Comprehensive Measurement and Spatiotemporal Evolution of County-Level Economic Density in Chongqing Based on PCA-TOPSIS (Post-Print)

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Abstract

Economic density is one of the important indicators for measuring regional economic development level and agglomeration degree. Taking the jurisdiction of 38 counties (districts) in Chongqing Municipality as the study area, this study establishes a comprehensive measurement indicator system combining per capita and per unit land area indicators, employs Principal Component Analysis to determine indicator weights, and applies the PCA-TOPSIS evaluation method to comprehensive economic density measurement. Based on the relative closeness of measured objects to optimal values, this study comprehensively measures county-level economic density in Chongqing for 1997, 2001, 2006, and 2013, obtaining the comprehensive economic density index and its ranking for each time cross-section. By utilizing ArcGIS mapping functionality to create grade distribution maps of economic density in Chongqing, the study reveals spatial differentiation evolution patterns. Using Moran' s I, LISA, and hotspot analysis, the study explores global and local spatial autocorrelation and spatiotemporal evolution patterns of county-level economic density, and discusses the main factors influencing economic density levels. Through comprehensive measurement of county-level economic density and investigation of its spatiotemporal evolution, this research provides a scientific basis for achieving scientific urban positioning and formulating medium- and long-term development strategies.

Full Text

Comprehensive Measurements and Principle Component Analysis of the Spatiotemporal Evolution of Economic Density in Chongqing City, China

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Abstract: Economic density is one of the most important indicators of regional economic development and agglomeration. We studied 38 counties in Chongqing City, China and developed a model for a comprehensive measure based on per capita and land factors. The weights of measure indicators were determined by principal component analysis. Principle component analysis with the technique for order preference by similarity to ideal solution was applied to measure economic density. Our metric of economic density was based on the Euclidean distance between the object value and its optimal value and worst value. The economic density composite index and ranking were obtained for each object. We used GIS to generate maps of economic density distributions in Chongqing City, which revealed changes in the spatial patterns of economic density over time. We used the rule of spatiotemporal variation of global and local spatial autocorrelation on county economic density as an opportunity to discuss the main factors affecting the levels of economic density. We identified three major findings: (1) the comprehensive economic density indices were calculated and ranked for 38 counties during four time periods. Economic density generally increased over time, while internal differences gradually decreased. (2) In terms of its overall distribution, economic density in Chongqing decreased from the center and northwest to the northeast and southeast. The distributions in areas with high economic density in the central region were significantly different from those with low density in the surrounding areas. (3) From the perspective of spatial autocorrelation, the Moran' s I index was greater than 0, showing a positive correlation, suggesting that economic density tended to gather in space. Moreover, the urban areas characterized by LH-type gradually decreased, and economic density became more spatially polarized. Hotspots and sub-hotspots of economic density were mainly distributed in the western part of Chongqing, while the secondary coldspots and sub-coldspots were mainly distributed in the east. The results of this study provide a scientific basis for the city' s strategies for long-term development.

Keywords: economic density; comprehensive measure; spatiotemporal evolution; PCA-TOPSIS; county

1 Introduction

1.1 Study Area

This study focuses on Chongqing municipality, located between 105°11 E to 110°11 E and 28°10 N to 32°13 N. The region covers an area of 8.24$×10^{4}$ km^2. According to 2013 data, the total population was 29.70 million, with GDP reaching 1265.669 billion yuan and an urbanization rate of 58.34%. The study period spans from 1997 to 2014, with data primarily sourced from the *Chongqing Statistical Yearbook*, *China County Statistical Yearbook*, and *Chongqing Economic Statistical Yearbook*. The analysis encompasses 38 county-level administrative units.

1.2 Data and Methods

1.2.1 Economic Density Measurement The economic density values ranged from 0.0151 to 0.8600 in 1997 (mean: 0.0933, coefficient of variation: 149.672%); from 0.0192 to 0.8081 in 2001 (mean: 0.0949, CV: 143.032%); from 0.0148 to 0.8207 in 2006 (mean: 0.1143, CV: 123.402%); and from 0.0438 to 0.8327 in 2013 (mean: 0.1311, CV: 101.044%). These results indicate that while economic density generally increased from 1997 to 2013, internal differences gradually decreased.

presents the county-level economic density rankings for Chongqing across the four time periods. provides detailed statistical results. Using ArcGIS 10.1, we generated spatial distribution maps of economic density [Figure 2: see original paper], which reveal distinct spatial clustering patterns.

3 Results and Discussion

3.1 Spatial Distribution Characteristics

Between 1997 and 2013, economic density in Chongqing exhibited clear spatial differentiation, decreasing from the central and northwestern regions toward the northeast and southeast. The high-density core areas showed significant differences from surrounding low-density regions. In 2006 and 2013, the spatial distribution patterns became particularly pronounced, with the central urban districts maintaining consistently high values.

From 1997 to 2001, the spatial distribution of economic density remained relatively stable, though some counties experienced rank changes. By 2006, the spatial polarization became more evident, with the core-periphery structure strengthening further by 2013.

3.2 Spatial Autocorrelation Analysis

3.2.1 Global Spatial Autocorrelation We employed GeoDa software to calculate Moran' s I values for economic density. The results show significant positive spatial autocorrelation: Moran' s I values were 0.2751 in 1997, 0.3210

in 2001, 0.4236 in 2006, and 0.3714 in 2013 (all significant at $p < 0.001$). This indicates that counties with similar economic density levels tend to cluster spatially.

The scatter plots [Figure 3: see original paper] illustrate the relationship between economic density values and their spatial lags. The clustering of points in the high-high (HH) and low-low (LL) quadrants further confirms the presence of spatial autocorrelation.

3.2.2 Local Spatial Autocorrelation Local Indicators of Spatial Association (LISA) analysis [Figure 4: see original paper] reveals four distinct spatial regimes: HH clusters (high-density counties surrounded by high-density neighbors), LL clusters (low-density counties surrounded by low-density neighbors), HL outliers (high-density counties surrounded by low-density neighbors), and LH outliers (low-density counties surrounded by high-density neighbors). The HH clusters were primarily located in the central urban core districts (Yuzhong, Jiangbei, Shapingba, Jiulongpo) throughout the study period, expanding to include surrounding districts by 2013. The LL clusters dominated the northeastern and southeastern peripheral counties.

Getis-Ord hotspot analysis [Figure 5: see original paper] identified statistically significant spatial clusters of high values (hotspots) and low values (coldspots). Hotspots and sub-hotspots were concentrated in the western region, particularly in the main urban districts and adjacent areas, while secondary coldspots and sub-coldspots were predominantly distributed in the eastern and northeastern counties.

The spatial polarization trend intensified over time, with LH-type areas (low-density counties adjacent to high-density areas) gradually decreasing, indicating strengthening agglomeration effects and weakening spatial spillovers from the core to the immediate periphery.

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Note: Figure translations are in progress. See original paper for figures.