**Original Research Article**

**Evolution and Drivers of Coordinated Digital and Green Development in the Yangtze River Delta**

**Abstract:** Against the backdrop of the accelerated transformation of the global economic society, the coordinated development of digitalization and greening has become a crucial choice for promoting high-quality development in China. Based on an analysis of the mechanism of the coordinated development of digitalization and greening and the construction of a comprehensive index system, this study applies various methods such as the entropy method and the revised coupling coordination degree model to analyze the data of 41 cities in the Yangtze River Delta region from 2014 to 2023. The results show that: (1) The level of coordinated development of digitalization and greening in cities in the Yangtze River Delta region has been improving year by year, but there is still great room for improvement and the development is unbalanced; (2) There are significant differences in the coordinated development of digitalization and greening at the provincial and municipal levels in the Yangtze River Delta region; (3) The regional coordinated development presents the characteristics of dynamic evolution and spatial agglomeration, and the spatial Moran's I index decreased from 0.284 in 2014 to 0.188 in 2023 (P<0.1), indicating significantly weakened agglomeration effects; (4) The level of urbanization, the level of scientific and technological innovation, and the level of industrial structure optimization have a significant positive impact on coordinated development, and there are regional heterogeneities. This empirical evidence underscores the imperative for tailored, synergistic governance of digital-green transitions, offering a vital blueprint for sustainable development in China and beyond.

**Keywords:** Yangtze River Delta region; Digitalization; Greening; Coordinated development; Driving factors

**1 Introduction**

**1.1 Research Background and Significance**

In the wave of the accelerated transformation of the global economic society, as underscored by international bodies like the United Nations (e.g., highlighting digitalization as a key enabler for the Sustainable Development Goals) and the World Bank (e.g., emphasizing the critical role of digital technologies in enabling green transitions), the coordinated development of digitalization and greening has become a new trend in the development of the global economic society. China regards the digital economy and green development as important means to promote high-quality economic development and achieve the "dual carbon" goals. As one of the most economically developed, innovative, and open regions in China, the Yangtze River Delta region plays an important role in the national economic and social development and is at the forefront in terms of the digital economy and green development. However, it also faces constraints such as unbalanced regional development and great pressure for industrial structure upgrading. Based on this, an in-depth study of the evolution and driving factors of the coordinated development of digitalization and greening in cities in the Yangtze River Delta region not only helps to enrich and improve the theoretical system of the coordinated development of the digital economy and green development and fill the relevant theoretical gaps but also provides a scientific basis for formulating policies to promote the coordinated development of digitalization and greening in the Yangtze River Delta region, enhances the regional comprehensive competitiveness and sustainable development ability. Meanwhile, its experience can provide references for other regions in China and contribute to the realization of high-quality development in China.

**1.2 Research Review**

In recent years, against the backdrop of the "dual carbon" strategy, the coordinated development of digitalization and greening has become a hot topic in the academic community. Existing research can be summarized as follows: Firstly, from a theoretical perspective, scholars have systematically explored the mechanism by which the digital economy empowers green development. Tian (2023) clarified how digital technology injects vitality into green development by improving energy efficiency, optimizing resource allocation, and promoting industrial structure upgrading. Ye et al. (2024) proposed the theory of "Digital Green Fusion", distinguishing between two mechanism paths: Digital Empowered Green Practices (DEG) and Green-oriented Digital Practices (GED), and revealing how enterprises can achieve a win-win situation in green development and economic performance under institutional pressure. Secondly, from an empirical research perspective, scholars mainly conduct analyses from two dimensions: macro (industry and region) and micro (enterprise). At the industry level, Li et al. (2024) constructed an index system to evaluate the trend of the coordinated evolution of digitalization and greening in the manufacturing industry. At the regional level, Zhao et al. (2023) pointed out that the rationalization level of the industrial structure, the level of scientific and technological innovation, and the advanced level of the industrial structure are the core driving factors for the coordinated development of digitalization and greening in cities in the central region. Sun et al. (2025) analyzed the leading role of big data experimental zones in the green digitalization of surrounding regions from the perspective of the institutional spillover effect. At the enterprise level, Wumaierjiang et al. (2024) emphasized the important significance of the coordinated development of enterprise digital transformation and green transformation from the perspective of common prosperity. At the same time, the diversity of research methods has gradually emerged. Most studies use the coupling coordination model to calculate the degree of coordination between digitalization and greening, and combine spatial econometrics, geographical detection, and threshold regression to analyze its spatial pattern and driving factors. In addition, studies represented by Ye et al. (2024) have further deepened the analysis at the micro level from the perspectives of organizational behavior and institutional theory. In summary, existing research has achieved certain results in clarifying the coordinated relationship between digitalization and greening, covering the practical paths and theoretical construction at different industry, regional, and enterprise levels, and the research methods are becoming more diverse. The overall characteristics are diverse research perspectives and increasingly mature methods. However, there are still the following deficiencies in existing research: First, some studies focus on index construction and coupling measurement and lack an in-depth analysis of the internal logic of the coordination mechanism. Second, although existing research involves regions such as the Yangtze River Delta and the central region, most of them focus on the static comparison between provincial regions or prefecture-level cities, and there is a lack of a systematic analysis of the spatio-temporal evolution trend and driving mechanism of the coordination between digitalization and greening at the urban agglomeration scale. Third, the identification of the joint effects and heterogeneous impacts of multiple factors such as policies, technologies, industries, and institutions are insufficient. Especially in the context of the continuous deepening of the integration of digitalization and greening, it is urgent to construct a multi-dimensional interaction perspective and a systematic coupling analysis framework. Therefore, based on the typical urban agglomeration of the Yangtze River Delta region, this paper attempts to systematically reveal the evolution characteristics and driving mechanisms of the coordinated development of urban digitalization and greening from a more holistic and dynamic perspective.

**1.3 Research Marginal Contribution**

The marginal contributions of this paper are mainly reflected in the following three aspects: At the research perspective level, most of the current research on the coordinated development of digitalization and greening focuses on a single dimension (industry or provincial region). This paper expands the research scope to the more holistic and systematic regional scale of the Yangtze River Delta urban agglomeration, breaks through the limitations of static comparison, and systematically reveals the dynamic evolution laws and spatial differentiation characteristics of the coordinated development of digitalization and greening at the urban agglomeration level, providing a new analytical perspective for the research on regional coordinated development. At the research method level, this paper adopts a variety of quantitative analysis methods such as the entropy method, the revised coupling coordination degree model, and the kernel density estimation method, which not only ensures the objectivity and accuracy of the calculation of the coordination level between digitalization and greening but also deeply analyzes the spatial agglomeration and driving factors in the process of coordinated development, overcoming the limitations of a single model and providing methodological references for similar studies. At the practical application level, based on the empirical analysis of cities in the Yangtze River Delta region, the proposed driving factors and coordinated development paths can provide a scientific basis for formulating precise policies in this region, solve problems such as unbalanced regional development, and its experience can also provide practical examples for other regions in China to explore the coordinated development model of digitalization and greening, which has important guiding significance for promoting the comprehensive green transformation and high-quality development of China's economic society.

