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# Research on the Economic Radiation Measurement of Surrounding Cities in the Guangdong Hong Kong Macao Greater Bay Area

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**Abstract:** By establishing a comprehensive index system of cities, this paper uses gravity model to measure the economic connection intensity of cities in Guangdong Province, and divides cities into four levels by k-means clustering analysis. The first level city is Guangzhou, which ranks first in the total economic connection intensity of the whole Guangdong Province. The second tier cities are Shenzhen and Foshan; The third tier cities are Dongguan, Zhuhai, Zhongshan, Jiangmen and Huizhou. The rest of the cities ranked fourth. Combining qualitative and quantitative analysis methods, this paper puts forward two suggestions on "measuring the economic radiation of the Guangdong-Hong Kong-Macao Greater Bay Area to the surrounding cities" : strengthening the economic strength and strengthening the radiation subjects; Make use of location advantages to improve traffic accessibility.

**Keywords:** Economic radiation, Entropy weight method, Gravity model, Cluster analysis.

## 1. Introduction

In recent years, the development of the Guangdong Hong Kong Macao Greater Bay Area has received increasing attention from provincial governments and the country. Establishing industrial clusters to promote industrial development and economic radiation is a good economic measure. In February 2019, the State Council released the "Outline of the Development Plan for the Guangdong Hong Kong Macao Greater Bay Area", which focuses on promoting the construction of the Greater Bay Area into a world-class urban agglomeration and an international center for scientific and technological innovation, as well as promoting coordinated economic development between cities and strengthening industrial cluster effects. Nie Wei, director of the China Institute of Transportation Economics at Shenzhen University, often travels to various cities in the Greater Bay Area. He also expressed a similar viewpoint: in order to achieve coordinated development of the Guangdong Hong Kong Macao Greater Bay Area as a whole, we must solve the problem of uneven development between cities.

The report of the 20th National Congress of the Communist Party of China also pointed out: "Building a coordinated development pattern of large, medium, and small cities based on urban agglomerations and metropolitan areas, and promoting urbanization construction with county towns as important carriers." Regarding the definition of urban agglomerations, it is said that urban agglomerations refer to a certain number of cities of different levels, sizes, and types within a specific regional scope. Therefore, studying the economic radiation measurement of the Guangdong Hong Kong Macao Greater Bay Area on surrounding cities can help us identify the current situation and room for improvement in economic radiation, propose corresponding countermeasures and suggestions to help cities develop industrial clusters based on their own advantages, enhance their competitiveness and economic radiation benefits, and achieve regional coordinated development. Combining the knowledge learned in this major, establishing an algorithm model and using data as support to complete the model building, solving, and analysis has important reference significance for the research of this topic.

## 2. Journals Reviewed

As early as the 1950s, the selection of models and methods for measuring economic radiation has been a hot topic for scholars both domestically and internationally. For the study of economic connections in urban agglomerations, foreign scholars mainly use multiple methods, scales, and perspectives to analyze their characteristics, influencing factors, manifestations, and development trends. As stated in "Assessing the Economic Impact of Cross Border Transport Infrastructure: A Gravity Model Approach" by Liu, Z., et al. (2018), this article evaluates the economic impact of cross-border transport infrastructure through a gravity model, analyzing its impact on regional economy from multiple scales and perspectives, and revealing its radiation effect on surrounding cities.

However, research on the economic connections between urban agglomerations in China started relatively late, mainly focusing on analyzing and measuring the economic connections between cities within urban agglomerations using urban flow models, social network analysis models, potential models, gravity models, and other methods. William Reilly first proposed the gravity model and the "retail gravity law" by combining Newton's theory of universal gravitation. In 1949, Converse developed Riley's theory and proposed the theory of fracture points. The fracture point theory model has been widely used in the study of urban interactions since its proposal, and has become a model adopted by many scholars to quantify economic radiation. For example, He Longbin explored the economic radiation force of Xi'an to southern Shaanxi based on the fracture point theory [2], Tao Haiyang analyzed the economic radiation of Shanghai and Nanjing to Zhenjiang based on the fracture point theory [3], and scholars such as Li Guoping (2001) [4], Chen Yanguang (2002) [5], Liu Chengliang (2007) [6] used the gravity model of spatial interactions to quantitatively measure the strength of urban or regional economic connections.

