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# Research on the Development Level, Spatiotemporal Evolution Characteristics, and Sustainable Development Path of the Digital Business Environment

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**Abstract:** This paper aims to measure the development level and dynamic evolutionary characteristics of the digital business environment, and explore its sustainable development strategies, which would contribute to the sustainable development of the digital economy. This study employs ecosystem theory to construct evaluation indicators for the digital business environment. Utilizing panel data from 272 cities in China between 2011 and 2020, the study applies the entropy weight method to measure the development level of China's digital business environment. It further examines the spatiotemporal evolution characteristics and sustainable development strategy of the digital business environment using methods such as kernel density estimation, Markov chain analysis, Moran's I index analysis, Dagum's Gini coefficient calculation and decomposition, and fsQCA analysis. The results indicate that the digital business environment steadily increased during the study period. Furthermore, there has been a gradual acceleration in the upward trend since 2017, with a higher probability of transition from cities with lower levels of the digital business environment to neighboring cities with higher levels. Cities with higher development levels are experiencing an increasing gap compared to the average level. There is a significant spatial positive autocorrelation in the efficiency of the digital business environment among Chinese cities, exhibiting a distribution pattern of "high-high" and "low-low" in spatial terms. Dagum's Gini coefficient reveals that the regional differences serve as the primary source of spatial distribution disparities in the digital business environment, and there are four configuration paths to promote a sustainable digital business environment. Moreover, our findings have implications for policy makers, such as increasing investment in digital infrastructure, leveraging the spatial spillover effects of regions with a high level of digital business environment development, and enhancing the diffusion mechanism for optimizing the digital business environment.

**Keywords:** digital business environment; ecosystem theory; fsQCA; spatial-temporal evolution; sustainable development



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## 1. Introduction

In recent years, the digital economy has experienced robust growth [1]. The combined size of the digital economy in 47 major economies worldwide exceeded USD 38.1 trillion in 2021, with China's digital economy also experiencing rapid expansion, reaching a scale of RMB 45.5 trillion in the same year, and ranking second globally [2]. In the era of the digital economy, the "digital space" continues to expand, and the effective use of digital technologies [3–6] enables the efficient exchange of traditional physical goods to digital goods and services, digital knowledge, and information [7,8]. The coupling and interaction between the "digital space" and the traditional "physical space" have become increasingly interconnected [9]. The digital economy has accelerated the transformation and upgrading

of the industrial structure [10], and the complex relationships and interactions among digitalized production factors, production systems, business models, and organizational systems [11] have formed a new economic model [12]. Digital economy agglomeration plays a significant role in supporting and leading sustainable economic development [13] through energy consumption, environmental pollution [14], economic growth, human capital, industrial structure, and technological progress [15]. However, the contradiction between the outdated and non-digital business environment and the rapidly developing digital economy at the current stage is irreconcilable [16], thus presenting new requirements for the business environment and making it imperative to construct a sound digital business environment [17].

Since the World Bank introduced the concept of "digital business indicators" in 2017 [18], creating a fair, open, and non-discriminatory digital business environment in various international forums has been an urgent issue [19]. Many countries attach importance to the development of the digital economy and are committed to creating a good environment for the development of the digital economy. For instance, China's "14th Five-Year Plan for Digital Economy Development" further emphasizes the need to promote the "further optimization of the digital business environment". It is evident that accelerating the construction and optimization of the digital business environment has become a major theoretical and practical issue in the world's current economic and social development.

In the context of economic transition, the optimization of the business environment helps to stimulate the vitality of enterprises [20] and, in particular, to promote the sustainable development of small and medium-sized enterprises (SMEs) [21]. However, conducting research on the construction and optimization of the digital business environment necessitates the prerequisite of evaluating and measuring the level of development in the digital business environment. Therefore, the study of the evaluation index system for the digital business environment is crucial for accurately measuring and assessing the business environment of cities. It also serves as a prerequisite for conducting other impact analyses [22]. Based on the above analysis, it is of utmost importance and urgency to address the question of how to analyze the elements of the digital business environment ecosystem and how to construct a more comprehensive, systematic, and granular evaluation index system for the digital business environment.

There are currently several international organizations that have established indicator systems related to the evaluation of the digital business environment, and some studies have addressed the evaluation of the digital business environment in China. However, previous research also has certain limitations. Firstly, the evaluation content does not consider the perspective of the digital business environment ecosystem and lacks sufficient theoretical support, which raises questions about the comprehensiveness of the indicator dimensions. Secondly, most studies on the digital business environment focus on the national and provincial levels; however, China has over 300 cities, making it difficult to reflect the true level of development and regional differences in the digital business environment in a more granular manner. Thirdly, although current research has evaluated the digital business environment of countries or within a country, there is a lack of analysis of its temporal and spatial evolution, in addition to a lack of relevant research on the topic of sustainable development of the digital business environment, indicating a deficiency in exploring the general patterns of digital business environment development. Lastly, current evaluation studies on the digital business environment of cities have relatively short time spans, with no research exceeding ten years, which prevents a comprehensive representation of the developmental and evolving characteristics of the digital business environment over time.

Based on this kind of research background, this study aims to address three crucial issues: (1) how to build a scientific and comprehensive digital business environment evaluation index; (2) how to explore the temporal and spatial evolution characteristics of the development of the digital business environment; and (3) how to determine the general configuration path of sustainable development of the digital business environment. The

fsQCA methodology is employed to shift the research perspective from a holistic view to a configurational view of the multidimensionality of the digital business environment and its supporting conditions, thereby allowing us to identify configurations that result in sustainability or non-sustainability performance outcomes.

The rest of this paper is organized as follows. Section 2 reviews the relevant literature on the evaluation index of the digital business environment. Section 3 proposes the theory foundation, method, and data used in this study. Section 5 analyzes the spatiotemporal evolution characteristics and sustainable development path of the digital business environment of Chinese cities. Section 6 discuss the conclusions and policy implications.

## 2. Literature Review

### *2.1. The Relationship between Business Environment and Digital Business Environment*

The digital business environment originates from the business environment, which encompasses the external factors and conditions related to the administrative, market, legal, and cultural aspects [23] involved in the processes of market entry, production and operation, and exit. The business environment is one of the important factors that influences the high-quality development of regional economies and societies, and it also reflects the comprehensive national strength [24–26]. The rapid development of the digital economy has accelerated the global digitization and informatization processes, leading to the digitization transformation and restructuring of the business environment.

From the perspective of institutional supply in the digital business environment, the digitization and informatization have improved the administrative environment by enabling e-government innovation [27]. This has reduced the time, search, and coordination costs [28] associated with traditional bureaucratic services between businesses and governments [29]. The digital business environment can intelligently integrate business information, government information, and social information, enhance market integration, and strengthen consumer protection capabilities [30]. Furthermore, it empowers data utilization [31], breaking the temporal and spatial constraints between government and enterprises, promoting transparency and fairness [32], and achieving precise governance, thereby further optimizing the business environment [33]. Additionally, it enhances public service efficiency [27].

From the perspective of market demand in the digital business environment, digital technologies empower the optimization and upgrading of the business environment, thereby driving reforms in the market-oriented allocation of factors and promoting the upgrade of the industrial structural [34]. Digital technologies and the process of digital transformation have revolutionized business models and processes, giving rise to innovative and personalized approaches [35]. This paradigm shift has led to the emergence of platform-based business models, disrupting traditional economies of scale that relied on supply-based approaches [36]. As a result, the dominance of large established companies has been challenged, and the utilization of digital technologies by small businesses has transformed their roles in engaging with producers and consumers [37]. Organizations now can interact, exchange, and generate value beyond the confines of their own boundaries, engaging with producers and users in new and dynamic ways [38]. A prime example of this transformation is Uber, a digital platform that operates as a two-sided transportation network. On one hand, it offers affordable and flexible services to meet the transportation needs of users. On the other hand, it provides a means for individual entrepreneurs to leverage their own vehicles and earn income by offering transportation services [39]. This, in turn, helps businesses optimize their commercial structures, such as in the case of B2B, by connecting customers, products, suppliers, markets, and other commercial information. Consequently, it strengthens the relevance between businesses and services, reduces transaction costs, and provides a better environment for innovation [40], thereby facilitating sustainable business development [41].

The digital business environment is an evolved and upgraded form of the business environment, encompassing the sum of new business conditions adapted to the digital

economy context. It can be observed that the digital business environment represents a significant aspect of digital government construction in the digital era, an inevitable trend in digital economy development, and an inherent requirement for digital social governance [33]. The endeavor to construct an open, fair, and non-discriminatory digital business environment, promote market-oriented allocation of factors, cultivate technology and data factor markets, and unleash the potential of various factors has become a crucial strategic initiative to drive high-quality economic development in countries worldwide.

### *2.2. Research on the Evaluation of the Digital Business Environment*

There have been numerous studies on the evaluation of the digital business environment worldwide. Table 1 presents the digital business environment indicators constructed by various institutions and scholars. These indicators include both evaluations specific to the digital business environment and evaluations related to the digital economy. International indicators encompass both of these two aspects, while research within China tends to focus more on the evaluation of the digital business environment.

**Table 1.** Literature on digital business environment evaluation index.

| Reference | Region | Time | Method | Evaluation Dimension |
|---|---|---|---|---|
| WB 2019 [42] | 21 countries | Since 2017 | Questionnaire survey method | Network connectivity, data privacy and security, logistics, payment, digital market supervision |
| WB 2020 [18] | 190 economies | 2002–2020 | Frontier Distance Score Evaluation Method | Open enterprises, apply for construction permits, obtain electricity, register property, protect small and medium investors, tax, cross-border transactions, executive contracts, bankruptcy, labor market supervision, government procurement |
| WB 2023 [43] | 180 economies | 2023 | Questionnaire survey method | Business entry, obtaining business premises, access to shared services, labor, financial services, international trade, taxation, dispute resolution, market competition, bankruptcy proceedings, digital technology, and environmental sustainability. |
| ITU 2022 [44] | 167 countries | Since 2019 | Principal component analysis | ICT access, ICT utilization, ICT skills. |
| UNCTAD 2020 [45] | 152 countries | Since 2015 | Weighted scoring method | Internet use, secure Internet servers, postal reliability, infrastructure, payment methods, presence of legal frameworks. |
| UNDESA 2022 [46] | More than 190 countries | Since 2001 | Average weighted scoring | online service delivery, telecommunication infrastructure, human capital, and the legal and policy environment |
| WIPO 2022 [47] | around 100 countries | Since 2007 | Weighted scoring method | Institutions: Assesses human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technology outputs, creative outputs |

**Table 1.** *Cont.*

| Reference | Region | Time | Method | Evaluation Dimension |
|---|---|---|---|---|
| WEF 2020 [48] | around 140 economies globally | Since 2004 | - | institutions, infrastructure, macroeconomic stability, health, primary education, higher education and training, goods market efficiency, labor market efficiency, financial market development, technological readiness, market size, business sophistication |
| CICSCERT 2021 [49] | G20 economies | 2021 | Analytic hierarchy process | Digital support system, data development and utilization and security, digital market access, digital market rules, digital innovation environment |
| Wang 2020 [50] | Countries along the Belt and Road Initiative | 2010–2016 | Grey clustering method | Basic carrier, customs environment, financial services, technical support, human capital, laws and regulations |
| Li and Shen 2022 [51] | 31 provinces in China | 2014–2019 | Entropy method | Digital infrastructure, logistics services, financial services, innovation environment, human capital, opening up, government environment, market environment |
| Zhao and Wang 2022 [24] | 31 provinces in China | 2020 | Principal component analysis | Digital infrastructure, digital rule of law environment, digital talent supply, digital government development, digital financial environment, digital market environment |
| Xu 2022 [25] | 31 provinces in China | 2020 | Coefficient of variation method | Digital infrastructure environment, innovation environment, data and security environment, government supervision and service environment, digital talent supply, market environment |
| Wang 2023 [26] | 36 cities in China | 2022 | - | Market subject protection, market environment, government service, market supervision |
| Zhang 2022 [52] | China | - | - | Digital facilities technology environment, digital market operating environment, digital policy, government affairs environment, digital judicial governance environment |
| Ma 2020 [53] | China | - | - | Digital infrastructure environment, innovative environment, competition and consumer protection environment, data and security environment, supervision and service environment |

Internationally, the World Bank's Digital Business Environment (DBE) indicators have had the most extensive impact. Since 2002, the World Bank has been publishing the Doing Business indicators, which include digital evaluation elements. These indicators assess 190 economies worldwide and establish a comprehensive indicator system around the entire lifecycle of businesses. The system evaluates eleven areas as primary indicators,

including starting a business, obtaining construction permits, accessing electricity, paying taxes, engaging in cross-border trade, enforcing contracts, and resolving insolvency [18].