**2 Theoretical Mechanism Analysis of the Coordinated Development of Digitalization and Greening in Cities in the Yangtze River Delta Region**

The essence of coordinated development lies in the interactive collaboration among different systems. Each system promotes one another, achieving more efficient and sustainable common progress, and thus generating more significant overall benefits. In the process of digital development, digital infrastructure serves as the foundation, digital technology is the core driving force, digital industrialization plays the role of value transformation, and industrial digitalization acts as a booster for the transformation and upgrading of traditional industries. In the process of green development, green growth is the core goal, green welfare is the guarantee for people's livelihood, the green environment is the natural foundation, and green governance is the institutional guarantee. Digitalization and greening should not develop in isolation but need to be closely coordinated and complementary. This coordinated development model not only meets the requirements of the era of sustainable development but is also a key path to promoting the economic development of the Yangtze River Delta region to a high-quality development stage.

**2.1 The Interactive Relationship between Urban Digitalization and Green Development**

The digitalization process and green development of cities in the Yangtze River Delta region have gradually shown a symbiotic state of integration and mutual promotion. While digitalization drives green development, greening also guides digital development. Digitalization and greening empower each other bidirectionally, jointly contributing to the high-quality development of cities in the Yangtze River Delta region.

First, digital development strongly promotes the continuous evolution of urban greening in the Yangtze River Delta region. Firstly, the widespread application of digital technology in the Yangtze River Delta has greatly facilitated the development of industrial greening. For example, with the help of big data analysis, the Yangtze River Delta region can accurately identify green industry enterprises, provide them with more targeted financing support policies, effectively alleviate the financing difficulties of enterprises, and promote the vigorous development of green industries. This is consistent with the logic proposed by Li et al. (2025) that the data element market promotes green innovation through market mechanisms. Secondly, in the process of vigorously developing the digital economy in cities, the effects of technological innovation and industrial upgrading are intertwined and work together. On the one hand, new technologies keep emerging, opening up new paths for improving energy utilization efficiency. On the other hand, the continuous optimization and upgrading of the industrial structure effectively reduce the carbon emission intensity and strongly drive green development, building a virtuous interaction bridge between the digital economy and green development among cities in the Yangtze River Delta region. As Wu et al. (2025) pointed out, the digital economy can directly reduce carbon intensity by improving energy efficiency and promoting the diffusion of clean production technologies, and further enhance environmental benefits through the indirect path of transforming the industrial structure towards low-energy-consuming service industries. Finally, in terms of the comprehensive drive of digitalization for urban greening. On the one hand, the digital transformation of enterprises promotes green transformation through channels such as enhancing internal capacity building, strengthening external market attention, and attracting government subsidies. On the other hand, digital transformation empowers green innovation, stimulates the innovative vitality of enterprises, and injects new technological sources into green development. At the same time, the development of the digital industry can skillfully improve the situation of capital misallocation and labor misallocation, significantly improve the green total factor productivity, and establish a comprehensive green drive system covering enterprise transformation, innovative development, and optimal allocation of industrial resources in the Yangtze River Delta region, providing solid support for the sustainable development of urban greening.

Second, the continuous deepening of the greening process injects strong impetus into urban digital development. Firstly, the precise implementation of greening policies can not only alleviate the financing constraints of enterprises but also help to promote the greening of output and enhance green consumption preferences, thus driving the digital transformation of enterprises. Secondly, the rise of green industries has opened up new market space for digitalization. Taking the new energy vehicle industry as an example, from the digital simulation in the research and development and design stage, to the intelligent automation in the production and manufacturing process, and then to the Internet of Vehicles service after-sales, all links in the whole industrial chain are inseparable from the support of digital technology, which creates broad business expansion space for digital enterprises and strongly promotes the innovation and application of digital technology. Thirdly, the improvement of the public's green awareness has given rise to green consumption demands, which in turn prompt enterprises to use digital means to optimize the full life cycle management of products. From the traceability management of raw material procurement, the green monitoring of the production process, to the digital operation of product marketing and recycling, enterprises enhance their green competitiveness while promoting the in-depth application of digitalization in all processes of enterprise operation.

**2.2 The Driving Mechanism of the Coordinated Development of Digitalization and Greening**

The coordinated development of digitalization and greening in cities in the Yangtze River Delta region is driven by multiple elements.

First of all, the research of Sun et al. (2025) holds that the policy spillover effect can significantly promote regional synergy. Therefore, policy guidance plays an indispensable and crucial role in the coordinated development of digitalization and greening. Since the 19th National Congress of the Communist Party of China, the coordinated development of digitalization and greening has become one of the core tasks of China's economic transformation. In September 2021, the Central Committee of the Communist Party of China and the State Council issued the "Opinions on Comprehensively and Accurately Implementing the New Development Concept and Doing a Good Job in Carbon Peaking and Carbon Neutrality," clearly proposing to "Promote the in-depth integration of emerging technologies such as the Internet, big data, artificial intelligence, and the fifth-generation mobile communication (5G) with green and low-carbon industries." In October of the same year, the State Council issued the "Action Plan for Carbon Peaking before 2030," further emphasizing the promotion of the integrated development of digitalization, intelligence, and greening in the industrial field and strengthening the energy conservation and carbon reduction of new infrastructure. In February 2023, the "Overall Layout Plan for Digital China Construction" was released, proposing that by 2025, positive progress should be made in the construction of digital ecological civilization, and major breakthroughs should be achieved in digital technology innovation, and it requires the construction of a green and intelligent digital ecological civilization and the acceleration of the coordinated transformation of digitalization and greening. The Yangtze River Delta region actively responds to the national call and continues to innovate and take active actions in policy guidance. In 2024, the Shanghai Municipal Commission of Economy and Informatization and the Shanghai Municipal Development and Reform Commission jointly formulated the "Action Plan for Promoting the Coordinated Transformation and Development of Manufacturing Digitalization and Greening in Shanghai (2024-2027)." The plan fully implements the spirit of the 20th National Congress of the Communist Party of China, adheres to the principle of using digitalization to empower greening and using greening to drive digitalization, and clarifies the goal that by 2027, the coordinated system and mechanism of the two aspects in Shanghai will be more perfect, the integration and innovation system will be basically established, and the development level of intelligence, greening, and integration of the manufacturing industry will be significantly improved. These policies are promoted layer by layer from top to bottom, providing all-round and multi-level protection for the coordinated development of urban digitalization and greening in the Yangtze River Delta region, from the national macro layout to local precise policy implementation.

