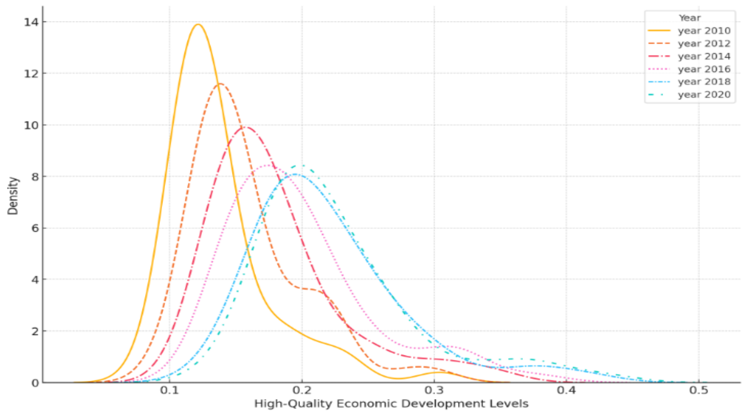

Figure 3 Density distribution curves

4.2 Evolutionary Trends of State Transitions Using Markov Chain Analysis

This study employs the Markov chain methodology to forecast the transition probabilities of high-quality economic development levels across Guangdong Province’s counties. The economic development levels are classified into four distinct categories: low (L), lower-middle (ML), upper-middle (MH), and high (H).

Table 2 Markov chain transition probability matrix.

		L	ML	MH	H
Overall	L	0.7051	0.2692	0.0192	0.0064
	ML	0.0400	0.6533	0.2867	0.0200
	MH	0.0000	0.0376	0.7368	0.2256
	H	0.0076	0.0229	0.0611	0.9084
Pearl River Delta	L	0.7600	0.2000	0.0400	0.0000
	ML	0.0625	0.6250	0.3125	0.0000
	MH	0.0000	0.0000	0.6000	0.4000
	H	0.0000	0.0000	0.0156	0.9844
Eastern Guangdong	L	0.6818	0.2727	0.0000	0.0455
	ML	0.0000	0.6364	0.3636	0.0000
	MH	0.0000	0.0455	0.7273	0.2273
	H	0.0714	0.0000	0.1429	0.7857
Western Guangdong	L	0.5385	0.4615	0.0000	0.0000

	ML	0.0313	0.6563	0.3125	0.0000
	MH	0.0000	0.0789	0.7632	0.1579
	H	0.0000	0.0000	0.0000	1.0000
Northern Guangdong	L	0.7188	0.2604	0.0208	0.0000
	ML	0.0500	0.6625	0.2500	0.0375
	MH	0.0000	0.0172	0.7586	0.2241
	H	0.0000	0.0833	0.1389	0.7778

From Table 2, it is observable that within Guangdong Province and its four major regions, the probabilities along the diagonal of the Markov transition probability matrices surpass those off-diagonal. This indicates that counties are most likely to maintain their current level of economic growth in the subsequent period, illustrating a pattern of "club convergence" and notable stability. Specifically, the likelihood of counties in Guangdong maintaining their current economic development status ranges from 65.33% to 90.86%. Within the Pearl River Delta, the stability of transition probabilities is ranked as follows: high (H) > low (L) > lower-middle (ML) > upper-middle (MH), reflecting a "Matthew effect" where counties with higher levels of development tend to maintain or improve their status more than others. Across all regions, the probability of counties advancing by one economic level is higher than that of advancing by two levels, indicating that significant jumps in economic development are rare. Moreover, the likelihood of upward movement exceeds that of downward shifts, reinforcing an overall positive trajectory in the counties economic development across Guangdong Province.

5. Regional Variations

This study employs the Dagum Gini coefficient decomposition method to analyze the regional disparities in economic development among counties in Guangdong, from 2010 to 2020. The overall Gini coefficient is broken down into inter-regional differences (G_w), intra-regional differences (G_{nb}), and contributions from transvariation density (G_t). This decomposition helps to elucidate the variances in economic development levels within regions, the disparities between regions, and the imbalances and sources of inequity due to regional overlaps.

