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Analysis of the Development Patterns and Improvement Strategies of China's Digital Economy—Drawing Insights from Data Collected across 227 Cities in China

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Abstract: The digital economy serves as a pivotal engine for both sustainable and high-quality urban development. However, the progress of this economy manifests a heterogeneous pattern when observed in various cities. Employing a hybrid approach combining QCA and NCA methods, this study delves into the configuration pathways that lead to high digital economic development in 227 Chinese cities at prefecture level and above. It further explores the heterogeneity characteristics and potential improvement strategies for digital economic development in each city. The findings reveal that the high-level development of the digital economy is a balanced outcome stemming from three pivotal factors: technology, organization, and the environment. Specifically, technological innovation, fiscal investment, and economic growth have consistently exhibited robust propelling effects throughout the development of the digital economy in different cities, regardless of their scale or economic standing. Notably, there are substantial disparities in the development trajectories of the digital economy among cities of varying sizes. For instance, in super and mega cities, technological innovation and industrial restructuring are the fundamental drivers of regional digital economic growth. On the other hand, for second-tier large cities, policy support, economic strengths, and fiscal investment are more pivotal in fostering the progress of the urban digital economy. These insights offer a deeper understanding of the mechanisms underlying the heterogeneity in digital economic development across Chinese cities, thus providing tailored theoretical guidance for cities at different development levels to enhance their digital economy.

Keywords: configuration perspective; digital economy; urban sustainable development; fuzzy-sets QCA; heterogeneity



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1. Introduction

The digital economy utilizes data resources as a key factor of production [1], and its development holds significant importance in strengthening national strategic technological capabilities, enhancing the autonomy and controllability of industrial and supply chains, expanding domestic demand, and adjusting and optimizing industrial and energy structures [2]. In recent years, the scale of the global digital economy has continued to expand, and it has become a crucial pillar of support for global economic development. Overall, developed and high-income countries account for over 70% of the global digital economy, occupying an advantageous position in its development pattern (<https://www.iyiou.com/research/202403221349>, accessed on 26 March 2024). In 2023, China released the “Overall Layout Plan for Digital China Construction” to expedite the integration and advancement of the digital economy with the real economy. Cities serve as the primary catalyst for the development of the digital economy across various regions.

Does each city adhere to a unique path in fostering this economy? Furthermore, how do diverse development paths influence the progress of the digital economy in distinct regions?

Considering China as a case study, since 2022, the land transfer fees across China have begun to show negative growth. As real estate continues to decline and land transfer fees sharply decrease, prefecture-level cities that overly rely on land finance are facing huge challenges in terms of sustainable urban development. It is a difficult problem for Chinese leaders to figure out whether the digital economy can stimulate urban vitality, unleash the value of data factors, and promote high-quality and sustainable urban development. The development of its digital economy is marked by imbalances, shortcomings, and inconsistencies. Notably, the advancement of the digital economy in different cities exhibits heterogeneity, with distinct regional characteristics prevailing overall [3]. Cities such as Beijing, Shanghai, and Tianjin lead the country due to their advantages in technology, economy, and talent. However, disadvantages in these areas brought by regional influences do not completely determine the level of digital economic development in a region [4]. For example, cities like Guiyang and Chongqing have injected strong vitality into their digital economic development through regional economic policies and the digitalization of core industries, leading the country in growth rates and demonstrating tremendous potential for development.

Most existing research literature analyzes this current situation primarily from a single perspective of environment, organization, or technology, focusing mainly on the heterogeneity of China's digital economy development at the provincial level. However, there is a lack of analysis that delves deeper into the prefecture-level city scale. Therefore, this article views the development of China's digital economy and its influencing factors as a configuration system. Utilizing a combination of Qualitative Comparative Analysis (QCA) and Network Comparative Analysis (NCA) methods, it takes the digital economy development of various cities in China as research cases, introduces city-level standards, and clarifies the configuration paths and key driving forces for digital economy development in cities of different sizes. This provides a certain reference for cities of similar sizes that exhibit relatively weaker digital economy development.