With the development of the digital economy, international efforts have been made to explore digital business environment indices that adapt to changing times. In 2017, the World Bank introduced the Digital Business Indicators, which measure the legal, regulatory, and bureaucratic aspects influencing digital businesses in 21 pilot countries. It covers five themes: connectivity, data privacy and security, logistics, payment systems, and digital market regulations [42]. The goal is to promote the digital economic development of governments worldwide and provide best practices for regulatory and policy frameworks from a business perspective [54].

In 2020, the World Bank further launched the Business Enabling Environment indicators, incorporating digital technology and environmental sustainability aspects into almost every primary indicator. The BEE indicators cover areas such as e-government, online services, environmental permits, and green taxation, aiming to provide a more comprehensive assessment of the business environment [55]. This initiative has evolved into the B-Ready project, which is expected to evaluate and start publishing relevant results in 2023 [43].

In addition, there are several evaluation indicator systems related to the digital economy field internationally, such as the Information and Communications Technology (ICT) Development Index, Business-to-Consumer Ecommerce Index, E Government Development Index, Global Innovation Index, and Global Competitiveness Index. Firstly, the ICT Development Index is a composite index that includes ICT access, ICT utilization, and ICT skills, and measures and compares the level of information and communication technology development among countries [44]. The UNCTAD B2C E-commerce Index is an annual report including Internet Use, Secure Internet Servers, and six other evaluation dimensions. It provides an assessment of the readiness and potential of countries to engage in online commerce, and has tracked the progress and developments in e-commerce readiness across different countries worldwide since 2015 [45], The evaluation results demonstrate that Europe exhibits the highest level of preparedness for global e-commerce., although there are significant disparities among countries.

The E-Government Development Index (EGDI) measures the progress of countries in utilizing information and communication technologies to provide e-government services to their citizens. This includes online service delivery and telecommunication infrastructure, and it was first published in 2001 [46]. The Global Innovation Index consists of institutional assessments, human capital and research, and five other dimensions, providing a comprehensive assessment of countries' innovation capacity and performance [47]. The Global Competitiveness Index is a comprehensive assessment of countries' competitiveness, published by the World Economic Forum. It includes Macroeconomic Stability, Technological Readiness, and 10 other dimensions, and has been evaluating countries' competitiveness since 2004 [48]. It encompasses not only economic data, but also health statistics and data related to the number of Internet users. The results reveal that Switzerland, Singapore, and the United States are ranked the highest.

By comparing the indicator systems of the aforementioned international organizations, it can be observed that, internationally, the indicators related to the digital economy's business environment primarily encompass four aspects: service environment, competition and consumer protection environment, data and security environment, and regulatory, innovation, and digital infrastructure environment [56].

In addition to international research, many scholars and institutions in China have also conducted research on the evaluation system of the digital business environment. In December 2021, ref. [49] proposed a global evaluation index system for the digital business environment that better reflects the actual construction of China's digital business environment. It includes five primary indicators: digital support system, data development and utilization, digital market access, digital market rules, and digital innovation environment. The results showed that developed countries rank high in terms of the overall digital business environment, with the United States, the United Kingdom, Canada, South Korea,

and Japan in the top five, with China ranking ninth and being the only developing country in the top ten. Ref. [50] measured the development of digital trade in countries along the Belt and Road Initiative. The measurement dimensions included infrastructure, customs environment, financial services, technological support, human capital, and legal regulations. The research found that the digital trade business environment in countries along the Belt and Road Initiative has been continuously improving, but there are significant differences among different countries.

Other scholars have focused on studying the digital business environment at the provincial level in China. Ref. [51] used the entropy method to calculate the digital trade business environment index of 31 provinces in China. They found that the digital business environment in China is steadily improving, and the regional differences are gradually decreasing. Zhao and Wang [24] constructed an evaluation index system for the digital business environment in China based on the construction of the "digital space" and the digital empowerment of traditional business environment factors. They used principal component analysis and Dagum's Gini coefficient analysis to assess and analyze the levels and differences of the digital business environment in various provinces in China. They found that provinces with a high level of digital business environment are mainly concentrated in economically developed regions, and regional differences are the main reason for the overall differences in the digital business environment. Ref. [25] evaluated the digital business environment in China in terms of six aspects: digital infrastructure, innovation environment, data and security environment, government regulation and service environment, digital talent supply environment, and market environment. They found that the Eastern region was significantly better than the Central and Western regions, and the Southern region was better than the Northern region.

In contrast to the aforementioned studies, Wang, 2023 [26], further explored the current development status of the digital business environment at the municipal level in China. They constructed an evaluation system having four dimensions: market entity protection, market environment, government service, and market supervision, and assessed the digital economic business environment in 36 major cities in China. The study reveals that the digital economy business environment has shown overall improvement, accompanied by numerous innovative measures at the local level to promote digital economic development. However, challenges remain in terms of incomplete foundational institutional frameworks for the digital economy and uneven regional development. On the other hand, Ma et al., 2020 [53], proposed a comprehensive policy framework for optimizing the digital economic business environment from the perspective of promoting the digital transformation of small and medium-sized enterprises. They focused on five aspects: digital infrastructure construction, market access facilitation, market order, cybersecurity and user rights protection, and government regulation and service capability.

Therefore, based on the aforementioned studies, but different from them, this research takes a perspective of the digital business environment ecosystem, incorporates more comprehensive dimensions of indicators, utilizes macro-level data from prefecture-level cities, and applies the entropy weighting method as an objective weighting approach for data processing and analysis. This approach allows a granular depiction of the actual development level and regional variations of the digital business environment. By combining the ecosystem concept with fsQCA (fuzzy-set qualitative comparative analysis) and applying it to the study of sustainable development strategies in the digital business environment, this study aims to uncover general patterns of sustainable development. It not only provides new ideas and frameworks for the indicator system for evaluating the digital business environment, but also offers valuable insights and guidelines about SMEs' sustainable development, especially for SMEs in developing countries.

## 3. Theoretical Framework for Evaluating the Digital Business Environment

### *3.1. Theoretical Foundation and the Construction of Evaluation Indicators*

Based on the theory of ecosystems, a business ecosystem is a set of acting entities, organizations, and individuals that build their abilities and roles and rely on one another for their overall performance and survival [57]. This ecosystem consists of market entities and the external environment they face, with the external environment being a crucial factor supporting the interaction among market entities within the ecosystem. By extension, the digital business ecosystem is an extension of Moore's business ecosystem [58] and refers to the sum of the external environment in which digital economy market entities engage in business activities. The digital ecosystem provides the digital technical capabilities that enable the development of a digital business ecosystem in manufacturing. In other words, without a digital ecosystem it would be impossible to fully utilize the benefits of digital technologies such as artificial intelligence (AI), digital twins (DTs), industrial Internet platforms (IIPs), big data, machine learning, and digital service [59]. The digital business ecosystem is a new environment which includes the government service environment, market environment, innovation environment, and governance environment; it is also a new landscape where both competition and collaboration occur [60].

The emergence and utilization of the digital business environment are not mutually exclusive, nor is their impact on market entities simply additive. On the contrary, it is crucial to consider the interaction of multiple factors. Therefore, in the next section, we review the existing literature on the multidimensionality of the digital business environment and the supporting conditions, aiming to provide a comprehensive understanding of their roles in creating a sustainable digital business environment. The objective of this study is to develop general propositions that clearly demonstrate how to comprehensively and scientifically evaluate the digital business environment, as well as explore configuration views for achieving sustainable development in the digital business environment. Building on the theory of ecosystems and the above analysis of the digital business ecosystem, a more comprehensive assessment of the external environment faced by market entities throughout their entire lifecycle can be achieved (see Figure 1).

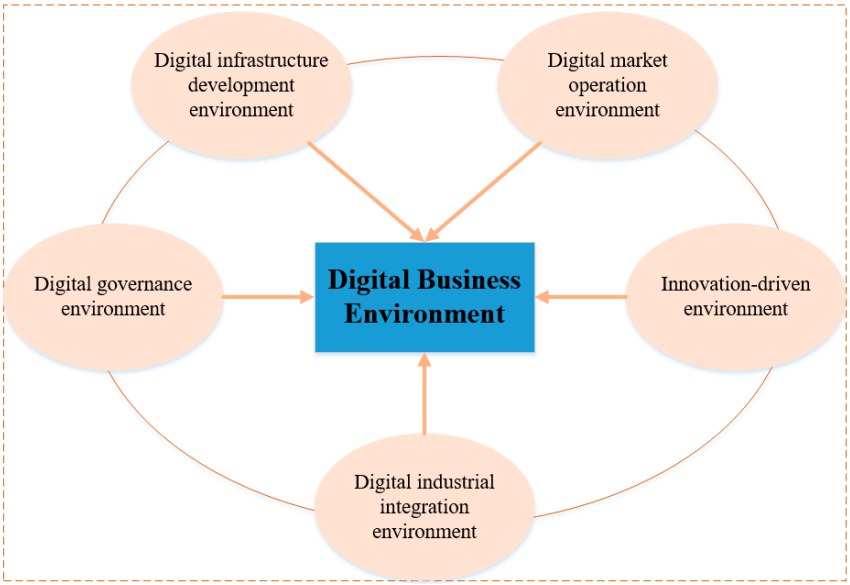


**Figure 1.** Theoretical model of digital business environment evaluation index.

(1) Digital infrastructure environment (DIE). One crucial task in building the digital economy is to establish stable, secure, and standardized information technology infrastructure. This involves developing fifth-generation communication networks, data storage and processing infrastructure, and "digital" infrastructure to provide equitable digital services to citizens. Of particular importance is the creation of a new

type of foundational infrastructure called the digital infrastructure platform, which offers significant advantages in its application across various economic sectors. The utilization of communication and information distribution channels plays a pivotal role in driving economic development. However, these platforms and other information infrastructure types must possess the ability to adapt, innovate, and incorporate new parameters to meet the evolving requirements of the digital economy [61]. First, digital infrastructure supports productive activities such as data transmission, big data computing, cloud computing, and blockchain [25]. Second, the development of the digital economy also relies on logistics services to ensure the circulation and delivery of digital products and services, promoting the integration of the industrial chain [62].

