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EXPLORATION OF MULTIPLE ENHANCING PATHWAYS OF DIGITAL ECONOMY DEVELOPMENT OF CITY CLUSTERS USING FUZZY-SET QUALITATIVE COMPARATIVE ANALYSIS

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Abstract. As a crucial catalyst for worldwide economic expansion, the digital economy (DE) has garnered widespread attention and has been regarded as crucial for the promotion of economic growth and innovation. The development of the DE brings both significant opportunities and challenges to city clusters. It enhances urban competitiveness, improves residents' quality of life, and strengthens urban governance, which is of great significance for the development of city clusters. In this context, although previous studies comprehensively analyzed the advancement of the DE of certain cities and revealed their strategies, challenges, and successful experiences in the development of their DE, research on the determinants and enhancing pathways of the digital economy development of city clusters (DEDCC) is scant. As the core node of DE development, city clusters, as well as their potential and influence, cannot be ignored. Therefore, this study investigates the Shandong Peninsula Urban Agglomeration in China, constructs a theoretical analysis framework for the DEDCC, and utilizes fsQCA (Fuzzy-set Qualitative Comparative Analysis) to examine the complex causal processes of the DEDCC. The fsQCA method is utilized from a configurational perspective to explore the complex driving mechanisms of DEDCC. The objective is to investigate the pathways for enhancing DEDCC and provide insights for the DE development of other city clusters. Results reveal the following: (1) the reciprocal collaboration between market factors and fundamental factors should be examined to accelerate the high-quality DEDCC. (2) technological innovation (TI) capacity is a crucial determinant of the high-quality DEDCC. (3) the coordinated development of the market, the foundation, and TI should be prioritized to achieve the high-quality DEDCC.

Keywords: digital economy, qualitative comparative analysis, enhancing pathway, city cluster.

JEL Classification: C18, O18, R11, R58.

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1. Introduction

The worldwide management of economic affairs is transitioning into a new phase as a result of digital transformation (Furr et al., 2022; He et al., 2020). The swift advancement of the DE has become a significant motivator for worldwide economic expansion and societal transformation (Dong et al., 2022). In recent years, the DE has had a significant impact on economic development worldwide. For instance, in the European Union (EU) region, the DE has become an integral part of the economy, contributing over 5% of the EU's GDP (Szeles & Simionescu,

2020). In the Asian region, the DE has facilitated the transformation and upgrading of traditional industries, overcoming past development barriers and bringing new opportunities for the region, leading to structural economic transformation and innovation implementation (Li et al., 2020). Furthermore, the DE has stimulated economic growth in countries along the Belt and Road Initiative by promoting industrial upgrading and employment structure adjustment (Zhang et al., 2022). Based on this background, the Chinese government also prioritizes the advancement of the DE and considers it as a key national policy in the "14th FYP for the Development of the Digital Economy" ("14th FYP for Digital Economy"). The policy explicitly advocates for the acceleration of the progress of the DE and generation of novel benefits in the field. As an agglomeration of economic activities and a spatial carrier of economic development (Fang & Yu, 2017), the level of the DEDCC can significantly influence the advancement of the local DE and the national DE.

An urban agglomeration is a significant catalyst for economic growth and the central node for DE development (Huang et al., 2020). The DEDCC represents the collaboration of the cities in an urban agglomeration to collectively advance the development of the DE (Su et al., 2022). The Silicon Valley region in the United States encompasses multiple cities and towns and is renowned for its innovative and technology-driven economic model. The region extensively utilizes digital technology, which have facilitated the rapid development of the DE (Wahome & Graham, 2020). In the Jakarta metropolitan area, which is the largest city cluster in the global south, the rise of the middle class has played a significant role in driving the development of the DE (Kurnia et al., 2023). As a result of the rapid advancement of globalization and digital technology, city clusters, as closely connected aggregates of adjacent cities and regions, have a large market size, rich resource advantages, and a strong innovation ability (Wang et al., 2022b). In this context, an in-depth examination of the enhancing pathways of the DEDCC is important for fostering the advancement of the DE.

Researchers have conducted thorough investigations in the DE domain. Despite differences in the definition and scope of the DE, a consensus has been reached that the DE encompasses a broad spectrum of economic activities facilitated by digital technology (Pan et al., 2022; Ren et al., 2022; Wang et al., 2022a). Investigations on the elements that can influence the DE found that TI, the digital infrastructure, the policy and legal environment, market demand, and consumer behavior are important factors that can influence DE development (Fast et al., 2023; Hosan et al., 2022; Liang & Li, 2023; Luo et al., 2023; Xia et al., 2024). In research on DE development paths, the endogenous growth path, the extension expansion path, the TI path, and the institutional innovation path represent different aspects of DE development. By emphasizing important factors at the internal and external, technical, and institutional levels, the aforementioned research offered theoretical and practical directions for the sustainable development of the DE (Chen, 2023; Huang et al., 2023a; Liang & Tan, 2024; Wan et al., 2023).

Although explorations have been conducted on the influencing factors and enhancing path of DE development, previous studies focused mostly on the impact of one or multiple factors on the growth of the DE and ignored the synergy of multiple influencing factors (Zhong et al., 2024). Moreover, research concentrated primarily on the theoretical aspects of the development trajectory of the DE but did not fully explore the complex configuration mechanism of the trajectory. At the same time, research on the advancement of the DE re-

lied primarily on the examination of certain cities through case studies and lacked in-depth investigations into the DEDCC (Charnock & Ribera-Fumaz, 2024; Zhu & Chen, 2022).

This study takes 16 prefecture-level cities in the Shandong Peninsula Urban Agglomeration (SPUA) in China as the research object and uses fsQCA as the research method. In addition, this study develops a research framework for the DEDCC based on the literature research and selects digital transaction (DTR), digital operation (DO), digital infrastructure (DI), digital R&D (DRD), digital technology (DTE), and other factors from the three main aspects of the market, the foundation, and TI. This study aims to analyze the factors that can impact the DE of the SPUA from a configuration perspective and investigate strategies for promoting intercity DE development. This study demonstrates innovation in the following aspects: (1) The analysis of this research reveals the synergistic effects among multiple influencing factors in the DEDCC, uncovering its complexity and diversity. It identifies multiple pathways for enhancing the DEDCC. (2) By adopting a city cluster perspective rather than focusing on a single city, this study sheds light on the interactions and network effects within and between city clusters in DE development. This perspective provides valuable insights into the dynamics of the DE in city clusters. (3) The fsQCA method application provides a new perspective that helps us understand the complex DE phenomena in city clusters. It provides a systematic approach to analyzing multiple causal configurations and exploring the conditions and combinations of factors that lead to specific outcomes.

The remaining parts of this paper are outlined as follows: Section 2 provides an overview of and condenses the literature, and Section 3 introduces the research methods, research object, theoretical framework, and index setting. Section 4 employs the fsQCA approach to empirically examine the enhancing pathways of the DE of the SPUA, and Section 5 presents the findings of the empirical investigation and examines them from theoretical and practical perspectives. The last Section summarizes the content, contributions, and shortcomings of the research and expresses the expectation of the improvement of the DEDCC.

2. Literature review

2.1. Concept and connotation of DE

The DE is a modern economic paradigm that emerged following agricultural and industrial economies and a new stage of economic development (Carlsson, 2004). The DE is a series of economic activities that use digital knowledge and information as key production factors, modern information network as an important carrier, and the effective use of information and communication technology (ICT) as an important driving force for efficiency improvement and economic structure optimization (Pan et al., 2022; Ren et al., 2022).

From a macro perspective, the DE is based on DTE, with data as the core element (Ayres & Williams, 2004; Xiao et al., 2023), and promotes economic and social development through the Internet, big data, cloud computing, artificial intelligence, and other technological means (Flyverbom et al., 2019). The emergence of the DE significantly influenced the entire economic system, changed traditional industrial structures and business models, and promoted economic growth and innovation (Cheng et al., 2023). From a mid-level perspective, the DE involves two aspects: digital industrialization and industrial digitalization. Digital industrializa-

tion entails the utilization of DTE to create novel products and services, including software, hardware, data services, and so on (Yuan et al., 2021; Yüksel & Dinçer, 2023). Meanwhile, industrial digitalization entails the utilization of DTE to revolutionize and enhance conventional industries, such as manufacturing, agriculture, services, and so on (Hao et al., 2023). From a micro perspective, the DE involves the digital transformation and innovation of individuals and enterprises (Gong & Ribiere, 2021). Individuals and businesses can enhance their worth by leveraging DTE and data resources to enhance their production efficiency, streamline their administration, and generate novel products and services (Belhadi et al., 2023).

Although existing studies clearly defined the concept of the DE, they have limited discussions on the connotation of the DEDCC and a limited understanding of the specific characteristics and internal mechanisms of the DEDCC and conducted insufficient investigations into the fundamental components of the DEDCC and their interconnection in urban areas.

2.2. Factors affecting DE development

The DE is important to the global economy and can significantly influence economic expansion, innovation, and social progress (Si et al., 2023). By examining the variables that can influence the growth of the DE, we can deeply understand the dynamic characteristics and development trend of the DE and determine the differences in and the characteristics of DE development in different countries and regions (Guo et al., 2023).

