# Comprehensive Evaluation and Spatial Evolution Analysis of High-Quality Development of Digital Economy in Anhui Province Based on Entropy Weight TOPSIS Method

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**ABSTRACT** Scientific evaluation of digital economy development in Anhui Province is important for identifying regional spatiotemporal evolution and supporting data-driven industrial upgrading. This study constructs a comprehensive evaluation framework based on the entropy weight TOPSIS method and analyzes the high-quality development level and spatial evolution characteristics of the digital economy in 16 prefecture-level cities in Anhui Province from 2015 to 2022. The results show that Anhui's digital economy maintained an overall upward trend during the observation period, with the average comprehensive development index increasing from 0.214 in 2015 to 0.587 in 2022, representing growth of approximately 1.74 times. However, significant intercity disparities remain, showing a development pattern of "core leadership and multi-polar differentiation." Spatial autocorrelation analysis indicates a stable positive spatial correlation, accompanied by high-high and low-low clustering, revealing a pronounced spatial polarization effect. Based on the empirical results, this paper proposes strengthening the radiating effect of core growth poles, compensating for regional development deficiencies, and optimizing spatial connection mechanisms.

**INDEX TERMS** digital economy, entropy weight topsis, spatial autocorrelation, regional development, anhui province

## I. INTRODUCTION

As the digital economy establishes data as a pivotal production factor, it is reshaping the global economic structure by driving the digitalization of traditional manufacturing and fostering a deeper integration between data-driven intelligence and industrial production.

In recent years, driven by the "Digital Anhui" strategy, Anhui has vigorously promoted new infrastructure construction, cultivated and expanded strategic emerging industries, electronic information industries, and artificial intelligence industries, and vigorously promoted the intelligent transformation of traditional industries, achieving progress in digital economy development. However, Anhui Province still faces some difficulties, including unbalanced development foundations, slow industrial capacity expansion, and insufficient regional coordination.

This study aims to provide empirical evidence and decision-making references for Anhui Province to accurately grasp digital economy trends, facilitating the digital empowerment of the industry to optimize regional strategies and promote high-quality, sustainable economic development. By integrating advanced manufacturing processes with data-driven frameworks, the research assists relevant departments in fostering a more efficient and balanced industrial evolution across the province.

## II. RELATED WORK

Against the backdrop of the global consensus that the deep integration of the digital economy and the real economy has become a global consensus, Yang and Han [1] explored the complex relationship between this new economic form and the ecological environment in the context of the rapid development of the digital economy. Li et al. [2] analyzed the reasons for different economic empirical conclusions. Li et al. [3] constructed a comprehensive index system for evaluating regional green and high-quality development and examined the direct impact, indirect transmission mechanism and spatial spillover effect of digital economic development on regional green and high-quality development. Li [4] analyzed the specific role and mechanism of economic

development in the environmental transformation of China's renewable energy sector. Kaggwa et al. [5] pointed out that emerging technologies are the core force driving contemporary economic development, promoting economic growth by improving total factor productivity and fostering emerging industries and new business formats.

Baranova et al. [6] believe that simply comparing the static level of digital economic development is not enough; we must pay attention to its dynamic development speed. Kryshtanovych et al. [7] pointed out that the pandemic has exacerbated the internal and external digital divide, and countries and groups with lower levels of digitalization face greater difficulties during the pandemic. Zhang et al. [8] analyzed the development of the digital economy. N Pluzhnikova [9] believed that the economy cannot function without human capital with digital literacy. Yali and Benwu [10] found that the digital economy helps cities better withstand external risk shocks and achieve rapid recovery. Most existing research results are concentrated at the national level or at the city cluster scale, lacking comprehensive evaluation research on the digital economy and its spatial evolution, especially at the provincial level in Anhui Province, a typical representative of the central region.

This paper aims to provide scientific basis and decision-making reference for policy formulation in Anhui Province and even the central region.

## III. METHODS

### A. EVALUATION INDEX SYSTEM

This paper constructs a comprehensive evaluation index system comprising 5 primary indicators and 18 secondary indicators, unfolding from five levels: basic support, scale and structure, comprehensive application, innovation-driven force, and shared benefits.