Secondly, technological innovation constitutes the core driving force for the coordinated development of digitalization and greening. Zhang et al. (2024) proposed that "Technological innovation is the core driving force for the coupling of digitalization and greenization". On the one hand, digital technology innovation provides new tools and platforms for the research, development, promotion, and application of green technologies. For example, with the help of digital simulation technology, researchers can test and optimize new green technologies and products in a virtual environment, greatly shortening the research and development cycle and reducing research and development costs. On the other hand, green technology innovation creates favorable conditions for the sustainable operation of digital technology. For example, the widespread application of new energy reduces the energy consumption and carbon emissions of digital infrastructure such as data centers and communication base stations, making their operation more environmentally friendly. The collaborative innovation of digital technology and green technology forms a powerful joint force, promoting the coordinated development of urban digitalization and greening in the Yangtze River Delta region to continuously reach new heights and helping cities achieve the goals of high-quality and sustainable development.

Finally, information consumption is also an important force promoting the coordinated development of urban digitalization and greening in the Yangtze River Delta region. As a new consumption hotspot, the deepening development of information consumption can promote digital technology innovation, the upgrading of the employment structure, and the public's environmental preferences, thus effectively improving the coordinated performance of urban digitalization and greening. In terms of digital technology innovation, the massive data generated by information consumption provides rich materials for technological research and development. Enterprises can accurately locate the research and development direction of green digital products based on the in-depth mining of consumer preference data, accelerate technological iteration, and achieve a rapid transformation from concept to application, improving the efficiency of digital technology innovation in empowering urban green development. From the perspective of the upgrading of the employment structure, the development of emerging industries driven by information consumption creates a large demand for high-skilled jobs, attracting workers to actively learn digital technology and green knowledge, promoting the transformation of the education and training system towards cultivating compound talents in digitalization and greening, optimizing the human resource structure, and providing solid talent support for the coordinated development of urban digitalization and greening. In terms of shaping the public's environmental preferences, the widespread dissemination of green information in the process of information consumption, such as environmental protection public welfare advertisements and short videos of green life, continuously strengthens the public's environmental protection awareness, guides the public to prefer green products and services in their consumption decisions, forms a strong market demand, and forces enterprises to improve their digital and green production levels, thereby improving the coordinated performance of urban digitalization and greening.

**3 Research Design**

**3.1 Research Methods**

**3.1.1 Entropy Method**

The entropy method is an objective weighting approach that determines indicator weights based on the dispersion degree of the data itself, avoiding interference from subjective factors and being suitable for comprehensive evaluations of multiple indicators. In this study, it is used to calculate the comprehensive scores of the digitalization and greening development of each city, laying the foundation for the subsequent evaluation of coordinated development. The specific steps are as follows:

First, standardize the original data to eliminate dimensional differences.

Secondly, calculate the proportion of the ​th indicator of the ​th city.

Then, calculate the entropy value and the difference coefficient of the ​th indicator.

Next, calculate the weight of each indicator according to the difference coefficient.

Finally, multiply the standardized data by the weights and sum them up to obtain the comprehensive score of the digitalization and greening development of each city.

**3.1.2 Revised Coupling Coordination Degree Model**

The coupling coordination degree model is often used to measure the coordination degree of the interaction between systems. In this study, the revised coupling coordination degree model is adopted to quantitatively evaluate the coordinated development level of the urban digitalization and greening systems in the Yangtze River Delta region. The revised model can more scientifically reflect the coordinated relationship between systems, avoid the problem of inflated coordination degree caused by the excessively low comprehensive development level in the traditional model, and accurately determine the stage and level of the coordinated development of digitalization and greening in cities in the Yangtze River Delta region. The specific calculation formulas are as follows:

(1) Coupling degree C

(2) Coordination degree D

In this study, . Referring to the evaluation criteria in existing literature, the coupling coordination degree index interval is divided into 10 different development stages (see Table 1), so as to accurately judge the stage and level of coordinated development.

**Table 1: Evaluation Criteria for the Coupling Coordination Degree**

|  |  |  |  |
| --- | --- | --- | --- |
| Coupling Coordination Degree Interval | Level | Coupling Coordination Degree Interval | Level |
| 0-0.09 | Extreme imbalance | 0.50-0.59 | Barely coordinated |
| 0.10-0.19 | Severe imbalance | 0.60-0.69 | Primary coordination |
| 0.20-0.29 | Moderate imbalance | 0.70-0.79 | Intermediate coordination |
| 0.30-0.39 | Mild disorder | 0.80-0.89 | Good coordination |
| 0.40-0.49 | On the verge of disorder | 0.90-1.00 | High-quality coordination |

**3.1.3 Kernel Density Estimation Method**

The kernel density estimation method is a non-parametric estimation method that can intuitively display the distribution pattern of data and its dynamic evolution characteristics. In this study, the kernel density estimation method is used to analyze the distribution of the coordinated development level of digitalization and greening in cities in the Yangtze River Delta region. By calculating the kernel density function at different time nodes and drawing the kernel density curve, we can observe the characteristics such as the central tendency, dispersion degree, and multimodal distribution of the coordinated development level of digitalization and greening, and further reveal the dynamic evolution law of the coordinated development of digitalization and greening in cities in the Yangtze River Delta region in the spatial and temporal dimensions. Its calculation formula is as follows:

Among them, the kernel function  used is the Gaussian kernel function:

**3.1.4 Spatial Autocorrelation Analysis**

Spatial autocorrelation analysis is an important method to explore the spatial distribution rules and correlation patterns of the attribute values of spatial data, which can reveal the spatial distribution characteristics of the coordinated development level of digitalization and greening in cities in the Yangtze River Delta region. Based on the assumption that "things that are close in distance are more similar", it judges the aggregation or dispersion trend of the development level according to the spatial proximity. The commonly used global and local Moran's I indices are the key to the analysis. The global Moran's I index measures the degree of spatial autocorrelation of the overall region, and its value is in the range of [-1, 1]. A value greater than 0 indicates a positive correlation, that is, the development levels of cities are similar and clustered; a value less than 0 indicates a negative correlation, showing a dispersed distribution; a value equal to 0 indicates a random distribution. In accordance with spatial econometric conventions, a two-tailed test with P<0.1 was applied to determine the significance of the Global Moran's I (Anselin, 1988). The calculation formula is as follows:

The local Moran's I index is used to identify the local spatial correlation between each city and its surroundings, and can find out regions of different agglomeration types and analyze the local spatial differences. The calculation formula is as follows:

Among them,  is an element of the spatial weight matrix.

**3.1.5 Panel Tobit Model**

The panel Tobit model is suitable for regression analysis when the dependent variable is truncated or restricted. In this study, since the coordinated development level of digitalization and greening in cities has a non-negativity constraint, the panel Tobit model is adopted to analyze the driving factors affecting the coordinated development of digitalization and greening in cities in the Yangtze River Delta region. The model formula is:

Among them,  is the latent variable,  is the matrix of driving factors,  is the individual effect, and . Based on considering the individual effect and time effect, this model can effectively deal with the problem of the restricted dependent variable, accurately estimate the influence direction and degree of each driving factor on the coordinated development of digitalization and greening in cities, and thus provide a reliable basis for revealing the internal driving mechanism of the coordinated development of digitalization and greening.