(2) Digital market operation environment (DMOE). Three main aspects of the factors influencing digital marketing operations can be identified: individual factors, organizational factors, and macro factors. Individual factors encompass the customers' level of awareness regarding online shopping and social media [63], as well as the cognitive and emotional factors of salespersons during digital transformation [64]. Organizational factors include value orientation [65], resources and capabilities [66], and management and innovation [67]. Macro factors encompass technology [68], economic factors [69], and social factors [70]. Firstly, the scale of the digital market reflects the demand and marketization process of the digital market [25,52]. Secondly, the development of the digital economy relies on the support of digital talents. The quantity and quality of digital talent directly affect the innovation and competitiveness of digital economy market entities [71]. Thirdly, in cities with a high degree of openness and internationalization in the digital market, digital economy entities can better access international market opportunities and resources, enhancing their international competitiveness [51]. Finally, the development of the digital economy also requires financial services support, including financing and investment [24].

(3) Digital governance environment (DGE). Digital governance involves the establishment and implementation of policies, procedures, and standards to ensure the proper development, use, and management of practices within the information domain. Digital ethics research and assessment focus on ethical considerations related to data and information (including data generation, use, and privacy), algorithms (including artificial intelligence and machine learning), and the associated practices and infrastructure. The goal is to formulate and support ethically sound behavioral values and norms. Digital ethics shapes digital governance through ethical evaluations of socially acceptable or desirable relationships [72]. Considering the externality and uncertainty of the digital economy, it not only needs the supervision of the government, but also needs the government to support the development of the digital industry through subsidies, tax incentives, and other policies. At the same time, in the process of the development of the digital economy, it is also faced with a series of legal and regulatory issues, and the digital economy entities need to operate in accordance with the law. Based on this, and drawing on the research of [51], this paper sets two aspects of government supervision, service and data security, under the dimension of digital governance environment.

(4) Digital industrial integration environment (DIIE). On one hand, the deep integration of the digital economy with the traditional economy can accelerate the digital transformation of enterprises, thereby promoting the development of the digital economy. On the other hand, the industrial scale effects unleashed by the development of the digital economy can enhance resource utilization efficiency, cost-effectiveness, competitive advantages, and innovation capabilities of digital economy entities. Digital industrialization can be characterized using indicators such as the number of company websites and the status of the digital transformation of enterprises [73]. Digital industrialization can be measured using indicators such as the number of companies

involved in e-commerce transactions and the status of digital economic development of enterprises [74].

(5) Innovation-driven environment (IDE). Innovation can continuously drive the innovation and upgrading of digital technologies, making digital economy products more intelligent and efficient, thereby enhancing the competitiveness and market share of the digital economy. In this study, the dimension of the innovation-driven environment is composed of two primary indicators: innovation input and innovation output [25].

At different stages of growth, digital economy market entities are influenced by digital infrastructure, supported by the digital market operational environment, regulated by the digital governance environment, guided by the digital industry integration environment, and supported by the innovation-driven environment. Therefore, based on the connotation of the digital business environment and following principles such as systematicity, scientificity, dynamics, comparability, and operability, this study constructs a digital business environment indicator system from the five dimensions mentioned above, comprising 28 representative indicators (see Table 2).

**Table 2.** Digital business environment evaluation index systems and their data source.

| First-Level Indicator | Second-Level Indicator | Third-Level Indicator | Weight, % | Data Source |
|---|---|---|---|---|
| Digital infrastructure environment | Digital information infrastructure | Number of international Internet users (households) | 3.74 | Urban Statistical Yearbook |
| | | Number of Internet users (per hundred people) | 4.98 | |
| | | Number of mobile phone users (per hundred people) | 3.04 | |
| | Logistics development level | Number of post offices at the end of the year (units) | 3.61 | EPS Database |
| | | Total freight volume (metric tons) | 0.77 | Urban Statistical Yearbook |
| | | Total postal service volume (CNY) | 0.90 | |
| Digital market operation environment | Digital market size | E-commerce sales revenue (CNY) | 1.51 | |
| | | Software business revenue (CNY) | 0.85 | |
| | | Information technology service revenue | 0.77 | |
| | | Per capita GDP (RMB) | 2.78 | |
| | Digital talent supply | Proportion of computer service professionals (%) | 1.76 | |
| | | Number of college students (individuals) | 11.89 | |
| | Level of openness | Import value of goods (RMB) | 4.33 | |
| | | Export value of goods (RMB) | 5.74 | |
| | | Foreign investment amount outside contracts (USD) | 0.66 | Wind Database |
| | Financial service guarantee | End-of-year financial institution loans (RMB) | 4.34 | |
| | | Digital inclusive finance index | 13.89 | CSMAR Database |

**Table 2.** *Cont.*

| First-Level Indicator | Second-Level Indicator | Third-Level Indicator | Weight, % | Data Source |
|---|---|---|---|---|
| Digital governance environment | Government supervision and service | Research and development expenditure (in RMB) | 7.92 | Urban Statistical Yearbook |
| | | Government digital attention | 1.99 | MARK Database |
| | Digital judicial governance | Information security revenue | 1.59 | |
| | | Number of digital intellectual property judicial cases (count) | 0.48 | |
| Digital industrial integration environment | Industrial digitalization | Number of websites owned by enterprises (count) | 5.89 | |
| | | Digital transformation of enterprises | 3.15 | |
| | Digital industrialization | Number of enterprises with e-commerce transactions (some) | 2.25 | EPS Database |
| | | Enterprise digital economic development | 4.08 | MARK Database |
| Innovation-driven environment | Innovation investment | R&D investment (10,000 CNY) | 2.25 | Urban Statistical Yearbook |
| | Innovative output | Number of digital economy patents (one) | 2.38 | EPS Database |
| | | Number of digital economic papers (articles) | 2.44 | |

### *3.2. Research Method*

#### 3.2.1. Entropy Power Method

In the process of establishing the relevant composite index, assigning weights is a crucial step. The existing literature has employed various methods to determine the weights, including the equal weighting method, subjective weighting method, and principal component analysis method. However, these methods have their limitations. The entropy weight method determines the weights of variables by using the output entropy of each variable and the fuzzy comprehensive evaluation matrix. Even indicators with a lower contribution will not be easily excluded. When a variable contains more useful information, it implies a greater weight should be assigned to that variable. This method provides an objective assignment of weight coefficients, effectively avoiding biases introduced by subjective factors and objectively reflecting the evaluation results, thus avoiding the subjectivity of subjective weighting [75]. In this article, it was decided to adopt the entropy weight method as a relatively scientific approach for determining weights among various methods. The entropy weight method can be realized through five steps:

Firstly, the calculation of indicator weights requires the standardization or normalization of the data. Since the data used in this study have different dimensions and there are target values that can be used as a reference, the standardization process for positive and negative indicators is differentiated. This study employs the utility value method to calculate the score of the city's business environment index. The specific calculation process and formula are as follows, where the formula for calculating the score of positive indicators is (1):

$$y_{ij}{}' = \frac{x_{ij} - \min\left(x_{ij}\right)}{\max\left(x_{ij}\right) - \min\left(x_{ij}\right)} \times 100, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n. \quad (1)$$

The calculation formula of the reverse index is (2):

$$y_{ij}{}' = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})} \times 100, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n. \quad (2)$$

where $x_{ij}$ represents the value of indicator $j$ for city $i$ in various years, $\max(x_{ij})$ represents the maximum value of that indicator, $\min(x_{ij})$ represents the minimum value of that indicator, and $y_{ij}$ represents the dimensionless value of indicator $j$ for city $i$ in various years after normalization. In order to avoid the impact of zero values on subsequent calculations after data standardization, it is common to perform a coordinate shift. However, it is also necessary to ensure that the shifted data remain within the range [0, 1]. Therefore, the formula is (3):

$$y_{ij} = 0.99 \times y_{ij}{}' + 0.001. \quad (3)$$

Next, the weight $P_{ij}$ of the $i$-th indicator for the $j$-th city is calculated through the formula of (4):

$$P_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}}. \quad (4)$$

Furthermore, based on the entropy values of each indicator, the information entropy value $E_j$ and the redundancy degree $F_j$ are calculated using the formulas of (5) and (6):

$$E_j = -\frac{1}{lnm} \sum_{i=1}^{m} P_{ij} \ln(P_{ij}), \quad (5)$$

$$F_j = 1 - E_j. \quad (6)$$

Then, the weight $W_j$ of the $j$-th variable is calculated by comparing the redundancy of a specific indicator with the total redundancy of all indicators, using the formula of (7):

$$W_j = F_j / \sum_{j=1}^{n} F_{ij}. \quad (7)$$

Finally, after performing the aforementioned calculations, the comprehensive index reflecting the current state of the digital business environment is obtained using the formula of (8):

$$DBE_{ij} = 100 \times \sum_{j=1}^{n} W_j y_{ij}. \quad (8)$$

3.2.2. Kernel Density Estimation Method

This paper employs the kernel density method to analyze the temporal evolution trend of the digital business environment level. This method starts from the data itself and investigates the distribution characteristics of the data. It can overcome the subjectivity issue of setting the functional form in parameter estimation and has weak model dependence and strong robustness. The basic functional form of the kernel density method is given by (9):

$$f(x) = \frac{1}{nh} \sum_{i=1}^{n} K\left(\frac{x - Xi}{h}\right). \quad (9)$$

where $n$ represents the number of observations, $X1, \ldots Xn$ represent the digital business environment level values of each city, and $x$ represents the mean. $K(\bullet)$ represents the kernel density function, and in this paper, a Gaussian kernel density function is used. $h$ represents the optimal bandwidth determined using the "rule of thumb" method.

3.2.3. Spatial Autocorrelation Analysis Method—Moran's I

To investigate whether there is spatial autocorrelation between the digital business environment of different cities, we use the global Moran's I to analyze the spatial autocorrelation of efficiency values, and adopt local Moran's I to analyze the spatial agglomeration characteristics of the digital business environment. The calculation formula of global Moran's I is (10):

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(y_i - \overline{y})(y_j - \overline{y})}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\sum_{i=1}^{n}(y_i - \overline{y})}. \quad (10)$$

where $n$ denotes the number of cities, and $y_i$ and $y_j$ denote the digital business environment of city $i$ and city $j$ respectively. $y$ is the average value of the digital business environment and $W_{ij}$ is the spatial weight matrix obtained based on the Rook adjacency criterion. Suppose Moran's I > 0, the digital business environment presents a spatial positive correlation. If Moran's I = 0, the digital business environment is randomly distributed. If Moran's I < 0, the digital business environment tends to be spatially negatively correlated. Local Moran's I is the decomposition form of global Moran's I, and can be used to further measure the spatial agglomeration features of individual locations and identify hotpots based on comparisons with adjacent regions. The calculation formula is (11):

$$I_i = \frac{n(y_i - \overline{y})}{\sum_{j=1}^{n}(y_i - \overline{y})^2}\sum_{j=1}^{n} W_{ij}(y_j - \overline{y}). \quad (11)$$

where $n$, $y_i$, $y_j$, y, and $W_{ij}$ are the same as in Equation (10). According to local Moran's I calculation, we can draw the Moran scatterplot and LISA cluster map. The four quadrants of the Moran scatterplot correspond to four cluster types, namely, high–high cluster (H-H), high–low cluster (H-L), low–high cluster (L-H), and low–low cluster (L-L).