Digital industrialization reflects the large-scale development of digital technology itself. It is characterized by the number of employees in information transmission, software and information technology services, the total volume of telecommunications business, and the proportion of the operating income of large-scale electronic information manufacturing industry to the total industrial output above the designated size. Industrial digitalization reflects the depth of digital economy's empowerment of traditional economy. It is measured by the number of computers used per 100 people in enterprises, the proportion of enterprises with e-commerce transactions, and the integration of informatization and industrialization development index. Digital innovation capability is the core driving force for development. It is measured by the proportion of internal R&D expenditure to GDP, the number of invention patents per 10,000 people, and the transaction amount of technology market contracts. Digital inclusive development focuses on the sharing of development results. It is measured by the digital inclusive finance index, per capita mobile internet access traffic, and the number of WeChat public accounts per 100 people [11].

The research data mainly comes from authoritative databases such as the "Anhui Statistical Yearbook". The research period spans from 2015 to 2022, and the research subjects are 16 prefecture-level cities in Anhui Province.

### B. ENTROPY WEIGHT TOPSIS COMPREHENSIVE EVALUATION MODEL

In order to objectively determine the weight of the indicators and calculate the relative closeness between each city and the ideal solution, this paper adopts the entropy weight TOPSIS method. First, the original data is standardized to eliminate the influence of the dimension. For positive and negative indicators, the range standardization method is used to perform positive and normalization respectively. After obtaining the weight, a weighted normalized decision matrix is constructed [12].

### C. SPATIAL AUTOCORRELATION ANALYSIS

This paper employs spatial autocorrelation analysis. The Moran index ranges from -1 to 1. When the index value is significantly greater than 0, it indicates that there is a positive spatial correlation, that is, areas with high development level tend to be adjacent to other high-level areas, or low-level areas tend to be adjacent to other low-level areas, showing a spatial agglomeration pattern. When the index value is significantly less than 0, it indicates that there is a negative spatial correlation, that is, high and low-level areas are spatially interspersed. When the index value is close to 0, it indicates that the spatial distribution is random. Considering that the flow of digital economy elements (data, technology, capital) relies more on efficient integrated transportation and information infrastructure than on geographical boundaries, this paper constructs a more economically meaningful spatial weight matrix based on the classic Queens adjacency rule. Specifically, this paper adopts an "economic distance weight matrix based on the reciprocal of the shortest road distance between cities" as the spatial association structure of the main model. In this matrix, the spatial weight between any two different cities is defined as the reciprocal of the shortest road distance between the two municipal governments (the distance is obtained through the Gaode Map API, in kilometers). This distance can more realistically reflect the time cost and physical resistance of the flow of elements between cities. The weight of the same city and itself is set to zero. For ease of comparison, this paper also calculates a binary adjacency matrix based on the Queens adjacency rule as a robustness test. The statistical significance of the Moran index is judged using the Z-test [13-14].

Local spatial autocorrelation uses Local Moran's I index and LISA clustering map to identify specific local spatial clustering types and their geographical locations. Because this study only includes 16 prefecture-level cities in Anhui Province, the sample size is relatively small. The Local Spatial Autocorrelation (LISA) test is quite sensitive to outliers, which may limit the statistical robustness of the

clustering. To alleviate this problem, this study uses panel data from 2015 to 2022 (a total of 8 years) to increase the information content, and performs 999 Monte Carlo random permutations in all spatial tests to calculate pseudo-p-values. This method can classify the relationship between each spatial unit and its neighboring units into four types: high-high clustering (HH type), which means that it is adjacent to areas with higher development levels; low-low clustering (LL type), which means that it is adjacent to areas with lower development levels; high-low clustering (HL type), which means that it has a high development level but is surrounded by low-level areas; and low-high clustering (LH type), which means that it has a low development level but is surrounded by high-level areas. Through LISA significance test, the spatial clustering areas with statistical significance can be displayed intuitively on the map [15].