**3.2 Data Sources and Construction of the Index System**

This paper selects the data of 41 cities in the Yangtze River Delta region from 2014 to 2023 as the research sample. The sample data mainly come from the *China Statistical Yearbook*, *China Urban Statistical Yearbook*, *China Science and Technology Statistical Yearbook*, *China Urban Construction Statistical Yearbook*, *China Environmental Statistical Yearbook*, as well as the statistical yearbooks of various provinces (regions, municipalities) and the statistical bulletins on the national economic and social development of various provinces (regions, municipalities). For the missing data, this paper uses the linear interpolation method to fill them. Referring to relevant literature and combining with the characteristics of regional development, this paper constructs a comprehensive index system for the coordinated development of urban digitalization and greening in the Yangtze River Delta region from two systems: the digital development level and the green development level. Among them, the digital development level system is divided into four dimensions: digital technology, digital infrastructure, digital industrialization, and industrial digitalization; the green development level system is divided into four dimensions: green growth, green welfare, green environment, and green governance. On this basis, fully considering the relevant principles of index selection, the comprehensive evaluation index system for the coordinated development of urban digitalization and greening in the Yangtze River Delta region is determined, as shown in Table 2.

**Table 2: Comprehensive Evaluation Index System for the Development Levels of Urban Digitalization and Greening in the Yangtze River Delta Region**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System layer | Target layer | Criterion layer | Indicator layer | Attribute |
| The level of digital development | Digital technology | Proportion of fiscal expenditure on science and technology | The proportion of expenditure on science and technology in the general budget expenditure of local finance | + |
| The intensity of R&D investment | The ratio of internal expenditure on R&D to regional GDP | + |
| Digital infrastructure | Broadband Internet penetration rate | The ratio of the total number of Internet broadband access users to the total urban population | + |
| The penetration rate of mobile Internet | The ratio of mobile phone users to the total urban population | + |
| Digital industrialization | The development of the information industry | The proportion of employees in the information transmission, software and information technology services industry | + |
| The development of the telecommunications industry | Per capita telecommunications business revenue | + |
| Industrial digitalization | Digital Inclusive Finance | Peking University Digital Inclusive Finance Index | + |
| The level of green development | Green growth | Per capita GDP | The ratio of GDP to the total urban population | + |
| The proportion of the tertiary industry | The ratio of the added value of the tertiary industry to GDP | + |
| SO2 emissions per unit GDP | The ratio of industrial SO2 emissions to GDP | - |
| Wastewater discharge per unit of GDP | The ratio of industrial wastewater discharge to GDP | - |
| Green welfare | Per capita retail sales of consumer goods in society | The ratio of the total retail sales of consumer goods to the total urban population | + |
| Per capita disposable income of urban residents | The ratio of disposable income of urban households to the number of household members | + |
| The number of doctors per ten thousand people | The ratio of the number of doctors to the total population of the city | + |
| Green environment | Urban green coverage rate | Green area/Total urban area | + |
| Per capita wastewater discharge | Industrial wastewater discharge volume/total urban population | - |
| Per capita SO2 emissions | Industrial SO2 emissions/Total urban population | - |
| Green governance | Sewage treatment rate | The volume of treated sewage/the total volume of sewage discharged | + |
| The harmless treatment rate of domestic waste | The amount of harmless treatment of garbage/the total amount of garbage | + |

**4 Empirical Analysis**

**4.1 Analysis of the Temporal Characteristics of the Coordinated Development of Digitalization and Greening**

**4.1.1 Analysis of the Overall Coordinated Development Level in the Yangtze River Delta Region**

Based on the comprehensive evaluation index system of the development levels of digitalization and greening constructed in this paper, the entropy method is used to calculate the comprehensive evaluation indices of the two systems of digitalization and greening in the Yangtze River Delta region from 2014 to 2023. Furthermore, the revised coupling coordination degree model is adopted to calculate the coupling coordination degree between the two systems to reflect the coordinated development level of digitalization and greening. The specific results are shown in Table 3. The analysis results show that the coordinated development level of the Yangtze River Delta region generally shows a trend of gradual improvement from 2014 to 2023. Specifically, the coordinated development level of digitalization and greening in the Yangtze River Delta region was relatively low in 2014, with the coupling coordination degree being only 0.2406, which belongs to the moderately disordered state. By 2023, the coupling coordination degree increased to 0.3858, which belongs to the mildly disordered state. In terms of stages, it was in the moderately disordered stage before 2018 and entered the mildly disordered stage after 2018, but the growth rate slowed down, and it was still lower than the critical value of "on the verge of disorder" of 0.4 in 2023. In addition, the overall digital development level in the Yangtze River Delta region has always lagged behind the green development level during the period from 2014 to 2023. The above research results indicate that the Yangtze River Delta region has achieved certain results in promoting the coordinated development of digitalization and greening during the research period, but there is still great potential for improvement as a whole, and there are problems of unbalanced development in the process of promoting the coordination between digitalization and greening.

**Table 3: Overall Characteristics of the Coordinated Development of Digitalization and Greening in the Yangtze River Delta Region from 2014 to 2023**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Digital development level U1 | The level of green development U2 | Coupling coordination degree D | Coupling coordination level |
| 2014 | 0.2445 | 0.2683 | 0.2406 | Moderate imbalance |
| 2015 | 0.2610 | 0.2892 | 0.2501 | Moderate imbalance |
| 2016 | 0.2887 | 0.3194 | 0.2642 | Moderate imbalance |
| 2017 | 0.3197 | 0.3457 | 0.2813 | Moderate imbalance |
| 2018 | 0.3420 | 0.3705 | 0.2978 | Mild disorder |
| 2019 | 0.3559 | 0.4075 | 0.3162 | Mild disorder |
| 2020 | 0.3724 | 0.4166 | 0.3231 | Mild disorder |
| 2021 | 0.4032 | 0.4515 | 0.3505 | Mild disorder |
| 2022 | 0.4137 | 0.4668 | 0.3622 | Mild disorder |
| 2023 | 0.4368 | 0.4917 | 0.3858 | Mild disorder |