3.2.4. fsQCA

As a new research paradigm in the field of social sciences, fsQCA overcomes the causal logic limitations of correlational relationships. It explores the effects of multiple antecedent conditions by combining a set-theoretic perspective with real-world cases. This method combines the advantages of qualitative and quantitative analysis. Unlike traditional regression methods, fsQCA uses Boolean algebra to compare and analyze cross-case configurations, thus avoiding omitted variable bias. Therefore, there is no requirement for controlling variables in the fsQCA method [76]. Currently, the method is widely used in research areas such as finance, economic management, and political science [77,78].

Moreover, fsQCA adopts a holistic perspective for comparative analysis across cases and focuses on exploring issues of causal complexity. It aims to identify the configurations of conditions that lead to the occurrence or absence of expected outcomes [79]. The complex mechanisms of the sustainable development of the digital business environment result from the combination of dimensions in the digital business ecosystem. By utilizing the fsQCA method to explore the sustainable development path of the digital business environment, different configurational paths for the sustainable development of the digital business environment can be identified. This method helps to understand the differentiated paths of digital business environment development and reveals the synergistic effects among different influencing factors.

## 4. Study Area and Data Sources

Studying the development of China's digital business environment holds significant importance for the advancement of global digital trade, considering China's status as the world's largest trading nation in terms of imports and exports. It can also provide valuable insights and guidance for other countries, particularly developing nations. Due to data availability issues, we excluded several regions, namely Hong Kong, Macau, Taiwan, and Tibet. We selected 272 cities and divided them into four regions based on China's

administrative divisions. This allowed us to evaluate the development level of China's digital business environment from 2011 to 2020 (see Figure 2).

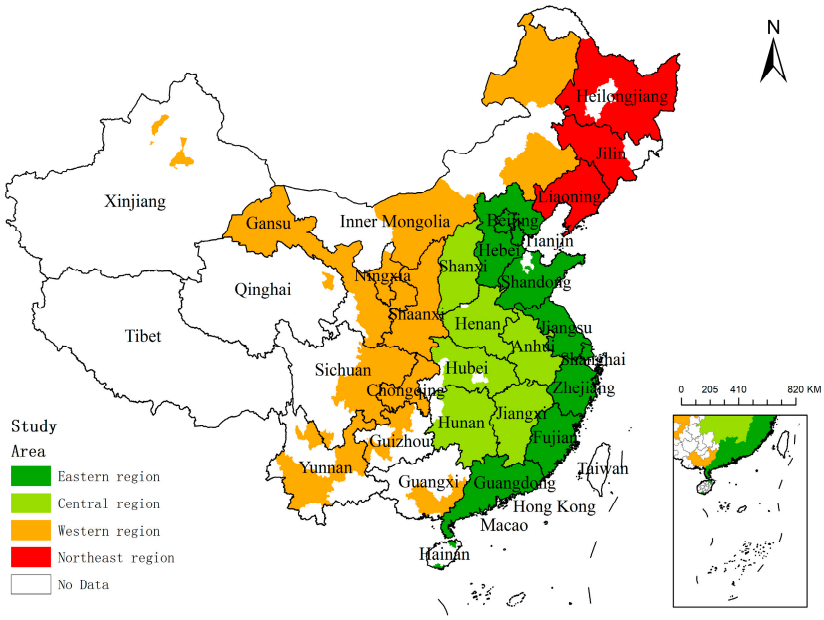


**Figure 2.** Study areas. (Note: The base map data for the China map are from the National Basic Geographic Information System database (http://www.ngcc.cn/ngcc/html/1//391/392/16114.html, accessed on 20 May 2023). The base map has not been modified.

The primary sources of data for this study include the "China City Database" from the EPS Global Statistical Data/Analysis Platform, as well as the WIND database, CSMAR database, Mark database, and urban statistical yearbooks. To obtain the government's digital attention index, we organized and extracted high-frequency terms such as digital technology, digital economy, information industry, digital governance, data governance, and quantitative finance from the official bulletins of city governments using ROST Content Mining 5.8.0. The calculation of the index for enterprise digital transformation follows the approach used by [73], which involves collecting information on the digital transformation of listed companies in each city and calculating the index based on their weighted operating income. To address missing and abnormal values in the data, we first conducted manual web searches and cross-checked the information with relevant city statistical yearbooks and statistical bulletins. For unverifiable abnormal values, we employed methods such as mean imputation, smoothing techniques, and regression imputation.

## 5. Results

Based on the methods described earlier and the proposed evaluation indicator system for the digital business environment, this paper calculated the overall index of the digital business environment development for 272 cities in China from 2011 to 2020.

### *5.1. The Overall Evolution Characteristics of China's Digital Business Environment*

Figure 3 presents the overall trend of the digital business environment development index for China and its regions. From the graph, it can be observed that the average and median values of the digital business environment development index for the whole country and the Eastern, Central, Western, and Northeast regions have shown a consistent upward trend over the years, with a noticeable increase in growth rate after 2017. Comparing the average and median values of the national digital business environment development index for the years 2011–2020, it is evident that the former is consistently higher than the latter each year, with the difference between the two widening significantly after 2015. This indicates a right-skewed distribution pattern in the digital business environment index

across the various cities in China, with the majority of cities having lower index values, while a few cities exhibit particularly high values.

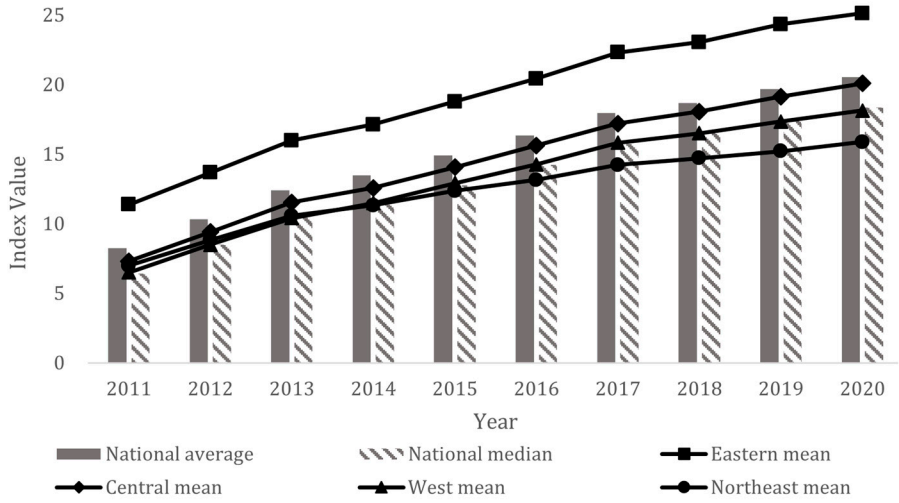


**Figure 3.** Development index trend of the digital business environment in China.

Figure 4 illustrates the evaluation results of the five sub-dimensions of the digital business environment in 2020. The figure reveals that among the national sub-dimension data, the digital market operation environment (DMOE) has the highest average value of 0.57, indicating a fast-paced development of the digital market operation environment nationwide. The values of the digital governance environment (DGE) and digital industry integration environment (DIIE) are relatively similar, suggesting that both are in the early stages of development. However, the innovation environment (IDE) lags behind with an average value of only 0.07, indicating ample room for improvement in China's digital market innovation capability. Based on the above analysis, it is evident that for enterprises, particularly small and medium-sized enterprises (SMEs), enhancing digital market operation capabilities and elevating their level of digitalization can lead to improved business performance and enhanced market competitiveness.

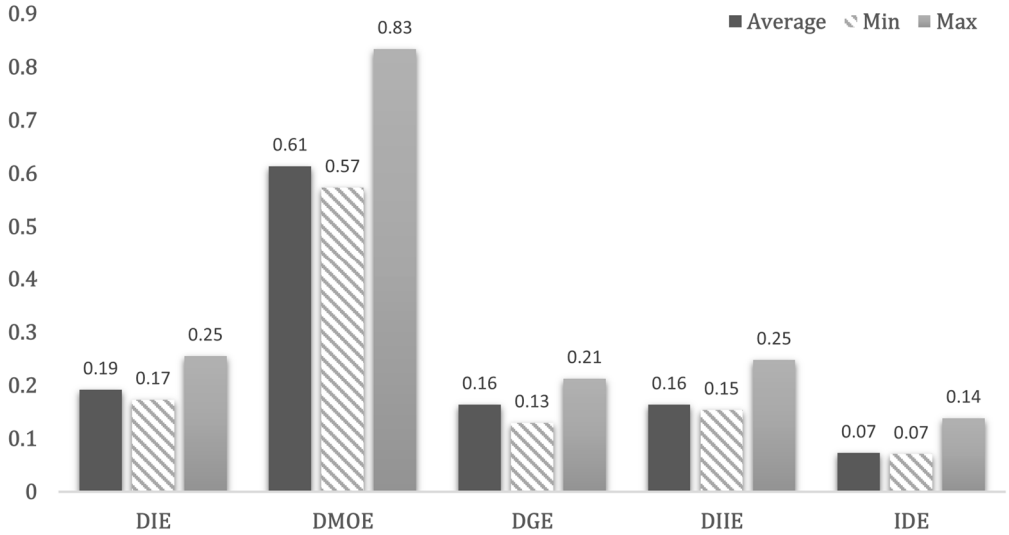


**Figure 4.** Evaluation results of each dimension of the digital business environment in 2020.

Figure 5 shows the spatial distribution of the digital business environment in 2011 and 2020. Jenks method was adopted to divide the digital business environment into five levels. Comparing the overall layout in 2011 and 2020, it can be observed that there are significant

regional disparities and hierarchical distribution characteristics in the high-quality development of the digital business environment in China. It can be seen that China's digital business environment has been greatly improved in the past decade, especially in the Eastern region, and cities with a larger digital business environment are mainly distributed in Beijing, Chongqing, Chengdu, Yangtze River Delta, Pearl River Delta, Wuhan, and Zhengzhou. Most cities in these areas have a large scale of the digital economy and digital technology is widely used. Cities in the third echelon are concentrated in the Central region. However, most cities in the Western region of China are in the fourth and fifth echelon. This phenomenon may be because many cities in western China have lower economic development levels and a poor industrial base, resulting in less product consumption, such as Gansu Shaanxi, Inner Mongolia, and Guangxi.

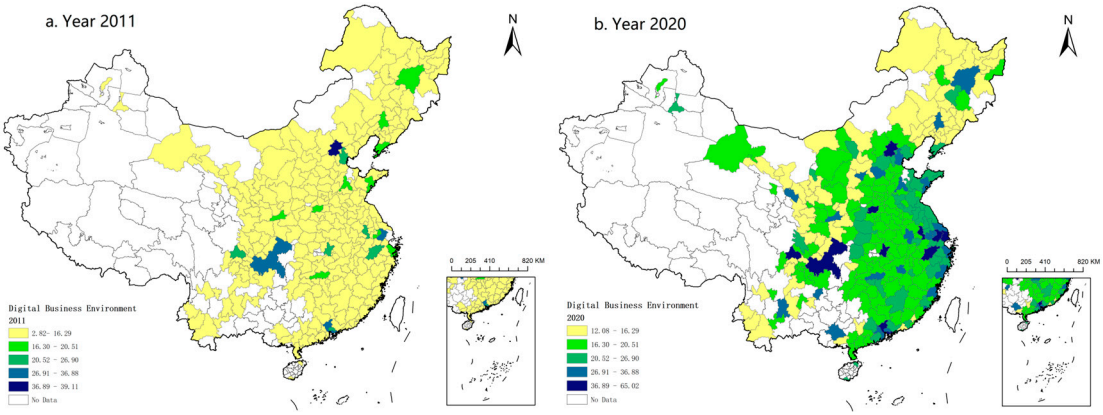


**Figure 5.** Spatial distribution of the digital business environment in 2011 and 2020.

From a regional perspective, the development index of the digital business environment in the Eastern region has consistently outperformed that of other regions. Before 2014, the average values of the digital business environment index in the Central, Western, and Northeastern regions were relatively similar. However, since 2014, significant differences have emerged, and the disparities between different regions have shown an expanding trend. When examining different cities at the prefectural level, taking 2020 as an example, four cities, namely Beijing, Shenzhen, Guangzhou, and Shanghai, had digital business environment development indices exceeding 50; 44 cities had indices ranging from 25 to 50; and 224 cities had indices below 25. Overall, China's digital business environment development level is still at a low and uneven stage of initial development.