That is to say, scholars at home and abroad are concerned about how to choose indicators to represent the comprehensive strength of a city, in order to more comprehensively measure the economic radiation power of each city. Feng Dexian et al. combined the breakpoint model and proposed seven indicators including economic integration, industry, enterprise, technology, opening up to the outside world, human resources, and infrastructure as primary indicators to analyze the current situation of Zhengzhou's urban radiation power [7]. The economic radiation power evaluation index system constructed by Shilu et al. is divided into two categories, seven aspects, and 20 indicators [8]. The two categories are comprehensive economic strength and degree of external connection, and the seven aspects are economic development level, city size, technological innovation capability, human capital, level of opening up to the outside world, external communication capability, and transportation access capability. Through principal component analysis, the main features are extracted, dimensionality is reduced, and the comprehensive score of each city is calculated.

# 3. Research Ideas

This article first reviews and reviews domestic and foreign literature related to economic radiation. Based on the theoretical foundation of previous research, a comprehensive index system for cities is constructed using the entropy weight method. Then, the economic connection strength between cities in Guangdong Province is calculated using a gravity model, and the total economic connection strength representing each city is summarized and added up. The k-means clustering analysis is used to classify each city into different levels. Finally, the solution results are analyzed using statistical analysis methods, and corresponding countermeasures are proposed.

# 4. Main Research Methods

This article mainly adopts methods such as literature research and mathematical statistical analysis to enhance the persuasiveness of the research results.

## 4.1. Literature Research Method

Literature research method refers to the research method of collecting and organizing the research results and model basis of domestic and foreign scholars on this topic over the years through a standardized process, in order to obtain relevant knowledge and theoretical support. This article collected theoretical explanations of the concept of "economic radiation" from domestic and foreign scholars through literature review, as well as the establishment and solution process of economic radiation measurement models such as the "gravity model" and "breakpoint model", including the advantages and disadvantages of various measurement models, providing a theoretical basis and research framework for my research.

## 4.2. Mathematical and Statistical Analysis

Mathematical statistical analysis refers to the method of analyzing data, extracting information, making objective inferences and predictions through mathematical and statistical principles. This article summarizes the basic characteristics of the data by collecting annual data on various indicators from the Guangdong Provincial Bureau of Statistics and calculating statistical indicators such as the average value of the indicator data. In addition, by defining the meanings of each indicator to establish a gravity model, and substituting specific data to calculate the results for comparison with the actual situation, the reliability and persuasiveness of the model established in this article can be evaluated.

# 5. Establishment of Model

## 5.1. Building a Comprehensive Evaluation Index System

The measurement of economic radiation between cities needs to rely on the comprehensive evaluation index system of cities. As stated in the literature, we follow the principles of scientific, systematic, representative, and obtainable indicators, and refer to the urban comprehensive competitiveness model established by Hodge [9]. We select a representative indicator from seven aspects: population size, economic aggregate level, per capita economic ownership level, foreign trade level, regional trade situation, employment scale, and tourism openness to construct a comprehensive evaluation index system for cities.

## 5.2. Objective Weighting Using Entropy Weight Method

At present, there are many models for evaluating the quality of indicators, such as comprehensive index method, PHP method, RSR method, fuzzy comprehensive evaluation method, grey system method, etc. These methods each have their own characteristics and advantages and disadvantages. Entropy weight method is a multi criteria decision-making method, whose principle is that the smaller the degree of change in the indicators, the less information they reflect, and the corresponding weight values are smaller. The basic steps are as follows:

Step 1: Establish a comprehensive urban indicator evaluation system based on 3.1, and create a normalized matrix.

$$Z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} (i = 1, \dots, m; j = 1, \dots, n) \quad (1)$$

Step 2: represents the number of selected cities, represents the number of constructed indicator systems, and represents the score of the th indicator for the th city;

Step 3: Calculate the information entropy of each indicator. For the th indicator, the formula for calculating its information entropy is:

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^{m} p_{ij} \ln(p_{ij}) \ (j = 1,2, \dots, n) \quad (2)$$

Step 4: Calculate the information utility value of each indicator, including the information utility value of the nth indicator. Normalize the information utility value to obtain the entropy weight of each indicator $W_j = \frac{d_j}{\sum_{j=1}^{n} d_j} (j = 1,2, \dots, n)$.

## 5.3. K-means Clustering to Classify Cities into Different Levels

After constructing the revised gravity model through 3.3, we need to classify 21 cities into different levels based on their economic gravity. We refer to Hodge's (2020) [9] and use SPSS software to cluster the total economic linkage strength of the cities. The basic idea of K-means clustering algorithm is introduced below:

Step 1: Determine the number of clusters K (i.e. the number of categories to be divided);

Step 2: Randomly select K data points as initial clustering centers;

Step 3: Calculate the distance from other data points to these K initial centers and assign them to the cluster to which the nearest cluster center belongs;

Step 4: Adjust the clustering based on the newly formed clusters and recalculate the centers of each cluster;

Step 5: Repeat steps 3 and 4 until the cluster center stabilizes (no longer undergoes significant changes) or reaches the preset number of iterations, and then stop the loop;

Step 6: The algorithm ends.