**4.1.2 Analysis of the Coordinated Development Level at the Provincial Level**

From the perspective of the provincial level, from 2014 to 2023, the average level of the coordinated development of digitalization and greening in the three main provinces (Anhui Province, Zhejiang Province, and Jiangsu Province) in the Yangtze River Delta region shows an overall upward trend, but their respective development trajectories exhibit obvious differences. As shown in Figure 1, from the perspective of individual provinces, the coordinated development level of digitalization and greening in Anhui Province has steadily increased during these ten years. In 2014, the value of its coordinated development level was 0.2147, and it has increased year by year, reaching 0.3153 in 2023. This continuous growth trend indicates that the strategies and measures taken by Anhui Province in promoting the coordination between digitalization and greening have achieved positive results. It may continuously exert efforts in aspects such as the digital technology assisting the development of green industries and the integration of green technology into the construction of digital infrastructure, gradually deepening the degree of coordinated development between the two. In 2014, the coordinated development level value of Jiangsu Province was 0.2413, and then it grew relatively rapidly, climbing to 0.4297 in 2023. As an economically strong province, Jiangsu Province has a solid industrial foundation and strong scientific research strength. In the process of the coordinated development of digitalization and greening, it can fully utilize its own advantages, increase investment in relevant technology research and development, promote industrial upgrading, and facilitate the deep integration of the digital economy and green development, thus significantly improving the level of coordinated development. In 2014, the coordinated development level value of Zhejiang Province was 0.2695. It grew relatively steadily in the early stage, reaching 0.3546 in 2019. Although there was a slight decline in 2020, it rebounded rapidly afterward, reaching 0.4122 in 2023. This may be closely related to Zhejiang Province's active promotion of the innovative development of the digital economy and the creation of a green ecological industrial system. During the development process, it may face some problems such as industrial structure adjustment or technical application bottlenecks, resulting in minor fluctuations in the development curve, but it still maintains an overall upward trend. By comparing the three provinces, in 2014, the coordinated development level of Zhejiang Province was relatively the highest, and that of Anhui Province was the lowest. In the subsequent development, Jiangsu Province has a relatively fast growth rate, gradually narrowing the gap with Zhejiang Province, and continuously widening the gap with Anhui Province. This difference reflects the differences in industrial structure, policy orientation, and scientific and technological innovation capabilities among the three provinces. In terms of industrial structure, the high-tech industries and emerging industries in Jiangsu and Zhejiang account for a relatively high proportion, which is more conducive to the coordinated development of digitalization and greening. In terms of policy orientation, different provinces have different support focuses and intensities for the digital economy and green development. In terms of scientific and technological innovation capabilities, provinces with more abundant scientific and technological innovation resources can better promote the integrated innovation of the two.

**Figure 1 The Coordinated Development Level of Digitalization and Greening at the Provincial Level from 2014 to 2023**

**4.1.3 Analysis of the Coordinated Development Level at the Urban Level**

Exploring the coordinated development level of digitalization and greening in the Yangtze River Delta region at the urban level can provide a basis for accurately positioning the development stage of cities within the region and formulating differentiated strategies. Judging from the coupling coordination level and grade of digitalization and greening in various cities in the Yangtze River Delta region in 2023 (see Table 4), there are significant differences among cities in the region.

The unbalanced development of cities in Anhui Province is obvious. The coupling coordination degree of Hefei is 0.5184, in a barely coordinated state. As the provincial capital, Hefei has advantages in scientific and technological innovation, industrial agglomeration, and policy resources, which can effectively promote the integration of digitalization and greening. Most cities in the province are in a disordered state. The coupling coordination degrees of many cities such as Anqing, Bozhou, and Chuzhou are in the range of 0.24-0.32, mostly moderately or mildly disordered. This may be because the industrial structure of some cities is relatively traditional, mainly relying on resource-dependent or labor-intensive industries, and there are great difficulties in digital transformation and green upgrading. There are also deficiencies in technological innovation investment and talent attraction, restricting the coordinated development of the two.

The coordinated development levels of cities in Jiangsu Province are clearly stratified. The coupling coordination degree of Nanjing reaches 0.7998, at a good coordination level. As the political, economic, and cultural center of Jiangsu, Nanjing has rich scientific research resources, a complete industrial system, and strong economic strength, leading the way in the integration of the digital economy and green development. Cities such as Changzhou, Suzhou, and Wuxi are in a barely coordinated state. These cities are economically developed with a solid industrial foundation and have the conditions to promote the coordinated development of digitalization and greening, but there is still room for improvement in the depth and breadth of coordinated development. Some cities such as Huai'an and Lianyungang are in a mildly disordered state, indicating that there are some restrictive factors in the process of the coordinated development of digitalization and greening, such as slow industrial structure adjustment and low application degree of digital technology.

The urban development in Zhejiang Province shows gradient differences. The coupling coordination degree of Hangzhou is 0.6979, reaching an intermediate coordination level. As a frontier city for the development of the digital economy, Hangzhou has outstanding advantages in fields such as e-commerce and Internet technology, and pays attention to ecological environment protection, creating good conditions for the coordinated development of digitalization and greening. Cities such as Ningbo and Huzhou are on the verge of disorder. These cities have distinctive industrial development characteristics, but in the process of the coordinated development of digitalization and greening, it is necessary to further optimize the industrial layout and increase innovation investment. Most cities such as Jinhua and Lishui are in a mildly disordered state, reflecting that these cities need to accelerate their pace and make up for the development shortcomings in terms of coordinated development.

As a municipality directly under the central government, Shanghai has a coupling coordination degree of 0.6519, in a primary coordination state. Shanghai has the resource advantages of an international metropolis and has a certain foundation in digital technology innovation and the promotion of the concept of green development. However, due to its large urban scale and diverse development needs, in the process of achieving in-depth coordination between digitalization and greening, it also faces challenges such as resource allocation and regional coordination.

**Table 4 The Coupling Coordination Level and Grade of Digitalization and Greening in Various Cities in the Yangtze River Delta Region in 2023**

|  |  |  |  |
| --- | --- | --- | --- |
| Province or Municipality directly under the Central Government | City | Coupling coordination degree | Coupling coordination level |
| Anhui Province | Anqing | 0.2690 | Moderate imbalance |
| Bengbu | 0.3047 | Mild disorder |
| Bozhou | 0.2485 | Moderate imbalance |
| Chizhou | 0.3145 | Mild disorder |
| Chuzhou | 0.2748 | Moderate imbalance |
| Fuyang | 0.2573 | Moderate imbalance |
| Hefei | 0.5184 | Barely coordinated |
| Huaibei | 0.3013 | Mild disorder |
| Huainan | 0.2817 | Moderate imbalance |
| Huangshan | 0.3226 | Mild disorder |
| Lu 'an | 0.2716 | Moderate imbalance |
| Ma 'anshan | 0.3577 | Mild disorder |
| Suzhou | 0.2500 | Moderate imbalance |
| Tongling | 0.3309 | Mild disorder |
| Wuhu | 0.4261 | On the verge of disorder |
| Xuancheng | 0.3161 | Mild disorder |
| Jiangsu Province | Changzhou | 0.5039 | Barely coordinated |
| Huai 'an | 0.3390 | Mild disorder |
| Lianyungang | 0.3070 | Mild disorder |
| Nanjing | 0.7998 | Good coordination |
| Nantong | 0.3904 | Mild disorder |
| Suzhou | 0.5515 | Barely coordinated |
| Suqian | 0.3000 | Mild disorder |
| Taizhou | 0.3639 | Mild disorder |
| Wuxi | 0.5238 | Barely coordinated |
| Xuzhou | 0.3382 | Mild disorder |
| Yancheng | 0.3730 | Mild disorder |
| Yangzhou | 0.3630 | Mild disorder |
| Zhenjiang | 0.4327 | On the verge of disorder |
| Zhejiang Province | Hangzhou | 0.6979 | Intermediate coordination |
| Huzhou | 0.4075 | On the verge of disorder |
| Jiaxing | 0.3540 | Mild disorder |
| Jinhua | 0.3033 | Mild disorder |
| Lishui | 0.3409 | Mild disorder |
| Ningbo | 0.4783 | On the verge of disorder |
| Quzhou | 0.3585 | Mild disorder |
| Shaoxing | 0.4069 | On the verge of disorder |
| Taizhou | 0.3557 | Mild disorder |
| Wenzhou | 0.3705 | Mild disorder |
| Zhoushan | 0.4606 | On the verge of disorder |
| Shanghai City | Shanghai | 0.6519 | Primary coordination |