The development of DI is crucial to the healthy development of the DE, which requires sound DI to support the transmission, storage, and processing of information and data, including broadband networks, cloud computing services, and data centers (Luo et al., 2023; Pan et al., 2022). Simultaneously, as novel DTE emerges, such as artificial intelligence, the Internet of things, blockchain, and so on, technological progress can provide new opportunities and possibilities for the DE (Teece, 2018; Xia et al., 2024). Technological advancements can have a substantial impact on the development of the DE. The emergence and progress of DTE completely transformed the production methods and business models of conventional industries and facilitated the transition and enhancement of the DE. DTE advancement also resulted in the development of innovative corporate structures and market opportunities as it enhanced production efficiency (Ancillai et al., 2023; Hosan et al., 2022). The DM plays a crucial role in driving DE demand and consumption. Changes in market demand and consumer demand can determine the development direction and scope of the DE. The market system efficiently allocates resources and attracts investment while providing essential capital and resource support for the growth of the DE (Fast et al., 2023; Watanabe et al., 2018). Legal and policy frameworks can also significantly influence the advancement of the DE. Specifically, the development and innovation of the DE can be supported and ensured by laws and regulations, as well as by intellectual property protection, data privacy protection, and other policies (Beaumier et al., 2020; Liang & Li, 2023).

Researchers have conducted thorough analyses on the factors that can influence the DE. However, current research concentrated primarily on individual or multiple elements that can influence conventional urban digital economy UDE, and in-depth research on the factors that can influence the DEDCC is scant. In addition, a variety of factors can affect the development of the DE, but comprehensive research on how such factors interact is scarce.

2.3. Research on development path of DE

The DE has become a powerful catalyst for economic development and presented opportunities for a new wave of scientific and technological advancements and industrial transformations (Yi et al., 2024). An examination of the enhancing pathways of the DE can offer a fresh outlook for theoretical investigations in the realm of the DE to further understand the law of DE development. Such an examination can also provide guidance for DE development practice and help us effectively grasp the DE development trend (Tan et al., 2023).

Current research on the development path of the DE mainly covered the endogenous growth path, the extension expansion path, the TI path, and the institutional innovation path. The endogenous growth path prioritizes the enhancement of internal elements within the DE to achieve development by enhancing production efficiency, reducing costs, and promoting economic growth (Liang & Tan, 2024). The extension expansion path focuses on external DE factors, including the growth of the market, the increase in investments, and the enhancement of technological capabilities. This path can promote the development of the DE by expanding the market share, attracting increased investments, and introducing advanced technology and other external factors (Dai et al., 2023; Wan et al., 2023). The TI path asserts that TI is the foundation for the advancement of the DE and can facilitate its growth by introducing novel technologies and solutions (Huang et al., 2023a; Zhou et al., 2020). Meanwhile, the institutional innovation path focuses on the institutional innovation of DE development and provides a favorable environment for DE growth by reforming and innovating existing systems (Chen, 2023; Ye & Zeng, 2024).

The DE has become a vital driver of worldwide economic advancement. However, the theoretical framework and the selection of development paths for the DE must be examined comprehensively and enhanced. The multifaceted nature of DE development entails the involvement of various fields and factors. Thus, a substantial number of empirical studies are necessary to validate and examine the impact of several factors on the development path of the DE. Moreover, current research on the path of the DEDCC is relatively limited, thereby necessitating further explorations into the formulation and implementation of comprehensive planning and strategies for the DEDCC. Such endeavors can foster the high-quality advancement of the DE of city clusters.

2.4. Analysis of research methods related to the DE

Traditional statistical techniques commonly inform current research on DE development. Some scholars have studied the impact of DE on carbon emission reduction through regression analysis (Yi et al., 2022); other scholars have explored how DE promotes green innovation using benchmark regression models, mediating effect models, and spatial Durbin models (Luo et al., 2023). These studies generally assume that the independent variables are independent of each other, causal relationships are symmetric and unidirectional, and the marginal "net effects" of the independent variables on the dependent variable are analyzed while controlling for other factors (Khan et al., 2024).

However, the emergence of any result is not solely caused by individual factors but rather by the complex interactions among multiple factors. Traditional statistical techniques may struggle to capture this complexity (Lee et al., 2022). In contrast, the fsQCA method can help

reveal nonlinear and interactive effects among multiple factors, providing insights into issues such as multiple concurrent causal relationships, causal asymmetry, and the equifinality of multiple solutions (Fainshmidt et al., 2020).

Furthermore, research fields such as political science, sociology, and economics have widely applied the fsQCA method. Berker and Pollex used QCA to explain the differential responses of political parties to the "Fridays for Future" movement in three European countries, identifying ideological orientation, traditional stance, and environmental preferences as key factors explaining variations in party responses (Berker & Pollex, 2023). Ingrams employed QCA to evaluate the association between substantive and political factors and the degree of content change, finding that the substantive contributions of the public do influence rule-making (Ingrams, 2023). Zhao utilized the fsQCA method to explore the relationship between spatial agglomeration, DE, and institutional environment, identifying five pathways that influence firm green innovation and proposing three distinct high-level categories of green innovation for firms (Zhao et al., 2023).

While traditional statistical techniques remain mainstream in the study of DEDCC due to their ability to analyze large-scale data and linear relationships between measurements, DEDCC is a complex system involving nonlinear and interactive relationships among multiple factors. This calls for a method to better understand these complex relationships. Although the use of QCA methods in DE research in city clusters is still relatively limited, it offers unique advantages. QCA allows for a holistic examination of multiple factors in city cluster development, revealing their nonlinear and interactive relationships.

2.5. State of the digital economy research in the city cluster

Urban cluster DE refers to an economic form within the scope of urban clusters where DTE serves as the foundation and digital industries serve as the core. It leverages digital innovation and applications to drive economic development and social progress (Zhong et al., 2024). It represents the specific manifestation of the DE at the urban cluster level and emphasizes the significance of urban clusters as essential spatial units for digital economic development (Zhang et al., 2022).

Current research primarily focuses on how the DE promotes the comprehensive development of urban clusters. Firstly, the DE plays a vital role in attracting talent and investment to urban clusters. For instance, research indicates that the DE has flourished in the Greater Paris Metropolitan Area, attracting a substantial number of high-tech talents and providing sustained talent support for regional development and digital entrepreneurship (Cornet et al., 2023). Secondly, the DE development accelerates the construction of infrastructure in urban clusters. For example, the Helsinki Metropolitan Area in Finland actively invests in DI and industries to cope with the global wave of DE. These initiatives have expedited the region's economic growth and improved the residents' quality of life (Anttiroiko et al., 2020). Furthermore, the DE can improve urban clusters' ecological well-being. Taking China's three major urban clusters as an example, the DE positively impacts ecological well-being performance by improving resource utilization efficiency, reducing pollution emissions, and promoting green development (Yang et al., 2023). Finally, the DE expands the market space for urban clusters. By promoting market integration and reducing transaction costs through informa-

tion technology, the DE can expand market size, thus stimulating economic development in urban clusters (Liang et al., 2024).

Although the rapid growth of DE has positive impacts on the comprehensive development of urban clusters, the current research on factors influencing the internal development of urban cluster DE is relatively limited, lacking specific factor analysis. Therefore, there is still a need for further exploration of pathways to enhance the DE in urban clusters.

2.6. Literature summary

The literature on the development of the DE enhances and enriches the pertinent theories. Previous studies improved understanding of DE development, revealed the key elements and factors influencing the DE, and provided practical guidance to decision makers and enterprises. However, the existing research has some deficiencies. (1) The advancement of the DE exhibits variation across countries and regions, which is subject to the influence of multiple factors, such as politics, the economy, and culture. Research on the factors that may influence DE development concentrated mainly on specific domains and primarily explored individual or multiple influential factors. However, systematic and comprehensive investigations into the factors that can influence the DEDCC are lacking. (2) Studies on the development path of the DE centered predominantly around comparative analyses of single or multiple cities, which necessitates further explorations into the diverse pathways of the DEDCC. (3) Regarding analytical methodologies, the literature primarily employed traditional regression analysis to examine the influencing factors and development paths of the DE. However, traditional regression analysis focuses mainly on the isolated impact of a single factor on the outcomes and overlooks the synergistic effect of multiple conditional variables. Thus, it fails to fully explore and comprehend the intricate configuration mechanisms underlying the complexities of the DE. (3) The rapid growth of DE plays a significant role in promoting the comprehensive development of urban agglomerations. This is particularly evident in attracting talent and investment, accelerating infrastructure construction, improving ecological well-being performance, and expanding market space. However, there is relatively little and insufficiently systematic research on the specific factors that influence the rapid development of DE within urban agglomerations.