### *5.2. Temporal Evolution Characteristics of China's Digital Business Environment*

#### 5.2.1. Nonparametric Density Estimation Analysis

Figure 6 illustrates the dynamic evolution trend of the digital business environment in 272 Chinese cities during the observed period. It can be observed that the development level of China's digital business environment is gradually increasing, but regional disparities are also widening, which is consistent with the analysis of basic characteristics. Specifically, over the 10-year period from 2011 to 2020, the center of the density function distribution continuously shifted to the right, and the peak of the curve decreased and widened each year. This indicates an upward trend in the development level of China's digital business environment and also suggests a certain degree of expansion in regional disparities. It is worth mentioning that the annual kernel density curves exhibit a certain degree of the right-tail phenomenon, indicating an increasing disparity between cities with high digital business environment levels and the average level within the country. This may be attributed to the significant improvement in China's digital business environment level in recent years due to rapid economic and social development, with most cities enhancing their digital business environment through the application of digital technologies and government-led "streamlining administration and delegating power" reforms. However,

due to differences in geographical advantages and path dependence of inherent development patterns, China's digital business environment exhibits insufficient and uneven development characteristics.

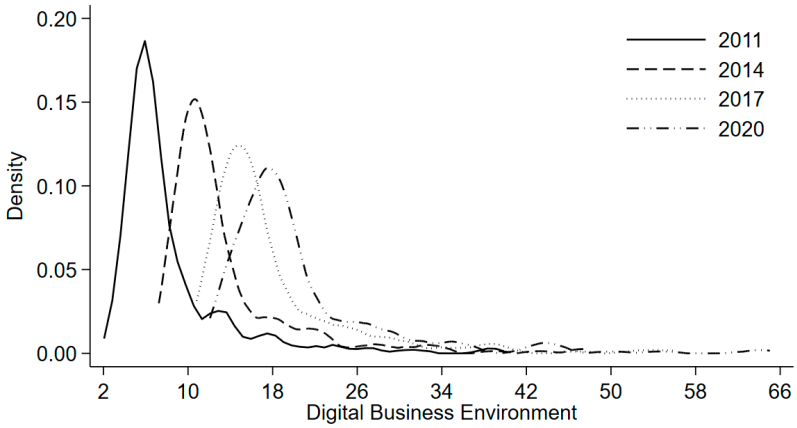


**Figure 6.** Dynamic evolution curve of China's digital business environment.

Figure 7 illustrates the distribution and evolution characteristics of the digital business environment in the Eastern, Central, Western, and Northeastern regions of China. In the Eastern region, the main peak height shows a "continuous decrease" trend, with the main peak continuously shifting to the right and the peak width exhibiting a "noticeable widening" trend, indicating a "continuous increase" in the level of digital business environment differentiation in the Eastern region. The trend in the Western region is similar to that of the Eastern region, with a slight increase in peak width but relatively small changes, indicating that the spatial development differentiation of the digital business environment in the Western region is smaller than that in the Eastern region. In the Central region, the central peak of the kernel density curve continues to shift to the right, but the height and width remain relatively stable, indicating a sustained increase in the level of digital business environment development in the Central region with minimal regional differences. The distribution curve in the Northeastern region exhibits a trend of "initial decrease, subsequent increase, and slight decrease" in peak height, indicating relatively large fluctuations in absolute differences in the digital business environment of the Northeastern region. In terms of the evolution of peak numbers, a "double-peak" pattern is observed during the observation period, but the side peaks are significantly lower than the main peak, indicating a certain gradient effect in the development of the digital business environment in the Northeastern region, with regions of lower digital business environment levels facing challenges in catching up with higher-level regions.

In general, the center of the kernel density curves for the digital business environment in different regions of China has continuously shifted to the right, indicating a continuous improvement in the development level of the digital business environment across various regions and exhibiting the pattern of "East > Central > West > Northeast". Furthermore, all the kernel density curves show a certain degree of the right-tail phenomenon and tail extension, indicating rapid development of the digital business environment in certain cities within each region and significant gradient differences in the level of the digital business environment.

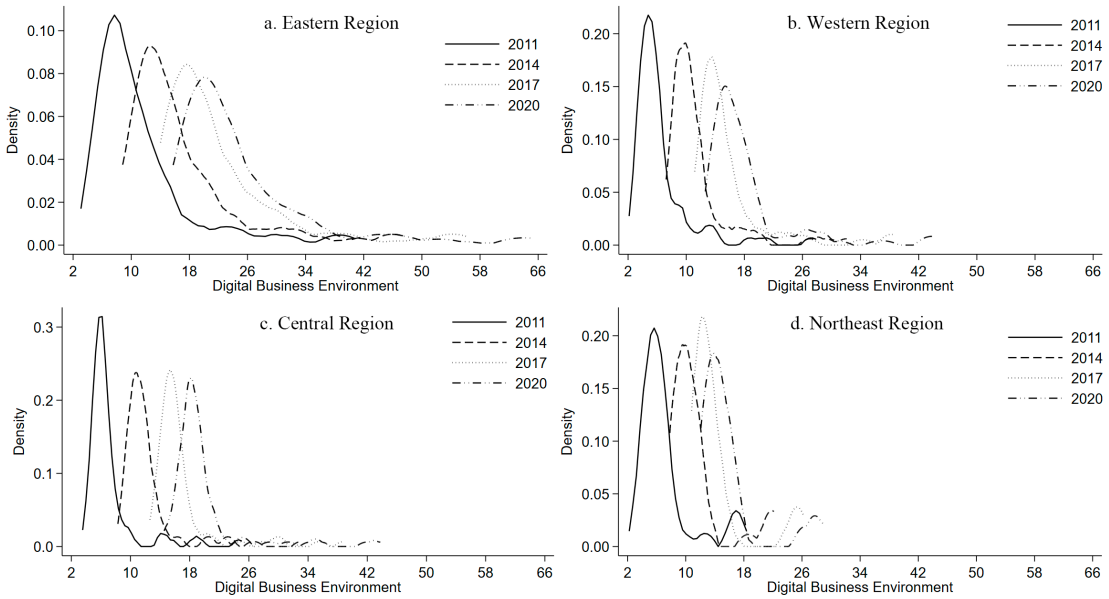


**Figure 7.** Dynamic evolution curves of the digital business environment in four regions.

#### 5.2.2. Markov Chain Analysis

The kernel density estimation curve primarily considers the possibility of changes in the development level of the digital business environment over time. Furthermore, the study employs a Markov chain transition matrix to examine the probabilities of transitions in the development level of the digital business environment. The 272 cities are classified into four levels (k = 4) based on percentile rankings: low level, medium level, medium-high level, and high level.

From Table 3, it can be observed that, except for the transition probability of 0 in the low-level state, the transition probabilities on the main diagonal are significantly higher than those off the diagonal, indicating a higher probability of maintaining an intermediate or higher level of development in the digital business environment in China during the sample period. The off-diagonal transition probabilities in the upper-right portion of the matrix are all non-zero, indicating that the development level of the digital business environment in cities can transition to higher adjacent states, and some cities even experience upward leaps across levels. However, all the off-diagonal transition probabilities in the lower-left portion of the matrix are zero, indicating that there is no risk of decline in the development level of the digital business environment in China, and it is not possible to experience a downward cross-level decline.

**Table 3.** Markov transition probability matrix of China's digital business environment.

| State i at Time t | The Probability of State j at Time t + 1 (%) | | | |
|---|---|---|---|---|
| | **Low** | **Medium** | **Intermediate-High** | **High** |
| Low | 0 | 51.18 | 47.06 | 1.77 |
| Medium | 0 | 91.88 | 7.99 | 0.13 |
| Intermediate-high | 0 | 0 | 100 | 0 |
| High | 0 | 0 | 0 | 100 |

### *5.3. Spatial Characteristics Analysis of China's Digital Business Environment Development*

#### 5.3.1. Global Spatial Autocorrelation

To further investigate whether the digital business environment level of cities in China is significantly correlated with the development status of neighboring cities, this study employs Moran's I index analysis to examine the spatial dependency and spatial clustering of digital business environment development. The global Moran's I index values of the

digital business environment are positive from 2011 to 2020. In the scatterplots (Figure 8), the points mainly arise in the first and third quadrants, thus confirming that there is spatial positive autocorrelation in most Chinese cities. Furthermore, the number of cities in the first and third quadrants has slightly increased, indicating a spatial pattern of "high-high" clustering and "low-low" clustering. This spatial clustering differentiation phenomenon shows a trend of exacerbation.

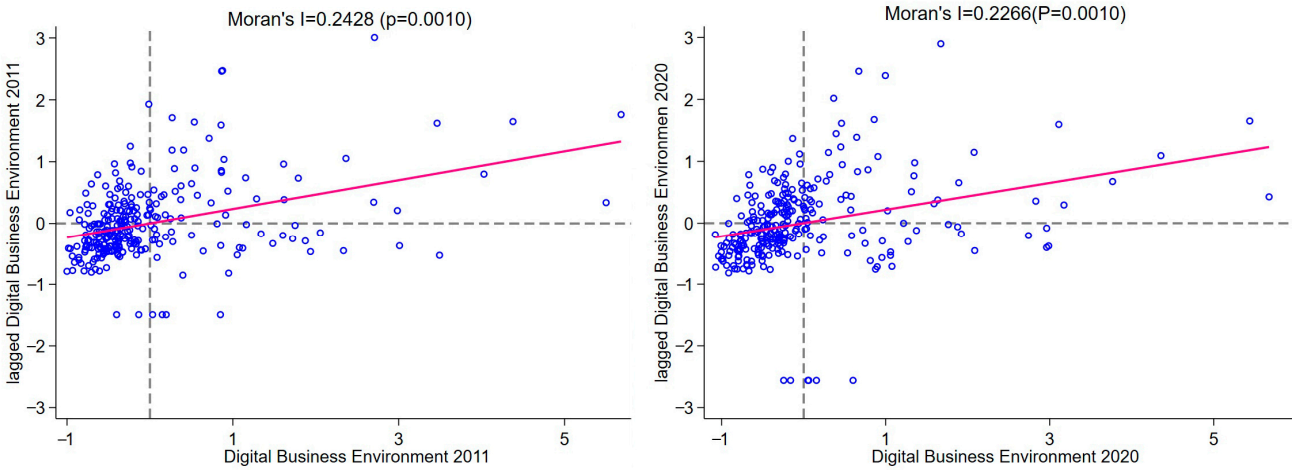


**Figure 8.** Global Moran's I scatterplots of the digital business environment in 2011 and 2020. Note: the blue circle represents the 272 cities, the red line indicates that the digital business environment is in positive autocorrelation.