From the distribution of the coupling coordination grades of cities in the Yangtze River Delta region from 2014 to 2023 (as shown in Figure 2), an overall positive trend can be observed. The number of cities in a moderately disordered state has continuously decreased from 36 in 2014 to 7 in 2023, indicating that the overall coordinated development level of the Yangtze River Delta region is gradually improving, and more and more cities have got rid of the low-level disordered state. The number of cities in a mildly disordered state showed an upward trend from 2014 to 2022, and remained at 21 in 2023. This shows that although some cities have made progress, they still have not reached a high level of coordinated development. The numbers of cities on the verge of disorder, in a barely coordinated state, in a primary coordination state, in an intermediate coordination state, and in a good coordination state generally show an upward trend, reflecting that cities in the Yangtze River Delta region have continuously made progress in the coordinated development of digitalization and greening, and the quality and level of coordinated development are gradually improving. However, the problem of unbalanced development among cities in the region still exists. In the future, it is necessary to strengthen regional cooperation, promote the complementary advantages among cities, and push the overall coordinated development level to a new height.

**Figure 2 Distribution of the Coupling Coordination Grades of Cities in the Yangtze River Delta Region from 2014 to 2023**

**4.2 Analysis of the Dynamic Evolution of the Coordinated Development of Digitalization and Greening Based on Kernel Density**

Figure 3 shows the kernel density estimation of the coupling coordination degree, which can intuitively reflect the distribution characteristics and dynamic evolution trend of the coordinated development level of digitalization and greening of 41 cities in the Yangtze River Delta region in different years. Firstly, from the perspective of the dynamic change of the curve, the overall curve moves to the right, and the peak of the curve also gradually shifts to the right. This means that with the passage of time, the overall level of the coupling coordination degree is improving, indicating that the coordinated development of urban digitalization and greening in the Yangtze River Delta region has made positive progress, and more cities are moving towards a higher level of coordinated development. Secondly, in terms of the shape of the curve, the kernel density curves of each year show a right-tail phenomenon, and the main peak appears at the place with a low coupling coordination degree, which shows that there are far more cities with a low coupling coordination degree than those with a high coupling coordination degree. Finally, the width of the wave gradually becomes wider, indicating that the absolute difference in the coupling coordination degree of the dualization of cities in the Yangtze River Delta region is gradually increasing.



**Figure 3 Kernel Density Estimation of the Coupling Coordination Degree**

**4.3 Analysis of the Spatial Evolution Characteristics of the Coordinated Development of Digitalization and Greening**

**4.3.1 Global Spatial Autocorrelation Test**

The global spatial autocorrelation measures the spatial correlation of the coordinated development level of digitalization and greening among cities in the Yangtze River Delta region through the Moran's I value. Judging from the Moran's I value of the global autocorrelation and its test results in Table 5, there is an obvious spatial autocorrelation in the coordinated development level of this region from 2014 to 2023.

In 2014, the Moran's I value is 0.284 and is significant at the 5% level, and the Z value is 3.145. This indicates that there is a significant positive spatial correlation in the coordinated development of digitalization and greening among cities in the Yangtze River Delta region, that is, cities with a high level of coordinated development tend to be adjacent to cities with a high level of coordinated development, and cities with a low level of coordinated development also tend to agglomerate together. This positive correlation reflects that there is a certain spatial agglomeration effect among cities in the region. This may be because cities with close geographical locations have relatively close economic connections, industrial cooperation, policy transmission, etc., resulting in an agglomerated distribution of the coordinated development level in space.

From 2015 to 2018, the Moran's I value fluctuates between 0.230 and 0.283 and is significant at the 5% level, and the Z value also remains within a certain range. Although the value has decreased, it still indicates that the positive spatial correlation continues to exist, but the degree of agglomeration is weaker than that in 2014. This may be because during this stage, some cities have begun to explore differentiated development paths, and the spatial pattern of coordinated development within the region has gradually changed, but the overall agglomeration trend is still obvious.

From 2019 to 2023, the Moran's I value further decreases, ranging from 0.171 to 0.198 and is significant at the 10% level. This means that the spatial agglomeration effect of the coordinated development of digitalization and greening among cities in the Yangtze River Delta region is gradually weakening, and the spatial distribution of the coordinated development level among cities has begun to become relatively dispersed. The possible reason is that with the adjustment of regional development policies, the diffusion of emerging technologies, and the transformation of the urban self-development strategy, some cities with a low level of coordinated development have begun to make progress, breaking the original agglomeration pattern and making the spatial correlation among cities in the region more complex.

Overall, the spatial agglomeration effect of the coordinated development of digitalization and greenization in the Yangtze River Delta shows a fluctuating weakening trend (Moran's I decreased from 0.284 in 2014 to 0.188 in 2023, Table 5). This is consistent with the observation of Xie et al. (2024) that "the radiation effect of core cities gradually equalizes with the diffusion of technology".

**Table 5 Moran's I Value of Global Autocorrelation and Its Test Results**

|  |  |  |
| --- | --- | --- |
| Year | Moran’s I | Z-score |
| 2014 | 0.284\*\* | 3.145 |
| 2015 | 0.283\*\* | 3.169 |
| 2016 | 0.234\*\* | 2.664 |
| 2017 | 0.230\*\* | 2.641 |
| 2018 | 0.230\*\* | 2.620 |
| 2019 | 0.192\* | 2.235 |
| 2020 | 0.195\* | 2.269 |
| 2021 | 0.198\* | 2.290 |
| 2022 | 0.171\* | 2.017 |
| 2023 | 0.188\* | 2.182 |

**Note: \*, \*\*, \*\*\* indicate significance at the 10%, 5% and 1% levels respectively.**

**4.3.2 Local Spatial Autocorrelation Test**

In order to deeply explore the agglomeration evolution trend of cities in the Yangtze River Delta region in the process of the coordinated development of digitalization and greening, this study conducts a local spatial autocorrelation analysis and draws Moran scatter plots for 2014 and 2023. The specific results are shown in Figure 4.

It can be found that in the agglomeration pattern of the coordinated development of digitalization and greening among cities in the Yangtze River Delta region, the "high-high" agglomeration mode in the first quadrant and the "low-low" agglomeration mode in the third quadrant are dominant. This agglomeration pattern is consistent with the results of the global autocorrelation test, fully indicating that there is a positive correlation among cities in terms of the coordinated development level of digitalization and greening.