## IV. RESULTS AND DISCUSSION

### A. COMPREHENSIVE EVALUATION RESULTS OF THE HIGH-QUALITY DEVELOPMENT LEVEL OF ANHUI PROVINCE'S DIGITAL ECONOMY

Based on the entropy-weighted TOPSIS model, the comprehensive index (proximity index Ci) in 16 prefecture-level cities of Anhui Province from 2015 to 2022 was calculated. From a time series perspective, the average comprehensive index for the entire province steadily increased from 0.214 in 2015 to 0.587 in 2022, with a cumulative increase of 174.3% over eight years and an average annual compound growth rate of approximately 15.6%. This indicates that, driven by the continuous advancement of the "Digital Anhui" strategy and external technological waves, Anhui Province's digital economy has achieved leapfrog development. From a spatial perspective, there are significant differences in the development levels of various cities, and this gap persisted throughout the observation period. Figure 1 shows the specific results to clearly illustrate the development levels and rankings of various cities in 2022.

The research results show that the development of the digital economy in Anhui Province exhibits a clear pattern of "one leading city and multiple strong cities, with tiered differentiation." Hefei, the provincial capital, boasts a comprehensive index of 0.892, ranking first in the province and possessing an absolute advantage, making it the core growth pole of the province's digital economy. Hefei has significant advantages in digital industrialization (such as integrated circuits and artificial intelligence) and digital innovation capabilities. Wuhu (0.721) and Ma'anshan (0.654), as important industrial cities in the Wanjiang urban belt, form the first tier with Hefei, possessing a relatively good foundation for industrial digitalization. Cities such as Chuzhou, Tongling, Xuancheng, and Chizhou, with comprehensive indices ranging from 0.562 to 0.618, form the second tier, with development levels in the middle of the province. Meanwhile, some cities in northern Anhui, such as Huangshan, Anqing, and Huainan, are in the third tier, while Huaibei, Bengbu, Fuyang, Suzhou, Bozhou, and Lu'an generally have comprehensive indices below 0.5, placing them in the lower fourth tier. The digital economy development in these cities lags behind, particularly in terms of digital infrastructure coverage density and digital innovation capabilities, where there is a significant gap compared to leading cities. This spatial differentiation pattern is largely consistent with the traditional economic geography of Anhui Province, reflecting the high dependence of digital economic development on existing economic foundations, locational conditions, and policy resources.

To further analyze the dynamics and correlations of the aforementioned spatial differentiation patterns, this paper calculates the global Moran's I index of the comprehensive development index, and the results are shown in Table 1.

Table 2 shows that throughout the entire study period from 2015 to 2022, the global Moran's I index remained positive and passed the significance test at the 1% level. More importantly, the Moran's I index rose continuously from 0.312 in 2015 to 0.395 in 2022, indicating that this spatial clustering effect has been continuously strengthening during the observation period. The factors of digital economy development (such as talent, capital, data, and technology) have stronger mobility and agglomeration preferences, enabling regions with a better foundation to continuously attract more resources through a cyclical accumulation effect, while regions with a weaker foundation face the pressure of factor outflow, thus leading to the solidification of development gaps between regions and the exacerbation of spatial polarization.

To identify specific local clustering types and their spatial locations, this paper selects representative years 2015 and 2022 for statistical comparison of local spatial association types, and the results are shown in Table 2.

The results in Table 3 show that the spatial polarization of the digital economy in Anhui Province is very obvious. First, the high-high agglomeration area (HH) has developed from only Hefei in 2015 to a dual-core structure of Hefei and Wuhu in 2022. This confirms that the radiation effect of Hefei as a growth pole has begun to emerge, generating positive spatial spillover to Wuhu, which is geographically close and economically connected, and has initially formed a highland for digital economy development in central Anhui. Second, the low-low agglomeration area (LL) has remained stable and slightly expanded, mainly concentrated in Fuyang, Bozhou, Suzhou, Huainan, and Bengbu in northern Anhui and Lu'an in western Anhui. These regions have relatively low levels of digital infrastructure, industrial digitalization, and innovation capabilities, resulting in a "low-level spatial lock-in state (i.e., LL agglomeration)" rather than "negative spatial lock-in." It's noteworthy that while the continuous rise in global Moran's I indicates increased cohesion within the HH agglomeration area (Hefei-Wuhu), this trend has not generated more LH (low-high) type regions as theoretically expected.