To overcome the constraints indicated in previous research, this study focuses on several objectives. (1) Based on the regional characteristics of the SPUA in China and the political, economic, and cultural differences among city clusters, combined with previous research, this study determines the factors that can influence the DEDCC and thoroughly examines the combined impact of several influencing factors on DE development to obtain comprehensive and accurate analysis results. (2) This study examines the multiple paths that may affect the DEDCC, compares and analyzes the differences between different development paths, and explores the development paths suitable for different countries or regions based on the development status, characteristics, and modes of the DE of different cities. (3) This study aims to investigate the various pathways of the DEDCC from a configuration standpoint. The DEDCC entails a substantial quantity of fuzziness and nonlinear factors. Therefore, fsQCA is selected for the empirical analysis. The fsQCA method can consider the interaction effect between different factors and find the multiple paths of the DEDCC under different factor

combinations. (4) This study explores the specific factors influencing the rapid development of DE within urban agglomerations. It analyzes the complex interrelationships among these factors and conducts an in-depth empirical analysis involving multiple urban agglomerations both domestically and internationally. The theoretical and managerial implications are discussed in detail.

3. Research design

3.1. Research object

In China's national 14th FYP, the government emphasized the need to enhance the planning and construction of city clusters and positioned them as pivotal drivers of coordinated regional development. The strategy promotes the coordinated growth of city clusters, emphasizing the reinforcement of internal coordination, facilitating the orderly flow and optimal allocation of resource elements, and ultimately establishing a novel framework for coordinated development. Furthermore, the "14th FYP for Digital Economy" explicitly identifies the DE as the third economic wave, following the agricultural and industrial economies. In addition, the DE is considered as the primary catalyst for the recent surge in scientific and technological advancements and industrial restructuring, which emphasizes its pivotal role in promoting sustainable economic growth and establishing a contemporary economic framework.

This study selects 16 prefecture-level cities, including Jinan, Qingdao, and Yantai, in the SPUA as the research object. The SPUA in China is one of the most important economic regions that are geographically adjacent and closely linked with one another. The different cities in an urban agglomeration are complementary in industrial structure and characteristics (Yan et al., 2023). The "Overall Plan for the Construction of the National Pilot Zone for Innovative Development of the Digital Economy" released by the CPC Central Committee and the State Council outlines the objective of achieving certain goals by 2025. Shandong Province will build a national DE innovation and development pilot zone, form a number of DE industrial clusters and innovation platforms with international competitiveness, and significantly enhance the level of the advancement of its DE. The "Plan for the Development of Digital Economy in Shandong Province (2021–2025)" states that by 2025, the added value of the DE of Shandong Province will contribute over 25% to its total GDP, and the added value of the core industries within the DE will experience a growth of over 100%. The initiative seeks to promote extensive integration between the DE and the tangible economy to facilitate comprehensive development in digital governance, the digital society, and digital well-being. Thus, the DE has become a prominent catalyst for the advancement of Shandong Province's economic and social development.

By choosing urban agglomeration cities as the research object, rather than a single city, this study can comprehensively consider the interaction of the different cities, analyze the correlation and influencing factors within the urban agglomeration, and reveal the overall effect of the DEDCC. The economic and industrial connections between metropolitan agglomerations have been constantly reinforced owing to the rapid advancement of the DE, and the DEDCC has become an important factor that cannot be ignored.

3.2. Research methods

The research approach used in this study is QCA, which is based on the configuration perspective. In the 1980s, sociologist Ragin (1987) took the lead in developing a QCA method (Marx et al., 2014). Initially, the QCA approach was predominantly employed in sociology, political science, and other social disciplines for conducting QCA on small sample sizes across different cases (Schneider & Rohlfing, 2013; Thomann & Maggetti, 2020). The QCA method garnered attention from management scholars owing to its effectiveness in handling large samples and analyzing complex configuration problems and has become a valuable tool for addressing the intricacies of causality in management, marketing, information systems, and other related fields (Chen & Tian, 2022; Ide & Mello, 2022; Zhu et al., 2023a). QCA can explore causality by comparing patterns and similarities between cases and does not rely on a large sample size or statistical significance, but rather focuses on understanding the complexity and context of causality (Haake & Schneider, 2023; Wang et al., 2024c).

QCA can be categorized into three types based on the variables used: csQCA (clear set qualitative comparative analysis), mvQCA (multivalued qualitative comparative analysis), and fsQCA (Thiem, 2014). CsQCA is limited to binary variables, in which the antecedents and outcomes must be calibrated to either 0 or 1. However, this restriction may result in information loss and the emergence of contradictory configurations and thus increase the complexity and challenges of the analysis. Meanwhile, mvQCA employs multivalued classification and allows for the conditions and outcomes to be multivalued nominal variables. Compared with csQCA, mvQCA is more suitable for handling variables with multiple categories and enhancing the Boolean assignment accuracy of fixed distance and fixed ratio variables (Ding, 2022). Last, fsQCA further enhances the method's capability to handle variables with a constant distance and ratio, thereby enabling the QCA to capture degree changes and partial subordination. In addition, fsQCA permits cases to have membership scores ranging from 0 (non membership) and 1 (full membership). Through the conversion of fuzzy set data into a truth table, fsQCA maintains the advantages of truth table analysis in handling qualitative data while considering the constraints of limited diversity and simple configurations. Furthermore, fsQCA exhibits the characteristics of qualitative and quantitative analysis techniques owing to its duality (Casady, 2021; Pappas & Woodside, 2021; Wang et al., 2024a; Zhai et al., 2024).

The DEDCC is a complex system involving the interactions of economic, social, technological, and policy dimensions. To effectively analyze the impact of these multi-layered factors on DEDCC, this study employs the QCA method. The QCA method is suitable for handling small datasets influenced by multiple factors. By systematically comparing and analyzing different cases, it can uncover the complex relationships and pathways of influencing factors and their combinations on DE development. Utilizing the QCA method, this study not only identifies the impact of individual factors but also explores the mechanisms of multi-factor interactions, providing a more comprehensive and detailed theoretical analysis and empirical evidence for DEDCC.

3.3. Research approach

The research approach of this paper is as follows: First, the key factors influencing the development of DE in urban agglomerations are identified as condition variables. The fsQCA method is then employed to conduct a necessity analysis, identifying which condition variables are indispensable for DEDCC. This means that, in the absence of these variables or if they do not meet certain conditions, the development of DE will be significantly constrained. Next, a configurational analysis is conducted to identify the key factors and enhancement pathways that drive DE development, as well as to explore the interactions between influencing factors. Based on the results of the QCA analysis, the paper provides policy recommendations for how policymakers can promote the development of DE in urban agglomerations. The theoretical framework is illustrated in Figure 1.

With the rapid development of the global DE, scholars have extensively studied its main directions. Information technology is a key factor in the development of the DE. The progress of information technology will continue to drive the development of the DE and give rise to new forms of digital economic activities (Wang et al., 2024b). Infrastructure development is the core competitiveness of DE development. It provides resources such as networks, data, storage, and computing for the DE, serving as a platform for innovation and development in the DE (Tan et al., 2024). The deep integration of the DE and the physical economy is an inevitable trend in the development of the DE. The DE can improve production efficiency, reduce production costs, and expand market space for the physical economy through information technology means, thereby promoting the development of the physical economy (Sun et al., 2024).

This study integrates the main directions of global DE development and is based on the key content proposed in the "14th FYP for Digital Economy" issued by the State Council of China. It emphasizes innovation-led development, optimization and upgrading of DE, and acceleration of market-oriented circulation of data elements, from the following aspects: (1) TI: Digital information technology provides infrastructure such as high-speed internet access, communication networks, and mobile communications, making the transmission, exchange, and sharing of information more convenient and widespread, thereby promoting the development of digital services (Trischler & Li-Ying, 2023). DTE innovations have introduced new

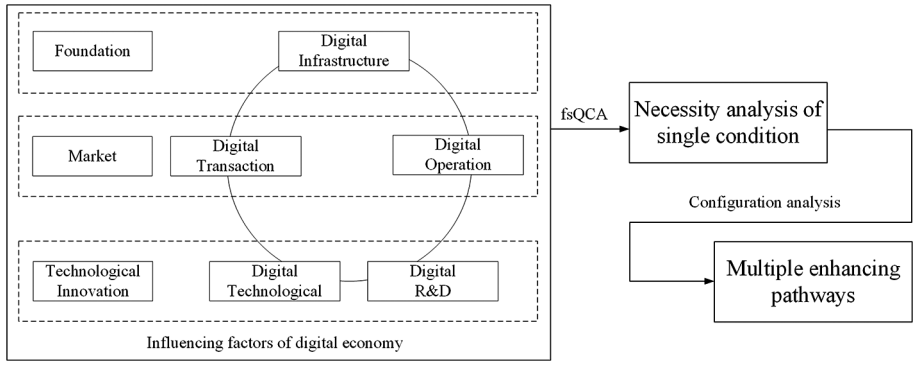

Figure 1. Theoretical model framework

business models and opportunities for digital entrepreneurship. Through TI, traditional industries can achieve digital transformation (Chen et al., 2023a; Ionescu et al., 2023), enhancing production efficiency and product quality, and facilitating the upgrading and transformation of DEDCC (Si et al., 2023); (2) the foundation: High-speed and stable internet connections, widely covered communication networks, and reliable data centers are key elements for the operation and development of DEDCC (Wang & Shao, 2023). They provide essential support for digital communication, data storage, and processing, creating the necessary conditions for various domains within DEDCC (Xing et al., 2023); (3) the market: Changes in market demand and shifts in consumer behavior are driving the direction and focus of DEDCC. Intense market competition encourages businesses and innovators to continuously introduce new products and services in the digital economy, thereby promoting DEDCC (Ancillai et al., 2023; Hagen et al., 2022). The expansion of the digital market size provides companies with broader market opportunities, attracting more investment and resources, which further facilitates the growth and prosperity of DEDCC (Tolstoy et al., 2023). This research constructs a theoretical analysis framework of the specific factors that may influence the DEDCC, in which the influencing factors interact to jointly promote the development of the DE. By reviewing and summarizing the literature, this study determines that the infrastructure provides the material basis, technical support, and application scenarios necessary for DE development (Xue et al., 2022).