5.1 Overview of Regional Disparities

As indicated in Table 3, the overall Gini coefficient slightly declined from 0.140 in 2010 to 0.133 in 2020. Although this reduction is modest, it suggests that notable disparities in the counties economic development levels within Guangdong Province persist.

Table 3 Trends in regional disparities.

Year	Overall Gini Coefficient	Intra-group Gini Coefficient				Inter-group Gini Coefficient					
		Pearl River Delta	Eastern Guangdong	Northern Guangdong	Western Guangdong	Pearl River Delta & Eastern Guangdong	Pearl River Delta & Northern Guangdong	Pearl River Delta & Western Guangdong	Eastern Guangdong & Northern Guangdong	Eastern Guangdong & Western Guangdong	Northern Guangdong & Western Guangdong
2010	0.140	0.187	0.076	0.093	0.063	0.176	0.214	0.170	0.106	0.082	0.118
2011	0.137	0.172	0.076	0.088	0.091	0.172	0.207	0.167	0.100	0.091	0.120
2012	0.139	0.167	0.107	0.096	0.079	0.168	0.204	0.163	0.119	0.104	0.114
2013	0.146	0.179	0.083	0.106	0.093	0.198	0.213	0.174	0.101	0.105	0.122
2014	0.142	0.189	0.072	0.097	0.068	0.203	0.219	0.181	0.090	0.086	0.109
2015	0.137	0.175	0.086	0.107	0.054	0.190	0.203	0.180	0.100	0.083	0.095
2016	0.144	0.182	0.080	0.112	0.082	0.187	0.210	0.190	0.106	0.085	0.107
2017	0.148	0.185	0.143	0.102	0.099	0.197	0.206	0.188	0.131	0.127	0.106
2018	0.135	0.178	0.080	0.103	0.088	0.188	0.192	0.180	0.094	0.089	0.099
2019	0.135	0.171	0.082	0.097	0.083	0.190	0.203	0.176	0.093	0.087	0.099
2020	0.133	0.171	0.081	0.086	0.084	0.190	0.206	0.187	0.087	0.087	0.094
Aver-age	0.139	0.177	0.087	0.098	0.081	0.187	0.207	0.177	0.102	0.093	0.107

5.2 Intra-regional Differences

Based on the intra-group differences shown in Table 3, The intra-regional disparities within the Pearl River Delta in terms of economic development are markedly higher than those in other regions. Specifically, these disparities in the Pearl River Delta are on a declining trend, while those in Western Guangdong are increasing, and fluctuations are notably significant in the Eastern Guangdong region. These variations can be attributed to differences in public investment, industrial configuration, openness to foreign investment, talent attraction, and innovation inputs across the counties within each region.

5.3 Inter-regional Disparities

Regarding inter-regional differences, the disparities between Northern Guangdong, Eastern Guangdong, and Western Guangdong have consistently hovered around 0.1. However, the biggest difference is the difference between the Pearl River Delta and the other three regions. Throughout the analysis period, the average disparities between the Pearl River Delta and each of these regions have consistently exceeded 0.177, with the gap between the Pearl River Delta and Northern Guangdong being the most substantial, consistently surpassing 0.2.

Figure 4 reveals that the predominant factor driving the overall disparities in counties economic development levels in Guangdong Province is inter-regional differences, which on average account for 48.5% of the total disparities. The next significant contributor is the transvariation density differences, which on average contribute 27.25%, followed by intra-regional differences at 24.25%. It is clear from these findings that reducing inter-regional disparities is crucial for addressing the regional inequalities in economic growth levels across Guangdong Province.