# 6. Solution

## 6.1. Research Scope and Data Acquisition

The spatial scope selected for this article is various cities in Guangdong Province, covering 21 prefecture level cities including Guangzhou, Shenzhen, Zhuhai, Shantou, Foshan, Shaoguan, Heyuan, Meizhou, Huizhou, Shanwei, Dongguan, Zhongshan, Jiangmen, Yangjiang, Zhanjiang, Maoming, Zhaoqing, Qingyuan, Chaozhou, Jieyang, and Yunfu. Considering the availability of data related to economic development and the rigor of calculations, this article obtained relevant indicator data for each city from the Guangdong Provincial Bureau of Statistics for the past five years, from 2018 to 2022, and used entropy weight method to objectively weight each indicator and establish a gravity model for solution.

## 6.2. Solution of Entropy Weight Method

We use Matlab to solve the entropy weight method algorithm model, and the weight value calculated through entropy value and difference coefficient can objectively reflect the degree of superiority or inferiority of different indicators. The value is between 0 and 1, the closer it is to 1, the more it can represent the comprehensive strength of the city, and the farther it is from 1, the less it can represent the comprehensive strength of the city. Table 1 shows the weight values of each indicator in 2022:

**Table 1.** Weight Table of Each Indicator

| Evaluation criteria, weight of evaluation indicators | Evaluation criteria, weight of evaluation indicators | Evaluation criteria, weight of evaluation indicators |
|---|---|---|
| Population size Permanent population 0.1108 | Population size Permanent population 0.1108 | Population size Permanent population 0.1108 |
| Economic aggregate level, regional GDP 0.1701 | Economic aggregate level, regional GDP 0.1701 | Economic aggregate level, regional GDP 0.1701 |
| Per capita economic ownership level, per capita gross domestic product 0.0707 | Per capita economic ownership level, per capita gross domestic product 0.0707 | Per capita economic ownership level, per capita gross domestic product 0.0707 |
| Foreign trade level: Import and export value of goods 0.2265 | Foreign trade level: Import and export value of goods 0.2265 | Foreign trade level: Import and export value of goods 0.2265 |
| Regional trade situation, retail sales of consumer goods, 0.1488 | Regional trade situation, retail sales of consumer goods, 0.1488 | Regional trade situation, retail sales of consumer goods, 0.1488 |
| Employment scale employed population 0.1224 | Employment scale employed population 0.1224 | Employment scale employed population 0.1224 |
| Tourism openness received 0.1506 overnight travelers | Tourism openness received 0.1506 overnight travelers | Tourism openness received 0.1506 overnight travelers |

In the end, we obtained the comprehensive strength scores of each city each year, and weighted the average of the comprehensive scores of each city each year as its final score, which represents the comprehensive strength of the city. This result is calculated through data deduction and is not subjective speculation, so it is reliable. Table 2 only displays the top five cities in terms of comprehensive strength ranking.

**Table 2.** Comprehensive scores of each city

| city | 2018year | 2019year | 2020year | 2021year | 2022year | Final Score |
|---|---|---|---|---|---|---|
| shenzhen | 28137.14 | 28486.31 | 26801.58 | 28107.09 | 29311.54 | 28168.73 |
| guangzhou | 19081.70 | 20580.19 | 19530.43 | 20483.93 | 20870.07 | 20109.26 |
| zhuhai | 15264.59 | 14875.44 | 13152.41 | 12883.53 | 13240.52 | 13883.30 |
| dongguan | 13482.52 | 14044.87 | 13109.19 | 13681.15 | 13681.57 | 13599.86 |
| foshan | 13588.73 | 14020.82 | 12901.99 | 13323.95 | 13931.57 | 13553.41 |

## 6.3. Solution of Modified Gravity Model

Through 4.2, we calculate the comprehensive strength score of the city; Objectively represent the number of permanent residents that a city can accommodate by using the average number of permanent residents in the past five years; Based on the latitude and longitude of each city, we calculated the spatial distance between cities, and finally calculated the economic connection strength between each city according to the formula. The specific data is shown in the appendix. Table 3 only displays the economic connection strength data between first and second tier cities and other cities.