The advent of TI revolutionized the functioning of conventional industries and gave rise to novel DE models and lucrative commercial prospects (Wu et al., 2022). Market rivalry, demand, resource allocation, and international cooperation can significantly influence the invention, development, and globalization of the DE (Dong et al., 2023). The three factors that can influence the DEDCC interact to form a virtuous circle. A robust infrastructure can facilitate and create favorable circumstances for TI and commercial growth. Meanwhile, TI has generated new business models and opportunities for meeting market demands and thus promoted the further development and upgrading of the infrastructure.

In summary, foundation, TI, and the market are indispensable factors in the DEDCC. The three factors mutually support and depend on one another to collectively foster the growth and continuous progress of the DE.

3.4. Variable selection

3.4.1. Conditional variables

The selection of the conditional variables depends on the theoretical framework of the factors that can influence the DEDCC constructed in this study. By reviewing the literature, this study selects the appropriate conditional variables from the three levels of TI, the foundation, and the market.

(1) TI

DRD: R&D innovation plays a crucial role in advancing and promoting the DEDCC. The DEDCC depends on advanced technology and innovative applications. The level and speed of the DEDCC can be directly affected by the strength of the TI capability (Lin & Huang, 2023). Indicators such as technology R&D investment, the number and quality of patents, and the transformation of scientific and technological achievements are typically used to measure

R&D innovation capability as a conditional variable (Fakhimi & Miremadi, 2022). This study employs the number of patent applications pertaining to the DE as a metric. The number of patent applications pertaining to the DE can serve as an indicator of the amount and caliber of R&D innovation within the DE domain (Liu et al., 2023a).

DTE: DTE is crucial in the DEDCC. The continuous advancement and widespread adoption of DTE significantly fueled the innovation and expansion of the DEDCC. In addition, it brought about transformative changes in production processes and business models, which enhanced production efficiency and improved resource utilization. DTE has empowered enterprises to efficiently manage their supply chains, facilitate e-commerce activities, implement automated production systems, and propel the overall digital transformation of the economy (Qin et al., 2023; Skare et al., 2023). This study employs income generated from information and software technology as a metric to assess the progress of DTE. A direct relationship exists between revenue from information and software technology and the advancement of DTE. As DTE develops, demand in the software industry grows, and revenue from information and software technology increases (Jin et al., 2023). Therefore, revenue from information and software technology can reflect the trend and scale of DTE development.

(2) Foundation

DI: The DI has established a strong basis for the execution of and serves as a basic guarantee for the DEDCC. The DE relies on high-speed, reliable, and secure DI, such as broadband Internet, mobile communication networks, and data centers. The development and operation of such infrastructure can directly affect the speed and scale of the DEDCC (Xiao et al., 2024). This study employs the number of Internet broadband users as a metric to quantify the DI in the SPUA. The Internet broadband user indicator can provide information on the coverage and popularity of the DI and thus reflect the development level of the DI in a region or an urban agglomeration (Wu et al., 2023).

(3) Market

DTR: DTR is one of the core components of the DEDCC. Owing to the advancement of DTE and the prevalence of the Internet, a growing number of economic activities have shifted from traditional physical transactions to DTR. The scale and growth rate of DTR are of considerable importance for the DEDCC (Geurts & Cepa, 2023). By examining DTR, we can understand the development of e-commerce and online markets, their competitive situation, and its impact on the economy. DTR holds immense importance for comprehending the business models, innovations, and competitiveness in the DEDCC (Ju et al., 2023; Zhou, 2023). This study uses e-commerce sales to express the scale of DTR. E-commerce encompasses business transactions involving products and services conducted on the Internet and via DTE. The use of e-commerce platforms has resulted in the substantial accumulation of user behavior and consumption data. The analysis of such data can help us understand the user group and market demand for DTR (Deshpande & Pendem, 2023).

DO: The "14th FYP" proposed the acceleration of digital transformation and the promotion of the high-quality advancement of the DE. As a crucial tool for facilitating digital transformation, DO plays a key role in the DEDCC. DO can increase data usage and enhance the availability of superior data components by enhancing the desirability of data packages,

providing improved network experience, and promoting data-intensive applications (Kache & Seuring, 2017). This study employs the aggregate quantity of telecommunications services as a metric to assess DO efficiency. Telecommunications services cover mobile communication and data transmission, including mobile phones, mobile data, and so on. By measuring the total amount of telecommunications services, we can understand the scale and growth trend of mobile communication and data transmission, as well as the impact of the progress and extensive use of mobile communication technologies on DO (Xia et al., 2024).

The index data of the conditional variables are sourced from the statistical yearbooks of Chinese cities, the Shandong statistical yearbook (Shandong Provincial Bureau of Statistics, 2012–2022), and the China Research Data Services platform (2022).

3.4.2. Outcome variable

According to related research, the use of relevant indicators from documents issued by research institutions as a method for measuring a construct is a common practice in academic research. Some academics utilized the digital inclusive finance index developed by the Digital Finance Research Center of Peking University as a measure to evaluate the extent of progress of digital inclusive finance. By using the measurement, researchers investigated the influence of digital inclusive finance on carbon emissions intensity in various cities across China (Zhao et al., 2023). Moreover, several scholars examined the influence of the DE on urban sustainable development by measuring the level of sustainable urban development as the outcome variable (Liu et al., 2023b). Another study investigated the correlation between DE development and haze pollution in China by referring to the "Blue Book of China Urban Digital Economic Index" (Che & Wang, 2022).

This study employs the development level of the UDE as the dependent variable. The "Blue Book of China Urban Digital Economic Index" (National Information Center, 2021) uses the DE index of 16 prefecture-level cities in the Shandong Peninsula in China as the measurement index for the result variable. The Blue Book was jointly released by the Cloud Computing and Big Data Research Institute of the China Academy of Information and Communications and the DE Research Institute of the Xinhua Group. The index covers the core content of the DE, the digital government, and the digital society and is consistent with the DE development requirements listed in China's National 14th FYP. The primary objective of the Blue Book is to investigate the trajectory of China's UDE in terms of sustainable development. In addition, it seeks to offer valuable counsel for the advancement of the UDE.

3.5. Calibration

In QCA, each conditional variable and outcome variable can be considered as a distinct set, and the cases have membership scores in many sets (Veri, 2020). Therefore, this study must first calibrate the original data. The goal of calibration is to accurately quantify the degree of data conformity, which reflects the degree to which certain data belong to the index. This study refers to the practices of other studies, considers the current state of the data, and determines the calibration standards of the variable data as the 0.95 quantile (full membership), the 0.5 quantile (intersection), and the 0.05 quantile (full nonmembership; Bullini Orlandi et al., 2022; Santamaria et al., 2021). Table 1 presents the calibration information of the outcome variable and conditional variables.

Table 1. Calibration information of each variable

Variable type	Variable	Anchor point		
		Full subordination	Crossover point	Full unsubordinated
Conditional variable	Digital R&D	14109.5	1566.5	1000.5
	Digital technology	35770.25	4599.5	2061.75
	Digital infrastructure	417.875	169.5	95.325
	Digital transaction	24810861	4214937	937444
	Digital operation	951.725	331.2	185.725
Outcome variable	Development level of UDE	74.25	61.5	46.75

4. Empirical analysis

4.1. Necessity analysis of single condition

The fundamental principle of conditional configuration analysis is the examination of the "necessity" of each condition. That is, to evaluate the consistency of the theoretical relationship between the empirical evidence and the set discussed. If a factor exists consistently when the result is generated, then the factor can be considered necessary for the generation of the result. The consistency index is used to measure whether the cases in the same configuration belong to the path and is an important reference standard for measuring whether the conditional variables are necessary. This study employs fsQCA 3.0 to analyze the essential circumstances, based on previous research. Based on the methodology employed by Zhao, the standard of the necessary conditions is set to a consistency greater than 0.9. When the consistency of a conditional variable exceeds 0.9, the condition is deemed necessary and will lead to the generation of the outcome variable (Zhao et al., 2022). The findings are displayed in Table 2.