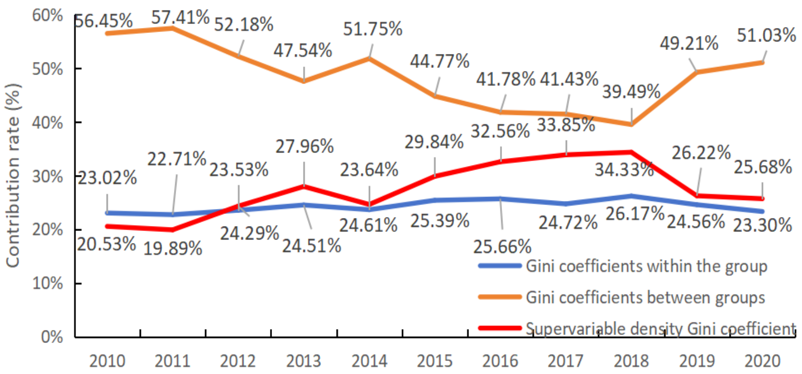

Figure 4 Contribution rate of regional differences

6. Research Conclusions and Policy Recommendations

6.1 Research Conclusions

This study has utilized advanced machine learning methods, including the entropy method, kernel density estimation, Markov chains, and the Dagum Gini coefficient, to assess and forecast the economic landscape of counties in Guangdong Province. The findings reveal a consistent upward trend in the overall level of counties economic development, with a spatial pattern marked by higher development in central areas and lower on the periphery. The dynamic evolution shows the central position of the density functions for economic development levels gradually shifting rightward, indicating a trend towards right-tail dragging, with a generally widening main peak, although polarization levels vary. Counties across all levels of development demonstrate substantial stability over time, exhibiting "club convergence" characteristics. Notably, the Pearl River Delta region displays some elements of a "Matthew effect." In terms of regional differences, while the overall disparity among counties shows a slight decline, these variations remain a significant factor contributing to regional disparities in high-quality economic development across the province.

6.2 Policy Recommendations

Firstly, it is essential to strengthen regional coordinated development to minimize disparities. This can be achieved through enhancing industrial collaboration and deepening synergistic development between the Pearl River Delta and other regions. Utilizing the driving role of the Pearl River Delta, efforts should be made to integrate and share resources including markets, technology, capital, and talent across the industrial chain. Additionally, strengthening the interconnectivity of regional infrastructure, such as transportation and information networks, is crucial to reduce logistics and communication costs between regions, thereby enhancing the overall competitiveness of county economies across Guangdong Province.

Secondly, promoting a green economy and sustainable development is vital. This involves limiting pollution emissions from high-energy-consuming enterprises. The government can foster the adoption of eco-friendly technologies and clean energy in companies through incentives like tax reliefs and financial subsidies, encourage green technological innovation, and minimize the environmental impact of industrial production.

Thirdly, enhancing innovation capacity is key to advancing high-quality counties economic growth. Counties in the Pearl River Delta should spearhead this initiative by fully implementing an "innovation-driven" strategy and playing a regional "leading" role. Through the innovation spillover effects, these areas can drive collaborative innovation in surrounding counties to achieve elevated economic development levels. Counties in northwestern Eastern Guangdong should deepen reforms in the industrial system. As they accept industrial transfers, these counties should actively implement strategies to strengthen their science and education sectors, guiding and supporting companies to increase R&D investments, enhance the aggregation of scientific and technological resources, and transform research outcomes into practical productivity through project cooperation, innovation reciprocity, and platform co-construction. This approach will enhance industry rationalization and promote high-quality economic development.

Acknowledgement

Philosophy and Social Science Planning Project of Guangdong Province: "Research on the Mechanism and Strategies for Digital Inclusive Finance Empowering High-Quality Economic Development in Western Guangdong Counties" (GD23YDXZYJ04); Key Project of Guangdong Province's Science and Technology Innovation Strategic Special Fund: "Research on Digital Economy Empowering Urban-Rural Integration and Regional High-Quality Coordinated Development under the Goal of Common Prosperity — A Case Study of Guangdong Province" (pdjh2024a239).

References

[1] Mullainathan S, Spiess J. Machine Learning: An Applied Econometric Approach. Journal of Economic Perspectives, 2017, 31 (2).

[2] Li Jinchang, Shi Longmei, Xu Yiting. Discussion on the evaluation index system for high-quality development. Statistical study, 2019, 36 (1): 4-14.