However, Moran's I index has a downward trend (Table 4), indicating that the spatial agglomeration of the digital business environment has a weakening trend. The Z-score for the Moran's I of the digital business environment passed the significance test ($p$ = 0.000). Moran's I is positively correlated, indicating that the digital business environment is characterized by high- and low-value concentrations.

**Table 4.** Global Moran's I of the digital business environment.

| Year | Moran's I | Z-Score | *p*-Value |
|---|---|---|---|
| 2011 | 0.243 | 6.053 | 0.000 |
| 2012 | 0.255 | 6.358 | 0.000 |
| 2013 | 0.253 | 6.306 | 0.000 |
| 2014 | 0.247 | 6.142 | 0.000 |
| 2015 | 0.256 | 6.370 | 0.000 |
| 2016 | 0.256 | 6.356 | 0.000 |
| 2017 | 0.264 | 6.553 | 0.000 |
| 2018 | 0.248 | 6.163 | 0.000 |
| 2019 | 0.235 | 5.856 | 0.000 |
| 2020 | 0.227 | 5.652 | 0.000 |

### 5.3.2. Local Spatial Autocorrelation

Global Moran's I index can only analyze the overall spatial autocorrelation of the digital business environment and cannot express the local spatial clustering characters of the digital business environment. To clarify the local clustering features of the digital business environment, we drew the local LISA clustering map of the digital business environment based on the local Moran's I index (Figure 9).

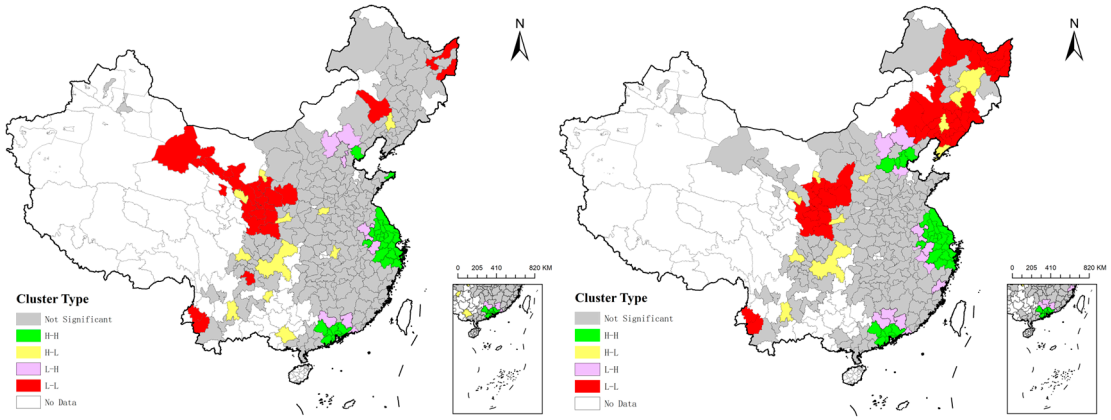


**Figure 9.** LISA for the digital business environment in 2011 and 2020.

We can see that the four association types of H-H, L-L, L-H, and H-L are distributed, indicating that there are two relationships of spatial positive correlation and spatial negative correlation in the Chinese digital business environment. Specifically, the H-H category indicates a positive correlation between the digital business environment development level of the observed city and its surrounding cities, as both are high. The L-H category indicates a negative correlation, as the observed city has a low digital business environment development level while its surrounding provinces have a high level. The L-L category indicates a positive correlation, as both the observed city and its surrounding regions have a low digital business environment development level. The H-L category indicates a negative correlation, as the observed city has a high digital business environment development level while its surrounding regions have a low level. More cities have H-H and L-L agglomeration types, confirming the conclusion that most cities in China have positive spatial autocorrelation. Among them, H-H agglomeration areas in 2011 were mainly located in the Yangtze River Delta, the Pearl River Delta, Tianjin, Yantai, and Qingdao. These cities have a relatively high digital business environment, forming a high-value cluster area. The L-L agglomeration areas are mainly located in Gansu, Ningxia, Shaanxi, Baoshan, Lincang, Tongliao, Jiamusi, and Jixi.

By 2020, the number of cities with the H-H agglomeration type changed little, and were mainly distributed in the same way as in 2011. However, the number of cities with the L-L agglomeration type changed a lot, and were mainly distributed in the Eastern region in Gansu, Ningxia, and Shaanxi; specifically, the number of "L-L" agglomeration cities increased significantly. In general, cities with the H-H agglomeration type are mainly located in the Eastern coastal areas and provinces, such as Guangdong, Jiangsu, Zhejiang, and Shanghai, whereas cities with the L-L agglomeration type are distributed in Northwest and Northeast China, such as Gansu, Liaoning, and Heilongjiang.

### *5.4. Regional Disparity and Source Analysis Based on Dagum's Gini Coefficient Method*

Dagum, 1997 [80], decomposed the overall Gini coefficient, G, into the within-region disparity contribution, G_W, the between-region net value disparity contribution, G_nb, and the super-variation density contribution, G_t, where G = G_W + G_nb + G_t. In this study, we adopted this method and combined it with four research regions, dividing the 272 cities studied into the Eastern, Central, Western, and Northeastern regions, to examine the regional disparities in the development of China's digital business environment and identify the sources of these differences.

The calculation and decomposition results of the Dagum Gini coefficient for China's digital business environment are shown in Table 5. The calculations reveal that the average overall Gini coefficient for the digital business environment in China during the period of 2011–2020 is 0.2, indicating the presence of certain disparities in the overall development level of China's digital business environment. From the evolution trend perspective, the

overall differences in the development level of China's digital business environment have gradually decreased in recent years, reducing from 0.293 in 2011 to 0.175 in 2020.

**Table 5.** * The Gini coefficients and contribution rates of China's digital business environment.

| Year | G_T | G_W | | | | | G_nb | | | | | | G_t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $G_{wt}$ | E | C | W | NE | $G_{nbt}$ | EC | EW | ENE | CW | CNE | WNE | |
| 2011 | 0.293 | 0.073 | 0.29 | 0.20 | 0.24 | 0.28 | 0.126 | 0.32 | 0.33 | 0.36 | 0.22 | 0.25 | 0.26 | 0.094 |
| 2012 | 0.242 | 0.060 | 0.25 | 0.16 | 0.19 | 0.22 | 0.108 | 0.27 | 0.28 | 0.31 | 0.17 | 0.20 | 0.20 | 0.074 |
| 2013 | 0.220 | 0.055 | 0.24 | 0.14 | 0.17 | 0.19 | 0.098 | 0.24 | 0.26 | 0.28 | 0.16 | 0.17 | 0.18 | 0.068 |
| 2014 | 0.208 | 0.052 | 0.23 | 0.13 | 0.17 | 0.16 | 0.093 | 0.23 | 0.26 | 0.26 | 0.16 | 0.15 | 0.17 | 0.064 |
| 2015 | 0.196 | 0.048 | 0.21 | 0.12 | 0.16 | 0.15 | 0.090 | 0.21 | 0.25 | 0.25 | 0.15 | 0.15 | 0.16 | 0.06 |
| 2016 | 0.187 | 0.045 | 0.19 | 0.12 | 0.16 | 0.14 | 0.090 | 0.20 | 0.24 | 0.26 | 0.15 | 0.16 | 0.16 | 0.052 |
| 2017 | 0.180 | 0.043 | 0.19 | 0.11 | 0.15 | 0.13 | 0.089 | 0.19 | 0.23 | 0.26 | 0.14 | 0.16 | 0.15 | 0.048 |
| 2018 | 0.178 | 0.042 | 0.18 | 0.11 | 0.15 | 0.13 | 0.087 | 0.18 | 0.22 | 0.26 | 0.14 | 0.16 | 0.15 | 0.048 |
| 2019 | 0.180 | 0.042 | 0.19 | 0.11 | 0.15 | 0.14 | 0.090 | 0.18 | 0.22 | 0.26 | 0.14 | 0.17 | 0.16 | 0.048 |
| 2020 | 0.175 | 0.041 | 0.18 | 0.14 | 0.11 | 0.13 | 0.087 | 0.18 | 0.22 | 0.26 | 0.14 | 0.17 | 0.15 | 0.046 |
| Average | 0.206 | 0.050 | 0.22 | 0.13 | 0.17 | 0.17 | 0.096 | 0.22 | 0.25 | 0.28 | 0.16 | 0.17 | 0.17 | 0.060 |

* Note: The data were calculated and organized using MATLAB R2022a software. G_T, G_Wt, and G_nbT represent the overall Gini coefficient, within-region Gini coefficient, and between-region Gini coefficient, respectively. E, C, W, and NE represent the East, Central, West, and Northeast regions, respectively.

According to Figure 10a, the Gini coefficient of China's digital business environment shows a continuous decrease throughout the entire observation period, indicating a declining trend in the overall spatial disparity of the digital business environment in China. Looking at the internal spatial disparities within the four major regions, the Eastern region exhibits the highest level of internal disparity, while the Northeast region shows the lowest level, but experiences a sharp increase in disparity during the later stage of development. In terms of trend, the Gini coefficients of the Eastern, Western, and Northeast regions all exhibit a pattern of initial decrease, followed by an increase, and then a decrease again. On the other hand, the Central region shows a trend of initial decrease followed by an increase, with smaller changes in the Gini coefficient compared to the Western and Northeast regions. These results indicate that significant regional disparities still exist in China's digital business environment. The internal disparities in the Eastern, Western, and Northeast regions are gradually narrowing, while the Central region shows an increasing level of disparity.

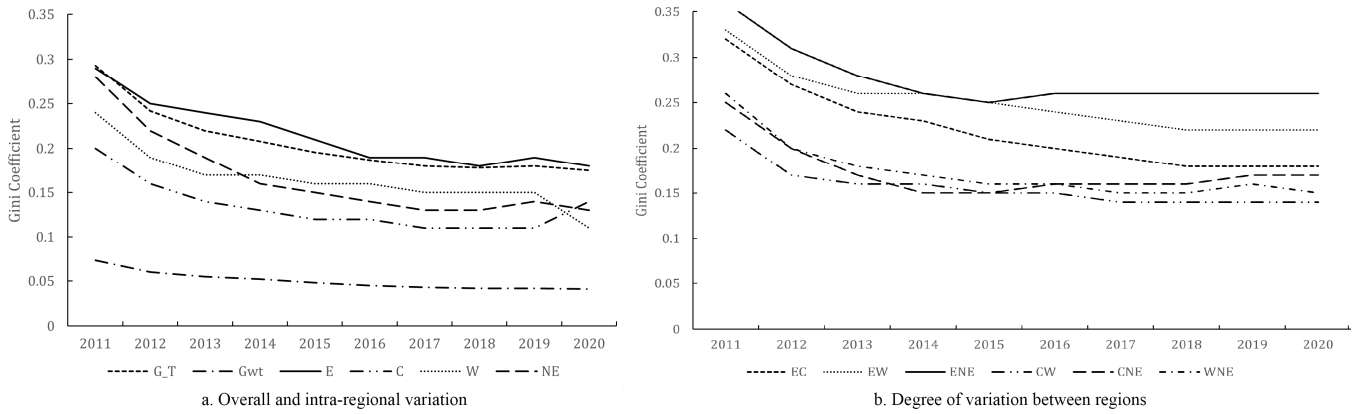


**Figure 10.** Trend of the Gini coefficient in China's digital business environment.

Figure 10b depicts the trend of Gini coefficients among regions in China's digital business environment during the study period. According to Figure 10b, the average Gini coefficient between the East and Northeast regions is 0.28, indicating the highest level of regional disparity. The decreasing order of spatial disparity is as follows: East vs. West,

East vs. Central, Central vs. Northeast, and West vs. Northeast, with the lowest level of disparity observed between the Central and Western regions.