Table 2. Necessity analysis results of fsQCA

Conditional variable	High UDE		Low UDE	
	Consistency	Coverage	Consistency	Coverage
High digital R&D	0.673	0.926	0.316	0.415
Low digital R&D	0.575	0.469	0.944	0.733
High digital technology	0.794	0.910	0.446	0.487
Low digital technology	0.553	0.511	0.918	0.809
High digital infrastructure	0.755	0.758	0.548	0.525
Low digital infrastructure	0.527	0.550	0.748	0.744
High digital transaction	0.811	0.882	0.456	0.473
Low digital transaction	0.515	0.498	0.886	0.817
High digital operation	0.729	0.773	0.487	0.492
Low digital operation	0.521	0.511	0.775	0.731

The analytical results of the necessary conditions for the high-quality development of the UDE in Table 2 show that the consistency of each condition is below the critical threshold of 0.9, indicating that the high-quality development of the UDE is a comprehensive indicator and cannot be determined by a single conditional variable. In the analysis of the necessary conditions for the low-level development of the UDE, the consistency of the two conditions of a low DRD and a low DTE exceeds the critical value of 0.9. This result shows that the two conditions may be necessary to explain the development of the DE of the low-level cities. However, further testing and analysis reveal that nearly one third of the case points are distributed above the diagonal in the X–Y scatter diagram of the two conditional variables and the outcome variable. This finding indicates that though the consistency of the two conditional variables passes the test, they do not constitute the necessary conditions for the low-level development of the UDE (Schneider & Wagemann, 2012). This result shows the complexity of the factors that can affect the DEDCC. That is, the market, foundation, and TI conditions must be coordinated and matched to jointly affect the development of the DE. In other words, the UDE development should comprehensively consider the concurrent synergy effect of multiple conditions on the three aspects of the market, the foundation, and TI.

4.2. Adequacy analysis of conditional configuration

The sufficiency analysis of the conditional configuration is conducted to determine the possible form and path of the configuration matching between different factors that can lead to the same result. Adequacy analysis also uses consistency for the test, but the standard and calculation method for the consistency level are different from those for the necessary conditions. Schneider and Wagemann proposed that the consistency of the adequacy of a conditional configuration should be greater than 0.75 (Schneider & Wagemann, 2012). The frequency threshold is generally set to 1 for a small sample size and above 1 for a large sample size. In this study, the determination of the consistency and frequency threshold should be controlled as a whole, according to the case. Based on previous research, this study establishes the adequacy analysis consistency criterion at 0.8 and the frequency threshold at 1. For the fsQCA 3.0 output, three solutions can be obtained, namely, a complex solution, a reduced solution, and an intermediate solution. The distinction between the three solutions lies in the selection of the "logical remainder." Researchers choose the intermediate solution, which incorporates a "logical remainder" that aligns with theoretical and practical knowledge. In this study, Ragin's recommended presentation of the configuration analysis data effectively demonstrates the relative significance of several antecedent conditions in the design. If the antecedent condition is present in the reduced solution, then the condition is the primary condition. Conversely, if the antecedent condition is present only in the intermediate solution, then the condition is a secondary condition (Ragin, 2008). FsQCA 3.0 is used to analyze 16 prefecture-level cities in the SPUA. The precise outcomes are displayed in Table 3.

The above table presents four driving paths to explain the high-quality development of the digital economy (HQDDE) in the SPUA. The overall solution and the single solution have a consistency level that exceeds the minimum acceptable threshold of 0.75. Specifically, the solution as a whole has a consistency level of 0.895 and a coverage level of 0.687.

Table 3. Configuration analysis results of high DE in SPUA

Type	Technology Innovation Led		Market-Foundation Linkage	Market-Foundation-Technology Innovation Collaboration
Configuration	S1	S2	S3	S4
Digital R&D	●	●	⊙	•
Digital technology	⊙	•	⊙	•
Digital infrastructure	⊙	⊙	●	●
Digital transaction	⊙	•	●	●
Digital operation	⊙	⊙	●	●
Raw coverage	0.258	0.239	0.298	0.514
Unique coverage	0.072	0.023	0.055	0.261
Consistency	0.906	0.970	0.830	0.986
Solution coverage	0.687			
Solution consistency	0.895			

Note: ● or • indicates that the condition exists, ⊙ or ⊙ indicates that the condition does not exist; • or ⊙ represents the core condition, • or ⊙ represents the edge condition. Blank indicates that the condition can either exist or not. The following table uses similar legends.

(1) Leading mode of TI

This mode includes S1 and S2. Under this mode, the main characteristics of the DEDCC are as follows: TI is very active and overcomes the defects and obstacles caused by insufficient infrastructure or inactive market factors to realize the HQDDE.

S1 shows that DRD plays a central role. That is, when DRD conditions exist, the other conditions will be irrelevant to the HQDDE. This finding shows that compared with the other conditions, DRD (TI) is crucial for the HQDDE, because the factor constitutes a sufficient condition for the interpretation results. In this configuration, when DRD (TI) exists, the other conditions will be irrelevant to the HQDDE; thus, this study refers to this configuration as the "TI led" mode. This finding means that the development and improvement of TI can effectively overcome the constraints of objective endowment conditions, such as the foundation and the market, to develop the DE. The configuration's consistency is 0.906, with a unique coverage of 0.072 and an original coverage of 0.258. This pathway accounts for approximately 25.8% of the high-quality UDE development cases. In addition, around 7.2% of the high-quality UDE development cases can be explained only by this path.

Typical cases in the research object: A typical case of S1 is Weihai City. Weihai is rich in industrial resources and has an innovation atmosphere and strong DRD capability. Weihai has rich marine resources and a stable marine industry foundation. Weihai has certain industrial advantages in advanced manufacturing, digital ocean characteristics, e-commerce, and other fields. The city has attracted a substantial influx of innovative enterprises and talents; actively promoted cooperation between the government, industries, universities, research, and application; built an innovation and entrepreneurship platform; and facilitated the extensive

incorporation of industries, universities, research, and application. The enterprises in Weihai have accelerated their transformation and upgrading in the field of the DE. For example, in the New Beiyang Intelligent Terminal Equipment Industrial Park, some enterprises have successfully transformed from traditional manufacturers into intelligent equipment and equipment solution providers through independent R&D and innovation. Weihai is committed to advancing digital industrialization and industrial digitalization, with the aim of expanding the digital industry and strengthening independent innovation capabilities. Such a commitment can provide robust support for the development of the DE and create a favorable digital environment for businesses and innovation projects.

In S2, DRD is crucial, whereas DTE and DTR serve as supplementary components. The development of the DE is driven mainly by DRD, and based on DTE, DRD can innovate and develop digital products and services, improve transaction efficiency and convenience through DTR, facilitate the advancement of the DE, and compensate for the lack of DI, to a certain extent. Moreover, DRD and DTE have strong spillover effects, which can drive the digital transformation of other industries. The driving path is composed of DRD (TI), DTE (TI), and DTR (market); thus, it is also called the "TI led" mode. The configuration exhibits a consistency of 0.970, with a unique coverage of 0.023 and an original coverage of 0.239. This pathway accounts for 23.9% of the high-quality UDE development cases. In addition, around 2.3% of the high-quality UDE development cases can be accounted for solely by this pathway.

Typical cases in the research object: A typical case of S2 is Weifang City. The number of DE patent applications in Weifang is above the average number of the 16 cities, and its DRD capability is relatively strong. Relying on the advantageous position of the sound, light, and electricity industry and the virtual reality industry, Weifang has aggressively promoted the advancement of the electronic information manufacturing industry; thus, its income from information, software, and technology has increased steadily. The Weifang municipal government issued the "Weifang Action Plan for Building a Capital of Technological Innovation and Industry in the Metauniverse (2023–2026)," which aims to achieve cutting-edge technological breakthroughs and enhance TI capabilities. At the same time, Weifang is one of the most important agricultural production areas in China and the capital of agricultural machinery in the country. The improvement of DRD capability and the advancement of DTE have facilitated the progress of distinctive digital agriculture and promoted the construction of a local standard system for agricultural big data, the application of new intelligent logistics technology, and the online sales and circulation of agricultural products and mechanical equipment through e-commerce and large-scale DTR. Weifang has promoted the integration of the real economy and DTE, which has provided a new impetus for the DE development of Weifang.

Typical cases of international city clusters in the leading mode of TI: The typical case that aligns with this mode is the Rhine-Ruhr City Cluster in Germany. The Rhine-Ruhr City Cluster is the largest city cluster in Germany and one of the largest in Europe. The region is renowned for its deep industrial tradition and expertise. With the rise of Industry 4.0, enterprises in the Rhine-Ruhr City Cluster actively adopt DTE, the Internet of Things, and automation systems to optimize smart manufacturing and production processes. This TI has had a positive impact on the development of the DE, enhancing production efficiency and competitiveness (Rehfeld & Terstriep, 2019). The Rhine-Ruhr City Cluster boasts multiple innovation centers and high-

level research institutions, including renowned institutions like RWTH Aachen University and TU Dortmund University. These institutions are dedicated to researching and developing new technologies, driving innovation and application in DE. Through close collaboration with enterprises, they facilitate the transformation and commercialization of TI, further promoting the development of the DE (Butzin & Flögel, 2023).

(2) Market-foundation linkage mode

This mode includes S3. Under this mode, the main characteristics of the DEDCC are as follows: the market and foundation factors are very active, and despite some potential problems or challenges in the TI capability, the city will be able to achieve HQDDE.