This is because: firstly, the spatial spillover effect of the digital economy significantly diminishes with increasing

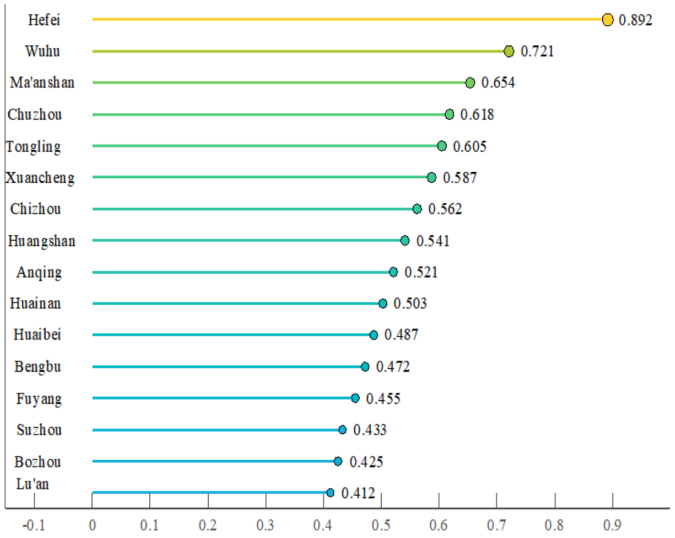


**FIGURE 1.** Comprehensive Index and Ranking of High-Quality Development of Digital Economy in Various Cities of Anhui Province in 2022

**TABLE 1.** Moran's I Index in Anhui Province, 2015-2022

| years | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Moran's I | 0.312 | 0.328 | 0.341 | 0.352 | 0.365 | 0.371 | 0.382 | 0.395 |
| Z-value | 2.874 | 2.961 | 3.102 | 3.154 | 3.287 | 3.325 | 3.401 | 3.513 |
| p-value | 0.004 | 0.003 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 |

**TABLE 2.** Statistics on Local Spatial Correlation Types of the Digital Economy in Anhui Province in 2015 and 2022

| Spatial association type | 2015 | 2022 | Typical representative cities (2022) |
|---|---|---|---|
| High-high aggregation (HH) | 1 | 2 | Hefei and Wuhu |
| Low-low aggregation (LL) | 5 | 6 | Lu'an City, Fuyang City, Bozhou City, Suzhou City, Huainan City, Bengbu City |
| Low-high aggregation (LH) | 3 | 1 | Chuzhou City (LH in 2015, type not significant in 2022) |
| High-low aggregation (HL) | 0 | 0 | none |
| Not significant | 7 | 7 | Ma'anshan, Tongling, Anqing, Xuancheng, Chizhou, Huangshan, Huaibei |

geographical distance, and peripheral cities outside Wuhu in the HH area have failed to effectively receive radiation from the core area; secondly, cities in the LL area generally suffer from weak digital infrastructure, insufficient industrial support capabilities, and a lack of human capital, meaning their "absorption capacity" is below the basic threshold required to absorb spillover effects, making it difficult to translate positive spatial

spillover into actual development. This explains why, against the backdrop of increased spatial correlation, the polarization pattern has been further solidified.

### *B. DISCUSSION AND POLICY IMPLICATIONS*

The above comprehensive evaluation and spatial evolution results show the achievements and difficulties involved in the digital economy of Anhui Province. The achievements are reflected primarily in the swift improvement in the overall level of the province and the first formation of core growth poles for the province. The problems are also manifested conspicuously in the widening regional disparities in the province, and the intensifying trend of spatial polarization. The "low-low" agglomeration in large areas of northern and western Anhui reflects the contribution of market mechanism and the natural radiation of individual growth poles is not enough to realize inclusive and balanced development of digital economy.