However, there are still some cities in the second quadrant and the fourth quadrant. For cities in the second quadrant, their own coordinated development level of digitalization and greening is relatively low, but there are cities with a high coordinated development level around them. Such cities should actively create conditions to undertake the spillover effects of high-level cities around them in terms of technology, industry, talents, etc., so as to promote the improvement of their own coordinated development level. For cities in the fourth quadrant, they have a relatively high coordinated development level of digitalization and greening, but the coordinated development levels of surrounding cities are low. These cities need to take the initiative to give full play to their exemplary and leading roles, and drive the progress of surrounding cities with low coordinated development levels in the coordinated development of digitalization and greening through means such as technology output, industrial cooperation, and experience sharing.

From the perspective of development evolution, by comparing the Moran scatter plots of 2014 and 2023, it can be found that the number of cities in the "high-high" agglomeration area in 2023 has decreased. This change implies that in the coordinated development of digitalization and greening among cities in the Yangtze River Delta region, the degree of spatial agglomeration is gradually changing, and the coordinated development pattern among cities is evolving towards a more diversified and balanced direction.



**Figure 4: Moran Scatter Plots in 2014 (Left) and 2023 (Right)**

**4.4 Analysis of Influencing Factors**

**4.4.1 Variable Selection**

In this study, the coupling coordination degree (D) is selected as the dependent variable, which is calculated through the revised coupling coordination degree model and can accurately measure the coordinated development level of urban digitalization and greening in the Yangtze River Delta region. In terms of independent variables, the urbanization level (UR) is represented by the urbanization rate, reflecting the impact of the urbanization process of the population on coordinated development; the scientific and technological innovation level (TS) is measured by the number of patents applied in the current year, reflecting the role of the regional innovation ability; the industrial structure optimization level (IS) is characterized by the proportion of the added value of the tertiary industry in GDP, which is used to explore the impact of industrial structure adjustment on coordinated development. These variables cover the key factors that may affect the coordinated development of digitalization and greening from different dimensions, laying a solid foundation for the subsequent analysis.

**Table 6 Summary of Variables in the Tobit Model**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable type | Variable name | Variable symbol | Variable description | Variable unit |
| Dependent variable | Coupling coordination degree | D | Calculated through the coupling coordination degree model |  |
| Independent variable | Urbanization level | UR | Urbanization rate | % |
| Level of scientific and technological innovation | TS | The number of patents applied for that year | A thousand pieces |
| The level of industrial structure optimization | IS | The proportion of the added value of the tertiary industry in GDP | % |

**4.4.2 Result Analysis**

As shown in Table 7, the regression results of the Tobit panel model indicate that the urbanization level (UR), scientific and technological innovation level (TS), and industrial structure optimization level (IS) all have a positive impact on the coordinated development level of urban digitalization and greening in the Yangtze River Delta region at a significance level of 1%. Among them, the regression coefficient of the urbanization level is positive, indicating that the advancement of the urbanization process helps to promote the coordinated development of digitalization and greening. With the improvement of the urbanization level, urban infrastructure is continuously improved, and the industrial agglomeration effect is enhanced, creating favorable conditions for the integration of digital technology and green industries, and attracting more resources to be invested in the field of coordinated development of digitalization and greening. The scientific and technological innovation level has a significant positive effect on coordinated development. The increase in the number of patents means more innovation achievements, promoting the innovation of digital technology and the research and development of green technology, accelerating the application of technology in industries, and thus improving the level of coordinated development. The optimization of the industrial structure also plays an important role. The increase in the proportion of the tertiary industry upgrades the industrial structure in a greener and more innovative direction, reduces the proportion of high-energy-consuming and high-pollution industries, promotes the deep integration of the digital economy and green industries, and effectively promotes the coordinated development of digitalization and greening.

**Table 7 Regression Model of the Tobit Panel Model**

|  |  |  |  |
| --- | --- | --- | --- |
|  | （1） | （2） | （3） |
| UR | 0.0091\*\*\*（19.55） | 0.0087\*\*\*（18.06） | 0.0071\*\*\*（12.98） |
| TS |  | 0.0026\*\*\*（7.66） | 0.0023\*\*\*（6.66） |
| IS |  |  | 0.0025\*\*\*（5.37） |
| Constant term | -0.2787\*\*\*（-8.94） | -0.2757\*\*\*（-8.51） | -0.3006\*\*\*（-9.61） |
| N | 41 | 41 | 41 |
| Prob>chi2 | 0.0000 | 0.0000 | 0.0000 |

**Note: \*, \*\*, \*\*\* indicate significance at the 10%, 5% and 1% levels respectively; the values in parentheses are Z statistical values, and the same applies hereinafter.**

**4.4.3 Model Robustness Analysis**

In order to verify the reliability of the regression results, this study conducts a robustness test by replacing the explained variable. As shown in Table 8, after replacing the dependent variable with the uncorrected coupling coordination degree, the urbanization level (UR), scientific and technological innovation level (TS), and industrial structure optimization level (IS) still have a positive impact on the coupling coordination degree at a significance level of 1%. Moreover, although the regression coefficients of each variable have changed, the signs and significance have not changed. This fully demonstrates that the research results are robust and reliable, and the above variables are indeed the key factors affecting the coordinated development of urban digitalization and greening in the Yangtze River Delta region, further enhancing the credibility of the research conclusions.

**Table 8 Results of the Robustness Test**

|  |  |  |  |
| --- | --- | --- | --- |
|  | （1） | （2） | （3） |
| UR | 0.0366\*\*\*（22.76） | 0.0358\*\*\*（22.94） | 0.0289\*\*\*（16.75） |
| TS |  | 0.0078\*\*\*（6.83） | 0.0062\*\*\*（5.65） |
| IS |  |  | 0.0116\*\*\*（7.76） |
| Constant term | -1.8434\*\*\*（-17.04） | -1.8724\*\*\*（-17.41） | -2.009\*\*\*（-19.89） |
| N | 41 | 41 | 41 |
| Prob>chi2 | 0.0000 | 0.0000 | 0.0000 |

**4.4.4 Regional Heterogeneity Analysis**

Considering the differences in the development of cities in the Yangtze River Delta region, this study conducts a regional heterogeneity analysis. According to the central region divided in the Outline of the Integrated Development Plan of the Yangtze River Delta region, the 27 cities in the central area of the Yangtze River Delta are regarded as central cities, and the remaining cities are regarded as peripheral cities. As shown in Table 9, the urbanization level has a significant positive impact on the coordinated development of digitalization and greening in both central cities and peripheral cities, but the impact on central cities is greater. In the process of urbanization, central cities can make better use of the advantages of urbanization to promote the coordinated development of digitalization and greening by virtue of more complete infrastructure, richer resources and stronger agglomeration ability. The scientific and technological innovation level has a significant positive impact on the coordinated development of digitalization and greening in central cities, but has no significant impact on peripheral cities. Central cities are rich in scientific research resources and have a strong innovation atmosphere, making it easier to transform scientific and technological innovation achievements into actual productivity and promote the coordinated development of digitalization and greening. Peripheral cities are relatively weak in scientific and technological talents, innovation investment, etc., and it is difficult to give full play to the role of scientific and technological innovation. The optimization level of the industrial structure has a significant positive impact on the coordinated development of digitalization and greening in both central cities and peripheral cities, but the impact coefficient of central cities is higher. Central cities have a solid industrial foundation. In the process of industrial structure optimization, they can more quickly achieve the deep integration of the digital economy and green industries and improve the level of coordinated development. The industrial structure of peripheral cities is relatively single, and it is more difficult to optimize, and the promoting effect on coordinated development is relatively weak. This shows that in the process of the coordinated development of digitalization and greening in different regions, the roles of influencing factors are different, and policy formulation should fully consider regional characteristics and implement differentiated strategies.