In S3, DTR, DO, and DI play a key role. Under the condition of weak TI capability, the construction and improvement of the DI will provide the necessary support and infrastructure assurance for the advancement of the DE. The DM offers an equitable and transparent platform for the advancement of the DE. The growth of the DM can foster competition, encourage innovation and competitiveness among businesses, and enhance the quality and efficiency of products and services. In addition, the construction and improvement of the DI can reduce the transaction costs of the DM. The flourishing and advancement of the DM can stimulate the expansion of the DI. The synchronized advancement of the two factors can reduce expenses associated with the DE. The driving path is composed of DTR (market), DO (market), and DI (foundation); thus, this path is referred to as the "market-foundation" mode. The design exhibits a consistency of 0.830, a unique coverage of 0.055, and an original coverage of 0.298. This pathway accounts for 29.8% of the high-quality UDE development cases. Furthermore, around 5.5% of the high-quality UDE development cases can be accounted for solely by this pathway.

Typical cases in the research object: Yantai is a typical case of S3. Yantai is not only the economic center city of the SPUA but also an important port city. Yantai's cross-border e-commerce enterprises have achieved rapid customs clearance and convenient logistics distribution through the policy advantages of special customs supervision areas, which have facilitated the advancement of international e-commerce. The Yantai municipal government has proactively facilitated the growth of the e-commerce sector, provided a satisfactory policy environment and support measures, and attracted a number of well-known e-commerce enterprises to set up their headquarters or branches in Yantai, such as Alibaba, JD.com, and so on. The establishment of such e-commerce companies stimulated the growth of Yantai's DM and increase in e-commerce transactions. The Yantai municipal government places significant emphasis on the advancement of DO and implemented a range of policies and measures to facilitate the development of this sector, such as the "Yantai Digital Operation Development Plan (2021–2025)," "Yantai Digital Operation Industrial Park Construction Plan (2021–2025)," and so on. The policies and actions offer robust assistance for the advancement of DO, such as the improvement of the construction of Yantai's communication network; the establishment of the 4G/5G network, which covers the whole city; and the enhancement of the fiber optic home entry rate, which has reached over 90%. Several large-scale data centers have also been built, with a total computer room area of more than 100,000 square meters, and the construction of the DI is nearly complete. Yantai's DI can offer technical assistance for

the advancement of the DM, and the DM can provide opportunities for the implementation of the DI. The two factors are interdependent and promote each other to jointly promote the development of the DE.

Typical cases of international city clusters in the market-foundation linkage mode: A typical case that fits this mode is the Greater Jakarta Metropolitan Area in Indonesia. The Greater Jakarta Metropolitan Area is located on the northern coast of Java Island, adjacent to the Java Sea. It is the largest urban area and the most populous city in Indonesia. The significant population size translates into a larger pool of potential users and consumers, attracting numerous DE enterprises to enter the market. The Greater Jakarta Metropolitan Area has a well-developed transportation network, communication infrastructure, and power supply, providing favorable infrastructure conditions for the development of the DE. Additionally, financial technology innovation in the area has driven the construction of digital payment infrastructure. The widespread adoption of electronic payment systems, mobile payment applications, and digital wallets has provided convenient payment methods, promoting the development of e-commerce and online transactions. During the global pandemic, Indonesia's e-commerce platforms have performed well, and online payments and the "contactless economy" have gained recognition among an increasing number of Indonesian businesses and consumers. While Indonesia's DE started relatively late, its large population base and the fact that one-third of the population consists of young people indicate vast prospects for DE development (Riadi et al., 2022).

(3) Market-foundation –TI collaborative development mode

This mode includes S4. Under this mode, the main characteristics of the DEDCC are as follows: the market, the foundation, and TI show a positive and active state and develop together to promote the growth and success of the UDE.

In S4, DTR, DO, and DI are crucial, whereas DRD and DTE serve as supporting factors. R&D stimulates the need for and the advancement of DTE and DI, which provide the basis and support for the implementation of DRD, whereas DTR and DO rely on the support and guarantee of DRD, DTE, and DI and provide them with application scenarios and market demands. The coordinated development of the market, infrastructure, and TI is the crucial element that drives the advancement of the DE. The rapid and sustainable growth of the DE can be achieved through the efficient facilitation of market operations, the construction of infrastructure, and the promotion of TI, which can provide a new impetus and opportunities for economic growth and social development. The configuration's consistency is 0.986, with a unique coverage of 0.261 and an original coverage of 0.514. This pathway accounts for 51.4% of the successful UDE development cases. Furthermore, approximately 26.1% of the high-quality UDE development cases may be accounted for solely by this pathway.

Typical cases in the research object: A typical case of S4 is Qingdao. Qingdao is located on the east coast of China and is an important port and trade city and node in the economic corridor of the new Eurasian Continental Bridge. Qingdao is actively building an international logistics center in Northeast Asia and an international logistics hub along the Silk Road, thereby increasing the prominence of its strategic position. Qingdao serves as a complete testing area for cross-border e-commerce in China. In 2020, Qingdao's e-commerce transac-

tion volume exceeded 1 trillion yuan, and DTR has developed rapidly. In addition, Qingdao has set up a number of large-scale data center nodes, such as the China Mobile (Qingdao, Shandong) data center and the China Telecom cloud base, which have achieved remarkable results in digital applications. The DM demand can promote the upgrading and expansion of the network infrastructure, and Qingdao has built eight large and medium-sized data centers with a complete DI, made full use of the national new infrastructure construction policy, accelerated the layout of the new infrastructure, and consolidated the digital Qingdao base. The security and stability of the DI can also provide a guarantee for TI. The software park and animation park in the Shinan District of Qingdao have strong advantages and scale in software information, scientific research and professional technical services, cultural creativity, and other industries and have been rated as key service industry parks in Shandong Province, along with the DE Park and DE Pilot Park. The DM can provide a platform for transactions and exchanges, the DI can provide strong support, and TI can promote the continuous innovation and upgrading of digital products and services. The three factors can jointly promote the success and development of the Qingdao DE.

Typical cases of international city clusters in the market-foundation – TI collaborative development mode: A typical case that exemplifies this mode is the Silicon Valley region in the United States. Located in Northern California, Silicon Valley is a world-renowned technology hub and a global leader in the development of the DE. The region's advanced level in the DE is attributed to the synergistic development of market, foundation, and TI (Wahome & Graham, 2020). Silicon Valley brings together the most innovative and technologically talented tech companies and research institutions in the world, providing scientists, engineers, and entrepreneurs with vast research resources and collaboration opportunities. Enterprises and research institutions in Silicon Valley have made significant breakthroughs in fields such as artificial intelligence, big data, cloud computing, the Internet of Things, and blockchain, providing cutting-edge technological support for the development of the DE (Sturgeon, 2021). Furthermore, Silicon Valley is renowned for its exceptional TI capabilities. It has given rise to numerous technology giants such as Google, Apple, Facebook, and Microsoft, which continuously drive and lead global DTE innovation. These tech giants in Silicon Valley are committed to pushing the boundaries of technology and maintaining a leading position in the digital realm. They invest heavily in research and development, introducing disruptive products and services that propel the flourishing of DE.

4.3. Stability test

The alteration of the consistency level and the modification of the calibration standard will impact the number of truth table rows (configurations) that will undergo logical minimization and thus influence the outcomes. Schneider and Wagemann (2012) introduced a method for testing the resilience of a system by altering the level of consistency and adjusting the calibration threshold. This study employs a calibration interval to modify the consistency level and manipulate certain conditions to assess the robustness. If a distinct hierarchical link exists between the configurations after the alteration of the consistency level or the modification of the calibration threshold, then the outcomes can be deemed resilient, regardless of the apparent dissimilarity in the configurations, and vice versa.

Adjustment of consistency level. In this study, the consistency level is increased from 0.80 to 0.82. The coherence and extent of the configuration outcomes and the overall solutions are in line with those of the initial results. Thus, the research conclusions are strong and reliable.

Modification of calibration method. To eliminate the difference in the calibration standards of the various conditions, this study uses 97%, 50%, and 7%, instead of 95%, 50%, and 5%, calibration intervals. The current frequency threshold remains at 1, whereas the consistency threshold stands at 0.82. Table 4 displays the outcomes of the configuration analysis. Compared with Table 3, the consistency and coverage of the overall solution in Table 4 have changed very slightly, the consistency decreases from 0.895 to 0.883, and the coverage decreases from 0.687 to 0.670. After the value is changed, four different lifting paths are formed, which are basically the same as the previous four conditional configurations, and the consistency level of each configuration exceeds the minimum permitted threshold, which means that the result is robust.

4.4. Research conclusion

Taking the SPUA in China as the research object, this study analyzes the conditional configuration of the factors that may influence the DEDCC using the fsQCA method; explores the linkage effect and improvement path of the DI, DTE, DRD, DTR, and DO factors on the level of the DEDCC; and reveals the complex relationship between the factors that can influence the DEDCC. This study draws several conclusions.

The development level of the UDE cannot be attributed solely to the market, foundation, and TI elements. This conclusion implies that a single factor alone cannot achieve the development of the UDE.