Therefore, future policy-making needs to go beyond a simple "support the best and strongest" approach, and move towards a more systematic strategy that emphasizes the collaboration of the region and categorized guidance. First, for some high-to-high agglomeration areas, such as Hefei and Wuhu, the policy focus should be to further build on its existing strengths, break through key core technologies, construct internationally competitive digital industry clusters, and make innovations in regional cooperation mechanisms. This includes doing a better job of transferring technology, capital and management experience to neighboring areas by joint construction of enclave parks and supply chain collaboration. Second, with regard to areas in northern and western Anhui with the characteristics of low-to-low

agglomeration areas, a strategy oriented to "digital new infrastructure" and the inclusive development of "industrial digitalization" should be realized. Increased investment and installation of new infrastructure such as 5G network, data centers and industrial internet in these areas are required to lower the cost and obstacle for enterprises to "go to the cloud, use data, and empower intelligence." By taking advantages of the local superiority in agricultural industry, agricultural product processing industry and labor industry, the development of unique digital agriculture industry, rural e-commerce industry and data labeling industry should be encouraged to develop endogenous driving forces. Third, for cities where the spatial connection is not so important or where the elements of industries are changing, such as Ma'anshan, Chuzhou, and Xuancheng, they should be encouraged to use location and industrial types of the economic sectors to make comparative advantages in particular sectors. For example, Ma'anshan could deepen intelligent transformation in traditional industries such as steel and automobile industry, and Chuzhou could strengthen digital economy cooperation with Nanjing to become "conversion bridge" between high value and low-value area. By building a new spatial development pattern for the digital economy in terms of "core-driven, axis-linked, and sector-coordinated," the overall digital economy in Anhui Province can be finally promoted.

## V. CONCLUSION

Based on the entropy-weighted TOPSIS and spatial autocorrelation results, an empirical study is conducted to evaluate the digital development level and spatial patterns of the industry across 16 prefecture-level cities in Anhui Province from 2015 to 2022. This approach integrates manufacturing digitalization into the broader regional analysis to reveal the spatiotemporal evolution of the province's modern industrial landscape. The main conclusions are as follows: First, the level of in Anhui Province has improved greatly during the observation period, but there is also a certain level of regional imbalance, forming a gradient pattern with Hefei as its absolute core, Wuhu, Ma'anshan and other riverside cities as secondary centers, and the north and west of Anhui as the ones lagging behind. Second, there is a significant and continuously strengthening spatial positive correlation between the development of the digital economy in Anhui Province, and there is an obvious spatial agglomeration effect. Specifically, this is expressed in the construction of the Hefei-Wuhu high-high agglomeration zone and the formation of large-scale stable low-low agglomeration zone in northern Anhui. Spatial polarization is the most important spatial feature nowadays. Third, radiation and driving capacity of growth poles is now mainly limited to relatively geographically adjacent areas, with little spillover effects in terms of spatial proximity to underdeveloped areas that are far away from growth poles.

Therefore, it is necessary to promote the high-quality development of the digital economy in Anhui Province to put forward the regional coordinated development strategy. On the one hand, on-going support should be given to Hefei to build a globally influential source of digital innovation and an industrial division center, and to strengthen the core engine function. On the other hand, strong intervention by government and precise policies in regions are key to increase investment in "digital infrastructure" and support for "digital empowerment" in low to low agglomeration areas, to break the "spatial cycle of poverty accumulation" and to facilitate a more equitable and efficient flow and sharing of digital elements and digital dividends among regions. Future studies could delve deeper into the specific driving mechanisms and thresholds that determine the spatial spillover of digital transformation within the manufacturing landscape, while evaluating how policy instruments—such as fiscal transfer payments, regional innovation alliances, and the strategic cultivation of digital talent—can effectively harmonize regional industrial upgrading and provide a refined blueprint for optimizing sector-wide policy.

## AUTHOR CONTRIBUTIONS

Yujuan Zhang designed, collected and analyzed the data, and drafted the manuscript. Yujuan Zhang conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Yujuan Zhang participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

## CONFLICTS OF INTEREST

The author declares no conflict of interest.

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