[3] Qi J. Fiscal expenditure incentives, spatial correlation and qual-ity of economic growth: evidence from a Chinese province. International Journal of Business and Management, 2016, 11(7): 191-201.

[4] Wang Hongwei, Zhang Jing, Jia Yangfan. Research on high-quality Regional Economy Development of in China. Technical economy, 2023, 42 (11): 120-131.

[5] Wu Gang, Wei Construction, Xie Fang. Area opening to the outside world, total factor productivity and economic high-quality development. Economic problems, 2022, (04): 108-115.

[6] Tu Jianjun, Kuang Renrui, Mao Kai et al. High-quality development level evaluation of Chengdu-Chongqing urban agglomeration. Economic Geography, 2021,41 (07): 50-60.

[7] Huang Huan, Wang Fan, Wu Anbing. The characteristics of timely empty evolution of high quality economic development in China. Statistics and Decision Making, 2021, 37 (17): 112-117.

[8] Ma Bo, Zhou Rui. Spatiotemporal pattern and convergence analysis of scientific and technological innovation efficiency in the Yangtze River Economic Belt. Soft Science of China, 2024, (S1): 401-413.

[9] Zhang Xiu, Zhang Yaofeng, Zhang Zhigang. High-quality growth of China's economy: measurement, spatiotemporal evolution and dynamic spatial convergence. Exploration of Economic Issues, 2024, (01): 15-37.

[10] Li Yong, Jiang Rui, Zhang Min, etc. High quality growth measurement of China digital economy timely air evolution analysis. Statistics and Decision-making, 2023, 39 (04): 90-94.

[11] Shi Caixia, He Xiaorong, Peng Kunjie. Spatio-temporal evolution and obstacle factor identification of high-quality development level in the Yangtze River Economic Belt. Economic Management of East China, 2023, 37 (06): 20-31.

[12] Fu Guo, Lei Lei. A Study on the spatiotemporal changes of economic spatial differences in eight coastal economic zones in China. Economic Geography, 2014, 34 (03): 6-9: 37.

[13] Xiao de, Yu Fan. Calculation and comparative analysis of high-quality China urban economic development. Macro-Quality Study, 2021, 9 (03): 86-98.

[14] Liu Hao, Liu Shulin. Quality measurement of new urbanization development under the framework of high-quality development. Statistics and Decision Making, 2021, 37 (13): 112-116.

[15] Chen Jiemei, Lin Zeng. Analysis of high quality development level of Agricultural circular economy in China. Exploration of Economic Issues, 2023, (10): 85-97.

[16] Guo Bingnan, Yu Wang, Zhang Hao. Spatio-temporal evolution, regional differences and spatial convergence of digital economy in the Yangtze River Economic Belt. Economic Management of East China, 2023, 37 (04): 24-34.

[17] Wei Yanhua, Wang Bingshen, Ma Liping. Research on high-quality economic development measurement and regional differences in China. Statistics and Information Forum, 2023, 38 (08): 41-54.

[18] Sun Xiao, Liu Ligang, Zhou Yang et al. Studies on the difference of high-quality development of tourism economy in different regions of China. Regional Research and Development, 2023, 42 (01): 108-112, 131.

[19] Zhang Naili, Li Zongxian. Research on the spatial-temporal pattern and convergence of China's economic development quality. Journal of Shandong University (Philosophy and Social Sciences edition), 2021, (02): 140-150.

[20] Ren Baoping,Song Xuecun. Analysis of the restricting factors and pathways of efficiency reform in China's high-quality development. Research on Financial Issues, 2019, (06): 25-32.

[21] D. Atanasov. Socio-economic development of agriculture based on technological change. Agricultural Sciences/agrarni Nauki, 2023, 15(37).

[22] Zhang Qian. Study on coordinating ecological environment protection and high-quality economic development in the northwest region of the middle and upper reaches of the Yellow River. Social Science in Ningxia, 2022, (03): 139-145.