Table 4. Robustness test results of adjustment of some conditional calibration intervals

Type	Technology Innovation Led		Market-Foundation Linkage	Market-Foundation-Technology Innovation Collaboration
Configuration	S1	S2	S3	S4
Digital R&D	●	●	⊙	●
Digital technology	⊙	•	⊙	•
Digital infrastructure	⊙	⊙	●	●
Digital transaction	⊙	•	•	•
Digital operation	⊙	⊙	●	●
Raw coverage	0.278	0.242	0.325	0.504
Unique coverage	0.071	0.020	0.050	0.226
Consistency	0.899	0.970	0.833	0.985
Solution coverage	0.670			
Solution consistency	0.883			

In the configuration analysis of the HQDDE in the SPUA, 1) based on the perspective of the mutual matching of the elements, three modes are determined, that is, the leading mode of TI, the linkage mode of the market and the foundation, and the comprehensive development mode of the market, the foundation, and TI. Among the modes, the first shows the positive and active state of the factors that may influence TI, and the remaining two elements demonstrate some defects. The second mode shows the state of the joint action of the market and the foundation. In the first mode, the TI factors have defects but play a leading role. In the third mode, the three elements show a positive and active state. 2) From the perspective of the specific conditional variables of the elements, in the leading TI mode, a high DRD is advantageous and plays a core role in both configurations, thereby highlighting the significance of innovation in the advancement of the DE. S2 also explains that the improvement in the DE level can be attributed to not only the impact of DRD. In the second mode, DRD and DTE demonstrate deficiencies, but in the realm of digital commerce, DO and DI play a significant role. This interaction can also facilitate the HQDDE and demonstrates that the DM can foster the establishment of the DI, which in turn can promote the advancement of the DM. Both factors are crucial in facilitating the accelerated advancement of the DE and can overcome the weak TI capability. In the third mode, with DRD and DTE, DTR, DO, and DI continue to be active, suggesting that the advancement of TI capability will not impede the progress of the DI and the DM. 3) In the comparison of the various configurations, S4 consists of the three elements of the market, the foundation, and TI, so the coverage and consistency level of this configuration are higher than those of the three other configurations. The consistency level is 0.986, which further indicates that the coordinated development of the three elements of the market, the foundation, and TI may be the key factor affecting the improvement of the development level of the UDE.

5. Discussion

This Section examines the theoretical and managerial implications of this study and its findings.

5.1. Theoretical significance

Through a literature review and summary, this study constructs a theoretical framework to explore the configuration effect of the market, the foundation, and TI on the DEDCC level and analyze it using the QCA method. The theoretical significance of the approach is as follows: previous studies typically took a single city as the research object to explore the causal symmetry and one-way linear relationship between the DE and the influencing factors; however, this study uses a typical urban agglomeration as the research object and constructs a new theoretical framework from the perspective of configuration. Through this framework, this study integrates the factors that may influence the DE, thereby increasing the clarity of the analysis of the internal mechanism of the DEDCC. This study also offers a theoretical foundation for future investigations of other city clusters and a new direction for the examination of DE development. The application of this research method can broaden the scope of DE research and provide empirical support for relevant decision making and policymaking.

5.1.1. Leading mode of TI

In the first mode dominated by TI, the progress of DRD and DTE introduced novel goods, services, and business models and served as a significant catalyst for the innovation and growth of the DE. This view is supported by theory of innovation diffusion, which recognizes that the adoption and application of innovation play a vital role in economic growth (Ali et al., 2018). The collaborative effort of DRD and TI aligns with China's policy of development, driven by innovation. An innovation-driven development strategy places innovation at the forefront as the primary driving force fostering economic development. An innovation-driven development strategy aims to foster scientific innovation and TI and facilitate the introduction and utilization of novel technologies, formats, and models (Yang et al., 2022). TI is crucial for advancing and implementing DTE in the field of the DE. By implementing an innovation-driven development plan, we may foster and introduce high-tech firms and thus facilitate TI and industrial upgrading in the DE (Pan et al., 2022). The DE is a worldwide economic forum, and TI is crucial in the DE, because it can facilitate not only the advancement and implementation of DTE but also the growth of emergent sectors and the transformation of current businesses (Huang et al., 2023b). Through continuous TI, the DE can continuously adapt to changes in market demand, provide highly competitive products and services, and promote sustainable economic growth.

Against the backdrop of intense global competition in the DE, enhancing TI capabilities is crucial for countries in Asia, Africa, and other regions to maintain competitiveness (Li et al., 2020). These countries need to undergo economic structural transformation and upgrading, shifting from traditional resource-dependent economies to technology- and knowledge-based digital economies. To achieve this goal, the introduction of advanced DTE and innovative solutions is essential. City clusters like the Greater Jakarta Metropolitan Area in Indonesia and the Johannesburg-Pretoria City Cluster in South Africa possess large populations and economic foundations, providing vast markets and resources for DE development. However, to achieve sustained economic growth, these city clusters need to strengthen their TI capabilities and drive the transformation and upgrading of their economic structures. By encouraging TI and research and development investments and promoting cross-sector collaborations and knowledge exchanges, these city clusters can gain a greater competitive advantage in the global DE competition (Aminullah et al., 2022).

5.1.2. Market-foundation linkage mode

In the market-foundation linkage mode, the development of the DE is inseparable from the strong ICT infrastructure, which is supported by ICT infrastructure theory. ICT infrastructure theory states that the development and innovation of the DE can be promoted through the construction of high-speed, reliable, and safe network infrastructure, including broadband networks, mobile communication networks, and cloud computing (Zhu et al., 2023b). Such infrastructure can enable data transmission, storage, and processing and thus facilitate the growth of the digital industry and digital services (Chen et al., 2023b). The discussion of DTR and DO in this mode shows that data can drive economic growth. The essence of DTR is the interchange and movement of data, and the DE takes data resources as the core production factor (Cha et al., 2023). By establishing an open, competitive, and innovative DM, the DE can

create broad market opportunities for enterprises and consumers and promote the supply and demand matching of digital products and services and thus the growth and innovation of the DE.

DM and DI are considered two cornerstones of DE development. The DM provides vast development opportunities, while the DI lays a solid foundation for the growth of the DE. In some countries or regions, the development of the DE is still in its early stages (Rodríguez Ruiz et al., 2024). However, these countries or regions can expedite DE development by leveraging the synergy between the DM and DI. Taking the example of the Rio de Janeiro Metropolitan Area in Brazil and the Guadalajara Metropolitan Area in Mexico, the governments in these regions have shown active support for DE development (Paschoal & Wegrich, 2019). The coordination between DM and DI can help city clusters attract and retain talent, foster innovation, and provide growth opportunities for businesses. Firstly, developing the DM can provide an open and competitive platform, encouraging businesses and investors to engage in commercial activities in the DE domain. This stimulates economic growth, creates employment opportunities, and fosters innovation and entrepreneurial activities. Secondly, establishing robust DI is crucial to supporting DE development. The construction of high-speed broadband networks, data centers, and cloud computing infrastructure, among other facilities, will provide businesses and individuals with a stable, fast, and secure digital environment, facilitating data exchange and innovative applications.

5.1.3. Market-foundation–TI collaborative development mode

In the market-foundation – TI collaborative development mode, the path toward the effective HQDDC can be supported by several findings. First, market demand for digital products and services plays a crucial role in fueling the development of the DE (Øverby et al., 2023). Second, the development of the DE needs sound infrastructure support, including an efficient ICT infrastructure and a reliable DI, which can provide the necessary support for various DE activities (Akter et al., 2022). Last, TI is considered as the primary catalyst for the development of the DE. Through the guidance of market mechanisms, the strengthening of the synergy of infrastructure construction and TI can realize the virtuous cycle and sustainable development of the DE (Marti & Puertas, 2023).

The synergistic development of market, foundation, and TI provides a universal framework aimed at adapting to and driving the development of the DE, benefiting regions worldwide. This development model has been validated and applied in advanced DE-leading cities and regions. For example, the Silicon Valley region in the United States has achieved remarkable results through market-driven innovation, the construction of a robust foundation, the promotion of TI, and policy support (Acs et al., 2021). Other city clusters can learn from and draw upon these success stories, adapting and localizing them to propel the development of their own digital economies. While the market-foundation – TI innovation synergistic development mode is universal, it is essential to consider the local characteristics and needs of each city cluster during implementation. Different regions have distinct market demands, foundation conditions, and TI capabilities. Therefore, when referring to this model, city clusters need to make adjustments and customizations based on local conditions to ensure alignment with local development goals and resources.

5.2. Management significance

5.2.1. Multiple pathways for developing the DE

This study explores multiple configurational pathways that influence the DEDCC. It further analyzes the differentiated matching of market, foundation, and TI in the configuration of DEDCC, emphasizing the importance of each factor. Each trajectory is validated through the enumeration of case studies from typical city clusters, providing valuable recommendations for studying different city clusters and promoting the level of DE development.