# 7. Empirical Analysis

## 7.1. Comparative Analysis

We calculated the comprehensive strength score of each city, the total economic connection strength of each city, and the classification of each city level through the solution of the model. Finally, we found that:

There are significant differences in the overall competitiveness and economic connectivity of cities within Guangdong Province. The city with the highest economic connectivity is Guangzhou (33215.41), followed closely by Shenzhen (22484.59) and Foshan (19698.43), while Chaozhou, Shanwei, and Yunfu rank last, second, and third respectively. This is consistent with the actual situation: Guangzhou, Shenzhen, and Foshan generally have high population, GDP, and foreign trade volume, with developed manufacturing, service, and high-tech industries. Guangzhou has countless clothing manufacturing factories and wholesale markets, gathering a large number of young migrant workers. Therefore, this industry has made a great contribution to Guangzhou's GDP; Shenzhen is home to Fortune 500 companies such as Tencent, Alibaba, and DJI, as well as the nationally renowned electronics manufacturing hub of Huaqiangbei; Foshan has the first furniture manufacturing industry cluster in the country; Chaozhou, Shanwei, and Yunfu have relatively small populations and low GDP levels, mainly focusing on agriculture, fisheries, and light industry. Their industrial advantages are not prominent, and young urban populations generally develop towards first - and second tier cities, which has a certain impact on the local economic development. From Figure 4, it can be seen that the cities with the highest total economic connectivity are located in the center of the entire Guangdong Province, namely the Pearl River Delta area, while the cities with the lowest total economic connectivity, such as Chaozhou, Jieyang, Shaoguan, Maoming, etc., are located at the outermost periphery of the entire Guangdong Province and have less close communication with the Pearl River Delta region, resulting in weaker economic connectivity.

## 7.2. Regional Economic Pattern

In terms of regional economic pattern, Guangdong Province has formed the Pearl River Delta Economic Zone with Guangzhou and Shenzhen as the core, and the Guangdong East West Economic Zone with Dongguan and Foshan as the core. The Pearl River Delta Economic Zone is dominated by manufacturing, high-tech industries, and service industries, forming a complete industrial chain and efficient market system. The economic zones in eastern, western, and northern Guangdong are mainly focused on manufacturing and traditional industries, with relatively low levels of development.

## 7.3. Market Demand

The Pearl River Delta region has a huge market demand, including both domestic and international markets, especially for high-tech products and services, and has developed transportation. Products are sold abroad through ports. The market demand in the eastern, western, and northern regions of Guangdong is relatively small, mainly dominated by the local market with a small market size. Provincial and municipal governments can gradually gather small enterprises through government guidance and market leadership, expand the scale and efficiency of local industrial parks, and enhance the comprehensive economic strength of small cities; In addition, the municipal government should take timely measures to attract population and improve the welfare benefits for local employment of young people to reduce population loss.

# 8. Summary and Countermeasures

## 8.1. Enhance Economic Strength and Strengthen Radiating Entities

We compared the comprehensive strength scores of various cities with their total economic connection strength, and found that the comprehensive economic strength is positively correlated with the economic connection strength of the city. Therefore, in order to enhance the economic radiation power of a city, it is necessary to strengthen its comprehensive economic strength. Only when the city's comprehensive economic strength is strong, will the population gather and industries develop. Through regional linkage, it can drive the improvement of the surrounding city's economy, thereby achieving the ultimate goal of enhancing the overall economic radiation effect.

## 8.2. Utilize Location Advantages to Enhance Transportation Accessibility

According to the principle of the urban economic linkage strength model, the economic linkage between cities is not only related to their overall strength, but also influenced by factors such as population and distance. In other words, the convenience of transportation between cities directly affects the economic radiation of cities. For example, since Guangzhou and Foshan connected by subway, "Guangfotong" has allowed Guangzhou residents to travel to Foshan for a day trip, and Foshan residents can commute to Guangzhou for work, greatly reducing commuting time across cities. This has greatly strengthened the economic connection and radiation effect between Guangzhou and Foshan. Therefore, transportation is an important link that affects the economic radiation of cities. The Guangdong Hong Kong Macao Greater Bay Area should strengthen urban road planning and transportation infrastructure construction, and enhance transportation accessibility through location advantages.

# 9. Innovations

## 9.1. Innovation Points

(1) Establishing a comprehensive urban indicator system using entropy weight method: By measuring the weights of each indicator using entropy weight method, a comprehensive urban evaluation indicator system is established. The final calculated urban comprehensive strength score has objectivity and persuasiveness, and is more reliable compared to the subjective weighting obtained by Analytic Hierarchy Process;

(2) The gravity model calculates the strength of economic connections between cities: The gravity model is an extended model based on Newton's theory of universal gravitation, which is innovative and can calculate the strength of economic connections through persuasive gravity formulas established by existing scholars; K-means clustering analysis for hierarchical classification: Using the k-means clustering algorithm to classify city levels helps us group cities at different levels based on the strength of economic connections between cities. We can also verifythe reliability and persuasiveness of our model based on the existing government classification of city levels.

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