In terms of the trend, most regions show a tendency of decreasing spatial disparity. The largest decrease in Gini coefficient is observed between the Northeast and Central regions, with an average annual decline of 6.1%. The decreases in Gini coefficients between the East and Northeast regions and between the Central and Northeast regions are relatively smaller, with average annual declines of 3.4% and 3.8% respectively. However, starting from 2015, there has been an upward trend in the Gini coefficient between the Central and Northeast regions, with an average annual increase of 2.99%.

Figure 11 illustrates the changing trends of the contribution rates of each component to the overall Gini coefficient during the study period. According to Figure 9, the contribution rate of inter-regional disparity to the overall spatial disparity is the highest. This finding is consistent with the research conducted by [24] and shows a continuous increasing trend. The second-highest contribution rate is attributed to the super-variation density, while the contribution rate of intra-regional disparity to the overall disparity shows relatively smaller changes and has the smallest contribution rate to the overall disparity.

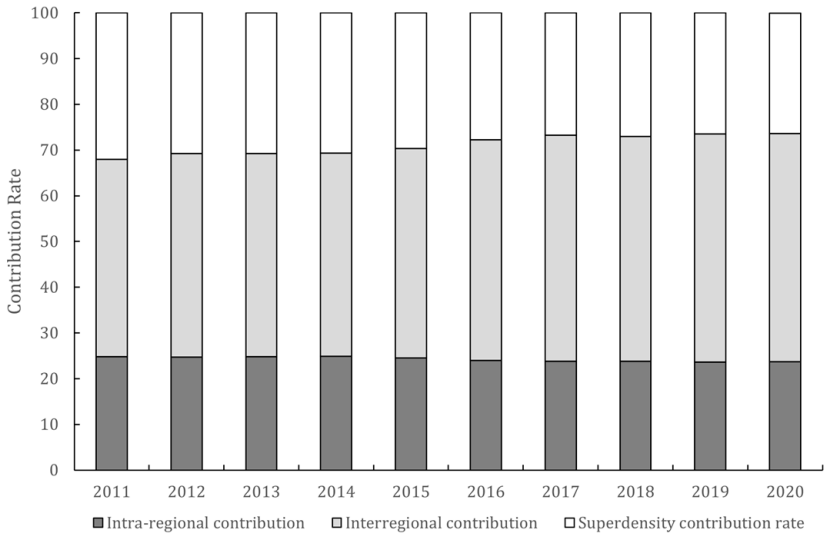


**Figure 11.** The contribution rates of spatial disparity in China's digital business environment.

These results indicate that inter-regional disparity is the main source of spatial disparity in the digital business environment, referring to the differences in the digital business environment across different regions. The second-highest contribution comes from the super-variation density, while the contribution of intra-regional disparity to the spatial disparity in the digital business environment is relatively minor.

### *5.5. The Sustainable Development Path of Digital Business Environment*

#### 5.5.1. Data Calibration

The variables in this study primarily represent wo aspects. The antecedent variables consist of various dimensions of the digital business environment, including digital infrastructure environment, digital market operations environment, digital governance environment, digital industry integration environment, and innovation-driven environment. The outcome variable is the level of development of the digital business environment. Prior to analyzing the data using the QCA method, it is necessary to set anchors for the data to mitigate the biases introduced by subjective judgment. Following the approach of previous studies, this research adopts the direct method and sets three anchors: full membership (95th percentile), midpoint (50th percentile), and full non-membership (5th percentile) [81]. The calibration information for each condition and outcome is presented in Table 6.

**Table 6.** Descriptive statistics and data calibration.

| Variable | Mean | Stan. Dev | Min | Max | Sample | Calibration Value |
|---|---|---|---|---|---|---|
| DBE | 0.205 | 0.078 | 0.121 | 0.650 | 272 | (0.288;0.183;0.143) |
| DIE | 0.192 | 0.011 | 0.173 | 0.255 | 272 | (0.205;0.188;0.183) |
| DMOE | 0.614 | 0.041 | 0.573 | 0.834 | 272 | (0.666;0.600;0.584) |
| DGE | 0.164 | 0.014 | 0.129 | 0.213 | 272 | (0.180;0.164;0.146) |
| DIIE | 0.163 | 0.013 | 0.154 | 0.248 | 272 | (0.177;0.159;0.155) |
| IDE | 0.073 | 0.006 | 0.071 | 0.138 | 272 | (0.075;0.071;0.070) |

#### 5.5.2. Necessity Analysis

In the NCA method, the effect values of the antecedent conditions should be above 0.1 [82], and the significance of the effect size should be less than 0.01 [83]. Table 7 presents the results of the NCA analysis, primarily using the CR and CE methods to calculate the effect sizes. The effect values of all the antecedent conditions are above 0.1, but the *p*-values are greater than 0.01, indicating that the significance did not pass the test. This suggests that the effect values did not pass the high-level test, while the *p*-values passed the test, indicating that the individual antecedent conditions do not constitute necessary conditions for a sustainable digital business environment.

**Table 7.** Necessary condition analysis results.

| Conditions [1] | Method | Accuracy | Ceiling | Scope | Effect Size [2] | *p* [3] |
|---|---|---|---|---|---|---|
| DIE | CR | 94.9% | 0.236 | 0.99 | 0.24 | 0.000 |
| | CE | 100% | 0.165 | 0.99 | 0.17 | 0.000 |
| DMOE | CR | 94.1% | 0.323 | 0.98 | 0.33 | 0.000 |
| | CE | 100% | 0.293 | 0.98 | 0.30 | 0.000 |
| DGE | CR | 94.5% | 0.252 | 0.99 | 0.26 | 0.000 |
| | CE | 100% | 0.239 | 0.99 | 0.24 | 0.000 |
| DIIE | CR | 97.4% | 0.171 | 0.96 | 0.18 | 0.000 |
| | CE | 100% | 0.094 | 0.96 | 0.10 | 0.000 |
| IDE | CR | 97.1% | 0.188 | 0.95 | 0.20 | 0.000 |
| | CE | 100% | 0.159 | 0.95 | 0.17 | 0.000 |

Note: [1] the data used consist of calibrated fuzzy set membership values. [2] $0 \leq$ effect size $< 0.2$: "low level", $0.2 \leq$ effect size $< 0.5$: "medium level", effect size $\geq 0.8$: "high level" [84]. [3] Permutation tests (with 10,000 resamples) were conducted in the NCA analysis.

Table 8 displays the necessary levels of conditions required for the occurrence of outcomes at established levels. To achieve a sustainable digital business environment, it is necessary to have the combined effect of different levels of antecedent conditions. The analysis shows that to reach maximum performance, the DIE level must be 86%, the DMOE level must be 91.2%, the DGE level must be 77.8%, the DIIE level must be 71.3%, and the IDE level must be 89%.

**Table 8.** Bottleneck analysis of necessary conditions.

| DBE | DIE | DMOE | DGE | DIIE | IDE |
|---|---|---|---|---|---|
| 0 | NN | NN | NN | NN | NN |
| 10 | NN | NN | NN | NN | NN |
| 20 | NN | NN | NN | NN | NN |
| 30 | NN | 2.9 | NN | NN | NN |
| 40 | NN | 15.5 | 6.5 | NN | NN |
| 50 | 8.5 | 28.1 | 18.4 | 0.0 | NN |
| 60 | 24 | 40.7 | 30.3 | 14.3 | 8.8 |
| 70 | 39.5 | 53.3 | 42.2 | 28.5 | 28.8 |
| 80 | 55 | 66 | 54 | 42.8 | 48.9 |
| 90 | 70.5 | 78.6 | 65.9 | 57 | 69 |
| 100 | 86 | 91.2 | 77.8 | 71.3 | 89 |

Before conducting configurational analysis, it is necessary to assess the necessity of individual antecedent conditions. Following the criteria for necessity analysis from existing research, this study sets the consistency threshold for necessity analysis at 0.9 [85]. Table 9 shows that only a few antecedent conditions have consistency coefficients greater than 0.9, indicating that most conditions are not necessary for a sustainable/non-sustainable digital business environment.

**Table 9.** Necessary conditions influencing the sustainability of the digital business environment.

| Conditions | Sustainable Digital Business Environment | ~ Sustainable Digital Business Environment |
|---|---|---|
| DIE | 0.813 | 0.420 |
| ~ DIE | 0.516 | 0.866 |
| DMOE | 0.906 | 0.422 |
| ~ DMOE | 0.518 | 0.946 |
| DGE | 0.895 | 0.432 |
| ~ DGE | 0.455 | 0.872 |
| DIIE | 0.812 | 0.407 |
| ~ DIIE | 0.509 | 0.872 |
| IDE | 0.861 | 0.405 |
| ~ IDE | 0.542 | 0.946 |

"~" represents the absence of conditions.

Based on the comprehensive analysis of the data, it can be observed that the effect sizes of the necessary conditions in NCA are all below 0.5. This indicates that the preceding conditions from 2018 to 2021 are necessary at a low or moderate level for the outcome variable but are not necessary conditions for creating a sustainable digital business environment. Therefore, this study suggests that there are no individual necessary preceding conditions that lead to a sustainable digital business environment, highlighting the need for a comprehensive analysis of the combined factors.

#### 5.5.3. Sufficiency Analysis

Based on the existing research, this study sets the original consistency threshold at 0.8 [79], the case frequency threshold at 1, and the PRI (Pattern Relationship Index) consistency threshold at 0.5 [86]. As no necessary conditions influencing the digital business environment were identified in the necessity analysis stage, it is assumed that the presence or absence of individual preceding conditions can impact the digital business environment during configurational analysis.

From the configuration distribution in Table 10, it can be observed that there are four configurations contributing to the development of a sustainable digital business environment. The core conditions driving the development of a sustainable digital business environment are digital governance environment, digital market operation environment, digital industry integration environment, and innovation-driven environment. On the other hand, there are four configurations leading to a non-sustainable digital business environment, primarily due to the absence of core conditions such as the innovation-driven environment, digital market operation environment, and digital industry integration environment.