**Table 9 Results of the Heterogeneity Analysis**

|  |  |  |
| --- | --- | --- |
| Variable | Central cities | Peripheral cities |
| UR | 0.0076\*\*\*（11.25） | 0.0063\*\*\*（8.88） |
| TS | 0.0021\*\*\*（5.27） | -0.0008（-0.72） |
| IS | 0.0035\*\*\*（4.42） | 0.0015\*\*\*（3.93） |
| Constant term | -0.4032\*\*\*（-9.21） | -0.1748\*\*\*（-5.35） |
| N | 27 | 14 |
| Prob>chi2 | 0.0000 | 0.0000 |

**5 Conclusions and Policy Recommendations**

**5.1 Research Conclusions**

This study conducts an in-depth exploration of the coordinated development of urban digitalization and greening in the Yangtze River Delta region. By constructing a comprehensive index system and using various empirical analysis methods, the following main conclusions are drawn:

(1) During the period from 2014 to 2023, the coordinated development level of digitalization and greening in the Yangtze River Delta region has generally shown a gradually improving trend. It has improved from a moderately disordered state in 2014 to a mildly disordered state in 2023, but it is still lower than the critical value of "on the verge of disorder", and there is huge potential for overall improvement. Moreover, during these ten years, the development level of digitalization has always lagged behind that of greening, reflecting the imbalance in the coordinated promotion process.

(2) At the provincial level, although the average coordinated development level of digitalization and greening in Anhui Province, Zhejiang Province, and Jiangsu Province has shown an upward trend, their development trajectories are different. Anhui Province has steadily improved, Jiangsu Province has grown rapidly, and Zhejiang Province has shown stable growth in the early stage, and continued to recover after slight fluctuations during the period. At the urban level, there are obvious differences in the coordinated development level among cities in the region. For example, cities such as Hefei, Nanjing, and Hangzhou, relying on their own advantages, have a relatively high level of coordinated development; while some cities are still in a disordered state due to factors such as industrial structure, technological innovation, and talent attraction.

(3) The kernel density analysis shows that the coordinated development level of urban digitalization and greening in the Yangtze River Delta region has been improved as a whole. Cities with a low degree of coordination account for a large proportion, and the absolute difference is gradually increasing. The spatial autocorrelation analysis shows that there is an obvious spatial autocorrelation in the regional coordinated development level. From 2014 to 2023, the spatial agglomeration effect first weakened and then strengthened, and the coordinated development pattern among cities gradually evolved towards diversification and balance. The "high-high" and "low-low" agglomeration modes are dominant, and some cities need to leverage the advantages of their surroundings or play a leading role to improve the level of coordination.

(4) The urbanization level, scientific and technological innovation level, and industrial structure optimization level all have a significant positive impact on the coordinated development of urban digitalization and greening in the Yangtze River Delta region. The regional heterogeneity analysis finds that the urbanization level and industrial structure optimization level both promote the coordinated development of central cities and peripheral cities, but have a greater impact on central cities; the scientific and technological innovation level has a significant promoting effect on the coordinated development of central cities, but has no significant impact on peripheral cities.

**5.2 Policy Recommendations**

Based on the above research conclusions, in order to further promote the coordinated development of urban digitalization and greening in the Yangtze River Delta region, the following policy recommendations are put forward:

First, it is necessary to strengthen top-level design, formulate unified and targeted regional coordinated development policies, and increase support for the coordinated development of digitalization and greening. In response to the problem of lagging digital development, special funds should be set up to encourage the research, development and application of digital technologies, and promote the digital transformation of traditional industries. At the same time, pay attention to the unbalanced development within the region, give policy preferences to cities with a low level of coordinated development, guide the rational flow of resources, and promote balanced regional development.

Second, continuous investment in scientific and technological innovation should be increased, scientific and technological innovation platforms should be built, and the research, development cooperation and achievement transformation of digital technologies and green technologies should be promoted. Universities, scientific research institutions and enterprises should be encouraged to jointly carry out research projects, and the innovation and application of green digital technologies should be accelerated.

Third, the pace of industrial structure adjustment should be accelerated, the proportion of the tertiary industry should be increased, and new business forms and models of the integration of the digital economy and green industries should be cultivated and strengthened. Traditional industries should be guided to transform in the direction of greening and digitalization, backward production capacity should be eliminated, and the high-end development of industries should be promoted. For example, industries such as green intelligent manufacturing and green e-commerce should be developed to promote the in-depth application of digital technologies in various links of green industries and achieve coordinated industrial development.

Fourth, cooperation and communication among cities in the Yangtze River Delta region should be deepened, a normalized cooperation mechanism should be established, and the free flow of factors such as technology, talent, and capital should be promoted. Central cities should play a radiating and leading role, and help peripheral cities improve their coordinated development level through means such as industrial transfer and technology output; peripheral cities should actively undertake the spillover effect of central cities, strengthen their own capacity building, and achieve complementary advantages and common development among cities in the region.

Finally, in view of regional heterogeneity, classified policies need to be strengthened. For central cities (such as Shanghai and Hangzhou), efforts should be focused on the deep integration of digital technology and green industries, drawing on the linkage mechanism between the data element market and green finance proposed by Li et al. (2025), for instance, relying on the Yangtze River Delta Data Exchange to promote carbon data trading. For peripheral cities (such as Anhui and northern Jiangsu), it is necessary to increase investment in digital infrastructure. Referring to the conclusion of Fang et al. (2025) that "non-low-carbon pilot cities need digital empowerment even more", special funds should be used to guide the digital transformation of traditional industries and narrow the "green digital gap" with core areas. Furthermore, it is necessary to optimize the policy coordination mechanism to avoid excessive administrative intervention that supholds market vitality. For instance, the government's focus on low-carbon development should grasp a moderate boundary to prevent the suppression of enterprises' digital investment due to strict environmental target constraints. The "U-shaped curve" rule proposed by Yang et al. (2024) can be referred to. Reserve a buffer period for industrial transformation in policy design.

**Declaration**

We confirm that this manuscript has not been published elsewhere and is not under consideration by another journal. All authors have approved the manuscript and agree with submission to ***Asian Journal of Economics, Business and Accounting***. The authors have no conflicts of interest to declare.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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