The research has confirmed that the development of the DE is influenced by various factors and follows multiple trajectories. Different markets and regions possess different endowments for these factors, resulting in diverse pathways for enhancing the DE. For instance, India has a competitive advantage in digital service outsourcing and information technology, while some European countries focus on data privacy protection and digital transformation. In Africa, some countries are committed to leveraging DTE to drive financial inclusion and e-commerce development. Therefore, to promote the development of the DE in different regions, multiple trajectories should be considered. Strategies and policies should be formulated based on market characteristics, local resources and advantages, the policy environment, and international cooperation, among other factors, to propel the development of the DE.

5.2.2. Tailoring DE development to local conditions

In each configuration analysis, the study of DEDCC considers the geographical, economic, cultural, and human resources characteristics unique to each city cluster. Therefore, it is crucial to fully consider these features and plan and layout accordingly in the development of the DE, adhering to the principle of tailoring strategies to local conditions and leveraging regional characteristics.

When considering the DEDCC, in addition to emphasizing the regional characteristics of each city cluster, it is also important to gain a deep understanding of the specific characteristics of each city. Weihai has rich marine resources and a marine industry foundation and certain industrial advantages in advanced manufacturing, digital ocean, and other fields. Relying on the advantageous position of the sound, light, and electricity industries and the virtual reality industry, Weifang actively promotes the development of the electronic information manufacturing industry. Yantai's cross-border e-commerce enterprises have achieved rapid customs clearance and convenient logistics distribution through the policy advantages of special customs supervision areas. Meanwhile, Qingdao is located on the east coast of China and is an important port and trade city and node in the economic corridor of the new Eurasian Continental Bridge. This research shows that each urban agglomeration has unique geographical, economic, cultural, and human resource characteristics. Therefore, such characteristics should be fully considered in DE development, and the corresponding planning and layout should be implemented according to the actual situation. The adjustment of measures to match the local conditions and the combination of regional characteristics are important practices that can promote the DEDCC. Performing in-depth analysis of each city within the city cluster, including its geographical features, population, industrial structure, economic characteristics, and other aspects, can lead to a more effective formulation of corresponding enhancement trajectories to promote DE development.

5.2.3. Focus on the development of DE

By comparing the three modes, this study shows that though TI plays a unique role in the DEDCC, the construction of the market and infrastructure is important. The swift advancement and extensive utilization of DTE facilitated the emergence of the DE, and the DM and DI play a crucial role in facilitating the advancement of the DE. Only by laying a strong foundation can we effectively cooperate with TI and realize the rapid development of the DE.

When considering the DEDCC, it is necessary to emphasize the influence of multiple factors to ensure the formulation of comprehensive development strategies. At the same time, it is important to highlight key areas to ensure the effective utilization of resources and efforts. Taking the Tokyo Bay City Cluster and the Seoul Capital Area in South Korea as examples, they have adopted different strategies to achieve sustainable growth in DE development. The Tokyo Bay City Cluster focuses on industries such as electronics, telecommunications, and creative industries, which are the region's core strengths. The city cluster places a strong emphasis on the development of high-tech industries and has attracted top global research institutions and technology innovation centers. These efforts have been successful in providing an innovative environment and attracting talent and capital. The Seoul Capital Area in South Korea focuses on developing DI and TI to drive DE growth. The region has formulated policies favorable to DE development and provided support measures for innovation and entrepreneurship. Through multifactor analysis, identification of key areas, allocation of key resources, policy support, and innovation environment development, as well as collaboration and synergistic development, comprehensive enhancement of the DE in city clusters can be achieved.

6. Conclusions

The DE is the main economic form after agriculture and industrial economy. In the shift in China's focus from rapid economic growth to high-quality development, the DE plays a significant role. The National Development and Reform Commission of China officially issued the "14th FYP for Digital Economy" on January 12, 2022. The plan is the first national-level plan for the DE in China, whose aim is to foster the advancement and growth of the DE, enhance the establishment of DI, elevate digital capabilities and security, facilitate the seamless integration of the DE into the tangible economy, and establish a digital industrial cluster with global competitiveness. The "14th FYP" refers to the initial five-year term of China's endeavors to construct a comprehensive modern socialist nation, following the successful attainment of its first centennial objective. The DE will become a powerful booster in the country's new journey of national development and release a steady stream of new kinetic energy.

As a key urban agglomeration in the national "two vertical and three horizontal" urbanization strategic layout, the SPUA in China covers the north-south and east-west, defends the capital and the sea and air, borders Japan and South Korea, faces Northeast Asia, and connects the "belt and road" externally. This study takes the SPUA in China as the research object and constructs a DEDCC theoretical analysis framework using theory of predecessors. The framework includes three elements, namely, the DM, DI, and TI; selects five influencing factors, that is, DTR, DO, DTE, DRD, and DI; and uses the fsQCA method to seek the complex driving mechanism of the DEDCC from the perspective of configuration to facilitate the in-

vestigation of the path of differentiated DEDCC effectiveness. Theoretically, the examination of the DE in the SPUA in China can deepen our understanding of the law of the DEDCC and provide new materials for the development of DEDCC theory. It can also provide decision support for and promote the development of the DE in the SPUA.

The study reveals several findings. 1) To expedite the advancement of the DE in the SPUA in China, the simultaneous promotion of market factors and foundation factors should be prioritized. DI can support DE development. Thus, the SPUA should increase investment, improve the level of DI construction, and provide a solid foundation for DE development. At the same time, given the substantial market demand in the SPUA, the advancement of e-commerce should be prioritized. By building an online unified market and overcoming time and space constraints, e-commerce can provide a convenient means for commodity circulation and promote the digital transformation of traditional industries. 2) The key factor that will enable the SPUA to achieve high-quality DE is the improvement of its TI capability. To achieve high-quality DE, the SPUA must strengthen its digital research and development, continue to break through key digital technologies, and occupy the commanding height of DTE. In addition, DTE proficiency should be enhanced, DTE utilization should be increased, and the seamless amalgamation of DTE and conventional industries should be facilitated. TI is the fundamental aspect of the DE, which drives the creation of new digital industries, formats, and models and thus facilitates the rapid advancement of the DE. 3) The key to achieving high-quality development in the SPUA lies in the effective coordination of the development of the market, the foundation, and TI. The growth and advancement of the DM created a wide range of opportunities and increased market needs for DI and TI. The continuous improvement of DI has provided solid technical support and data resources to the DM and TI. As a driving force, TI can provide a new impetus and innovation opportunities for the development of DM and DI.

For city clusters in different countries and regions, the research findings of the SPUA in China can be drawn upon. (1) For city clusters that need to strengthen their TI capabilities, emphasizing the coordination between DI construction and DM is an effective way to promote DE development. The Rio de Janeiro City Cluster in Brazil can leverage its advantages in the tourism and service industries to promote the development of the DM through the construction of digital platforms and applications such as virtual tourism and online services. (2) Strong TI capabilities are crucial drivers for DE development and can be promoted through various mechanisms and channels. London Tech City in the United Kingdom, relying on its robust financial services and research foundation, can further develop fintech and digital services while strengthening digital security and regulatory technology to promote compliance and risk management. (3) The coordinated development of market, foundation, and TI provides a general and effective framework for the growth of the DE in city clusters. This framework emphasizes the interaction and interdependence of the three key elements: market, foundation, and TI. It is applicable to most city clusters worldwide that aspire to promote DE development. Just like the success of Silicon Valley in the United States, it is attributed to its strong TI capabilities combined with mature markets and an advanced foundation, making it a global leader in DE.

This study makes three main contributions: (1) Theoretical Contribution: The proposed theoretical model and analytical framework provide a new structured perspective for studying

the factors influencing the DEDCC. It helps to systematically understand and analyze the complex phenomena of the DE in city clusters. By focusing on city clusters rather than individual cities, the study reveals the interactions and network effects within and between city clusters in DE development. (2) Practical Contribution: Based on the configurational perspective, this study identifies multiple enhancing pathways that influence DEDCC and systematically analyzes the complex causal relationships among the influencing factors, taking into account regional characteristics. The research emphasizes that most city clusters can achieve rapid development of the DE through strengthening DI, stimulating market vitality, and enhancing TI capabilities, forming a mutually reinforcing virtuous cycle. (3) Methodological Contribution: This study employs the fsQCA method to investigate the case of the SPUA. Compared to single-case studies, fsQCA utilizes a multi-case approach that fully recognizes the heterogeneity and complexity of individual cases. It can analyze multiple combinations of causal relationships, identify the configurational conditions that lead to a given outcome, and explore the equifinality among different configurations of conditions. The application of the fsQCA method provides a new perspective for understanding the complex phenomena of the DE in city clusters, effectively linking qualitative and quantitative analyses. It examines the relationships between configurational conditions and outcomes from a set-theoretic perspective.

This study has some limitations and deficiencies. In the future, scholars can undertake comprehensive investigations on several facets. (1) Taking 2020 as the time node, this study analyzes the static driving path of the factors that may influence the DE in the SPUA in China. A follow-up study can choose another time range, replace the urban agglomeration as the research object, and conduct comparative analysis at home and abroad. (2) Under the guidance of the theoretical framework of the market, the foundation, and TI, this study selects representative and meaningful variables; however, the DEDCC may be affected by other factors. Subsequent studies can further explore the impact of other factors on the DEDCC.

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Author contributions

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The authors declare no conflict of interest.

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