**Table 10.** Sufficiency analysis of antecedent conditions under different results.

| Conditions | Sustainable Digital Business Environment | | | | ~ Sustainable Digital Business Environment | | | |
|---|---|---|---|---|---|---|---|---|
| | **S1** | **S2** | **S3** | **S4** | **NS1** | **NS2** | **NS3** | **NS4** |
| DIE | • | | | ⊗ | | ⊗ | ⊗ | ⊗ |
| DMOE | ● | ● | | ⊗ | ⊗ | ⊗ | | ⊗ |
| DGE | | ● | ● | ● | ⊗ | | ⊗ | • |
| DIIE | | | ● | ● | | | ⊗ | ⊗ |
| IDE | ● | ● | ● | | ⊗ | ⊗ | ⊗ | |
| Consistency | 0.986 | 0.994 | 0.991 | 0.965 | 0.975 | 0.974 | 0.993 | 0.986 |
| Raw Coverage | 0.706 | 0.773 | 0.706 | 0.338 | 0.810 | 0.811 | 0.659 | 0.367 |
| Unique Coverage | 0.038 | 0.032 | 0.007 | 0.024 | 0.092 | 0.026 | 0.017 | 0.007 |
| Solution Consistency | 0.968 | | | | 0.960 | | | |
| Solution Coverage | 0.868 | | | | 0.927 | | | |

Note: "●" refers to the occurrence of core conditions "⊗" refers to the absence of core conditions, "•" refers to the occurrence of peripheral conditions, "⊗" refers to the absence of peripheral conditions, Blank indicates no impact on the configuration. "~" means the Unsustainable digital business environment

(1) Configurations leading to a sustainable digital business environment. S1 demonstrates a configuration in which digital market operation and innovation environment are core conditions, while digital infrastructure serves as an edge condition, resulting in a sustainable digital business environment. The presence or absence of other conditions does not have any impact on the final outcome. S2 indicates that a sustainable digital business environment can be achieved through the driving forces of digital market operation, digital governance, and innovation environment, while the development of digital infrastructure and digital industry integration has no significant effect on the final outcome. S3 confirms that the three driving factors of digital governance, digital industry integration, and innovation environment contribute to the development of a sustainable digital business environment, with the influence of digital infrastructure and digital market operation being negligible. S4 illustrates that even with low levels of digital market operation and digital infrastructure, as long as there are high levels of digital governance and digital industry integration as core conditions, a sustainable digital business environment can be established. In this configuration pathway, the presence of an innovation environment does not have any impact on the outcome. Overall, the coverage rate of configurations leading to a sustainable digital business environment is 0.868, indicating that the results encompass approximately 87% of the samples, thus confirming the validity of the generated configuration paths.

(2) Configurations leading to a non-sustainable digital business environment. NS1 and NS2 indicate that a non-sustainable digital business environment is likely to occur when the level of digital market operation environment and innovation environment in a city is low, and when the levels of digital governance or digital infrastructure are also low. NS3 shows that a non-sustainable digital business environment occurs when there are low levels of digital industry integration and innovation environment, accompanied by low levels of digital infrastructure and digital governance. However, the level of digital market operation does not significantly impact the outcome. NS4 demonstrates that even with improved digital governance, the absence of core conditions such as digital market operation and digital industry integration, as well as the absence of digital infrastructure as an edge condition, leads to a non-sustainable digital business environment. In summary, the configurations resulting in non-sustainable digital business environments have a coverage rate of 0.927, indicating that the results encompass approximately 93% of the samples, thus confirming their validity

The robustness of the antecedent configuration of the scale of digital economy is tested by adjusting the calibration sub-points. The specific practice is to adjust the "no affiliation at all" (0.05) and "full affiliation" (0.95) to "no affiliation at all" (0.25) and "full affiliation" (0.75), respectively, and the other steps remain unchanged. In the output results, the core

conditions and configuration paths do not change substantially, which proves that the conclusions of this paper are robust.

## 6. Conclusions and Policy Implications

### *6.1. Conclusions*

Given the critical role of the digital business environment in the realization of high-quality development of the digital economy, based on a deep understanding of the digital business environment and ecosystem theory, this study constructed the evaluation index system of the digital business environment and applied the entropy weight method to estimate the digital business environment of 272 Chinese cities from 2011 to 2020. It further studied the spatial characteristics of the digital business environment from a geospatial perspective. Our main findings are summarized as follows.

Firstly, in general, China's digital business environment has shown a year-on-year increase in development level, with an accelerated growth rate after 2017. At the same time, the digital business environment in China exhibits a right-skewed distribution, indicating that the majority of cities have lower digital business environment indices, while a small number of cities have higher levels. Overall, China's digital business environment is still in its early stage, characterized by low levels and imbalances.

Secondly, in terms of temporal evolution, the overall kernel density curve of China's digital business environment shows an increasing right-tail trend over time. This indicates a widening gap between cities with high digital business environment levels and the average level nationwide. Examining the temporal evolution by region, the digital business environment levels in the four major regions have generally improved, following the trend of East > Central > West > Northeast in terms of development. In terms of spatial evolution characteristics, we found that the Chinese digital business environment has a significant spatial positive correlation by calculating Moran's I. The LISA clustering map shows that, in 2011, H–H clustering cities were mainly distributed in the Yangtze River Delta, the Pearl River Delta, Tianjin, Yantai, and Qingdao, while L-L clustering cities were distributed in Gansu, Ningxia, Shaanxi, Baoshan, Lincang, Tongliao, Jiamusi, and Jixi. However, in 2020, cities with the L-L agglomeration type were distributed in Northwest and Northeast China, such as Gansu, Liaoning, and Heilongjiang.

Thirdly, the Dagum Gini coefficient indicates that there is a certain level of disparity in China's digital business environment, and this disparity has gradually decreased over time. The internal disparities within the Eastern, Western, and Northeastern regions in terms of the digital business environment have shown a tendency to gradually decrease, while the Central region has exhibited an increasing trend in internal disparities. In terms of inter-regional disparities, the greatest disparity exists between the Eastern and Northeastern regions, while the smallest disparity is observed between the Central and Western regions. Inter-regional disparities are the main source of spatial distribution differences in the digital business environment, followed by hyper-variability density, with internal disparities within regions contributing the least to spatial disparities in the digital business environment.

Lastly, the study identified four configuration paths that lead to the achievement of a sustainable digital business environment. In configurations S1 and S2, both high levels of digital market operation environment and innovation environment are present. In this context, sustainable digital business environment outcomes can be achieved with a certain level of digital infrastructure environment or a high level of digital governance environment; that is, the platform streamlines B2B commercial structures by connecting customers, products, suppliers, markets, and other relevant information [87]. In configurations S3 and S4, high levels of digital governance environment and digital industry integration environment are present. In this case, sustainable digital business environment development can be achieved with a high level of innovation environment, without the need for digital infrastructure environment and digital market operation environment. Additionally, the research also identified four paths that lead to non-sustainable digital business environ-

ment configurations. It can be observed that the configuration of antecedent conditions for non-sustainable digital business environment outcomes is not a complement of the antecedent condition configuration for a sustainable digital business environment. Low levels of digital market operation environment and innovation environment serve as the primary driving conditions. Furthermore, in the presence of low levels of digital industry integration, insufficient innovation or an unfavorable digital market operation environment can also lead to non-sustainable digital business environment outcomes.

### *6.2. Policy Implications*

The above findings can provide policy insights for policymakers to improve the digital business environment.

First, based on the results of various dimensions of the evaluation of the digital business environment, it is evident that regions with a higher level of digital business environment development are primarily concentrated in the Eastern and Central parts of the country, particularly in the Beijing–Tianjin–Hebei region, the Yangtze River Delta, and the Pearl River Delta. These regions share common characteristics, including widespread digital infrastructure, a larger digital market scale, a higher level of digital governance, deeper industry integration, and a more vibrant innovation ecosystem. Thus, cities should increase investment in digital infrastructure to improve the accessibility and coverage of Internet infrastructure, ensuring seamless integration between online and offline business operations. Additionally, efforts should be made to promote talent development, innovation, and entrepreneurship. This involves enhancing digital literacy, improving policies for talent attraction, establishing support institutions for innovation and entrepreneurship, providing financial and resource support, and nurturing innovative enterprises and entrepreneurs. Importantly, stability and predictability of the digital business environment must be ensured. This requires establishing a sound legal framework encompassing areas such as data protection, cybersecurity, and e-commerce, providing legal safeguards and regulations for the high-quality development of the digital economy.

Secondly, harnessing the spillover effects of regions with a high level of digital business environment can help alleviate regional disparities. Through an analysis of the spatial characteristics of digital business environment development, it becomes apparent that there are regional variations in the level of development across China. Regions with higher development levels are primarily concentrated in the Eastern coastal areas, including the Yangtze River Delta, the Pearl River Delta, and the Beijing–Tianjin–Hebei region. Furthermore, there are observable patterns of "H-H" clustering, "L-H" clustering, and "H-L" clustering. It is also observed that cities with lower levels of digital business environment are more likely to transition to a higher level when surrounded by cities with a high level of digital business environment. This highlights the significant positive spillover effects of the digital business environment.

As pioneers in the rapid development of the digital business environment in China, the Eastern regions should proactively leverage their geographical and developmental advantages to amplify the spillover effects of economic growth. Emphasizing the chain effect and gradually fostering a cooperative development trend can stimulate the growth of surrounding areas, particularly in supporting the development of Western regions. This will enable the maximization of the overall utility of the digital business environment development level.

Thirdly, it is essential to further enhance the diffusion mechanisms that optimize the digital business environment, addressing issues of imbalance and insufficiency in its development. Through an analysis of the sustainable development path of the digital business environment, four configurations of antecedent conditions leading to a sustainable digital business environment have been identified, each supported by real-world urban case examples. For regions with a higher level of digital business environment development, it is crucial to promptly and comprehensively synthesize relevant experiences and leverage the advantages in the digital technological environment, digital market operation environment,

digital governance environment, digital industry integration environment, and innovation-driven environment. These valuable optimization experiences can then be generalized to identify common patterns. This will enable the optimization of antecedent condition configurations for the digital business environment within existing constraints, maximizing the effectiveness of optimization measures. By aligning the supply of the digital business environment with the actual demands of high-quality digital economic development, the coordinated growth of both can be fostered. For regions with medium to low levels of digital business environment development, a two-step strategy is recommended, taking into consideration local characteristics and development realities. Firstly, learning from cities that share similar development attributes and drawing on their successful experiences, while adapting them to local conditions, will enable a process of localization. Secondly, innovation and surpassing mere imitation become paramount. Once the local digital business environment reaches a certain level, further innovations are needed to transform and enhance it; for example, increasing investments in digital infrastructure, improving the efficiency of "Internet+ government service platforms," and ultimately strengthening the business environment's foundation to create a more favorable, stable, and appealing digital business environment for investment.

### *6.3. Limitations and Future Research Directions*

This study has certain limitations that need to be addressed in future research. Firstly, the evaluation of the digital business environment in this study was based on five dimensions: digital infrastructure, digital market operation, digital governance, digital industry integration, and innovation environment. However, the digital business environment is a complex multi-stakeholder system, and there may be additional dimensions that should be considered. Therefore, future research should explore the inclusion of more factors to ensure a more comprehensive and scientifically grounded evaluation of the digital business environment. Secondly, this study employed the entropy weight method as the sole approach for evaluating the digital business environment. However, there are alternative evaluation methods such as the Analytic Hierarchy Process (AHP), Principal Component Analysis (PCA), and Grey Relational Analysis. Future research could consider integrating subjective and objective approaches to provide evaluation results that are more reflective of the actual development situation. Thirdly, the analysis of sustainable development strategies for the digital business environment in this study relied on cross-sectional data from 2020. However, it is important to recognize that the optimization of the digital business environment is not a static process and requires a long-term perspective. Future research could employ dynamic panel data and utilize fsQCA analysis or a system dynamics model to uncover valuable insights into the general dynamic patterns of digital business environment development. This would enable the formulation of more constructive policy recommendations for optimizing the digital business environment. In summary, addressing these limitations in future research will contribute to a deeper understanding of the digital business environment and facilitate the development of effective strategies to enhance its sustainability.

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