2. Literature Review and Research Framework

The digital economy, based on the latest generation of information technology, has increasingly become a crucial driver of economic growth. With its strong permeability, the digital economy has disrupted traditional economic models, deeply and widely integrating into the production, distribution, exchange, and consumption links of the national economy. It has emerged as the most innovative and wide-reaching economic development model, leading the way in national economic progress [5]. The digital economy serves as a critical support for driving high-quality economic development, stabilizing the macroeconomic situation, and responding to sudden external shocks [6]. It significantly enhances the international competitiveness of China's regional economy [7] and plays a role in promoting urban green development [8], integrated urban–rural development [9], and empowering rural revitalization [10] to varying degrees. The development of the digital economy can significantly boost the total factor productivity [11] and innovation performance of enterprises, leading them towards industrial upgrading and integrated development [12], especially by providing high value-added services to the manufacturing sector [13]. Finally, the development of the digital economy also provides varying levels of support for enhancing the efficiency of local government public services [14,15]. With the booming development of the digital economy, its influence and status in various social fields are constantly rising, drawing more and more scholars to study the development level and influencing factors of the digital economy in various provinces and cities in China. In terms of measuring the development level of the digital economy, existing research has mainly evaluated the current stage of China's digital economy based on value-added calculations [16], satellite account construction [17], and index compilation [18]. Although scholars have used different methods and constructed indicators with varying perspectives

when measuring the digital economy development level in various provinces, they have reached similar conclusions: there are significant differences in the development of the digital economy among provinces and cities in China, mainly manifesting as a higher level of digital economy development in the south compared to the north, and exhibiting a trend of “eastern leadership and central-western catching up” [19]. Some scholars have begun to explore the reasons for these differences, such as the innovation dimension of the digital economy, core industries of the digital economy [19], technological innovation levels, and financial input [4]. However, these studies mainly analyze the reasons from a single perspective or only investigate the heterogeneity of digital economy development levels at the provincial level, lacking a more in-depth analysis at the prefecture-level city level, where cities are precisely the main drivers of digital economic development in various regions.

This article introduces the TOE (technology–organization–environment) theoretical framework [20] to enhance the TOE system that impacts the development of the digital economy. From a configuration standpoint, the article integrates QCA and NCA methods, examining the system from three dimensions: technology, organization, and environment. An experimental analysis is conducted, comparing cities with high and non-high levels of digital economy development. The study covers 227 cities across different regions and development levels, aiming to address the following questions: Is the configuration path unique for cities with advanced digital economies? Do all factors exert an equal degree of influence on the development of urban digital economies? And is there a consistent development trajectory for digital economies in cities of varying sizes?

At the technological level, it mainly includes the level of technological innovation and human capital in the region [21]. Technological innovation, especially the research and development of core technologies related to the digital economy, is an important force determining the integration of digital technology and the real economy. Scientific and technological talents are not only the developers of digital technology but also the practitioners of its specific applications in physical enterprises, playing a crucial supporting role in the development and application of regional digital technology.

At the organizational level, it includes the technological fiscal expenditure of local governments [4] and policy support [22]. Fiscal investment in the technology sector directly impacts the construction of digital infrastructure and significantly promotes the initial stage of regional digital economic development [4]. Meanwhile, policy support and legal norms related to the local digital economy also safeguard the healthy development of the regional digital economy. However, excessive intervention by the government may hinder the innovation and technological progress of digital enterprises when the regional digital market matures [23]. Therefore, the impact of government behavior on the digital economy has a dual nature.

At the environmental level, the level of economic development provides environmental guarantees for the healthy development of the digital economy [4]. Economically developed regions possess superior resource endowments, well-developed infrastructure, and a concentration of innovative talents, resulting in strong backup for innovative development. Additionally, the development of the digital economy is closely related to the level of industrial structure. As traditional industries evolve from labor-intensive to capital-intensive, technology-intensive, and knowledge-intensive industries, the digital economy will experience rapid growth. The deep integration of the digital economy with industries will also drive the upgrading of industrial structures [24]. The research framework is illustrated in Figure 1.

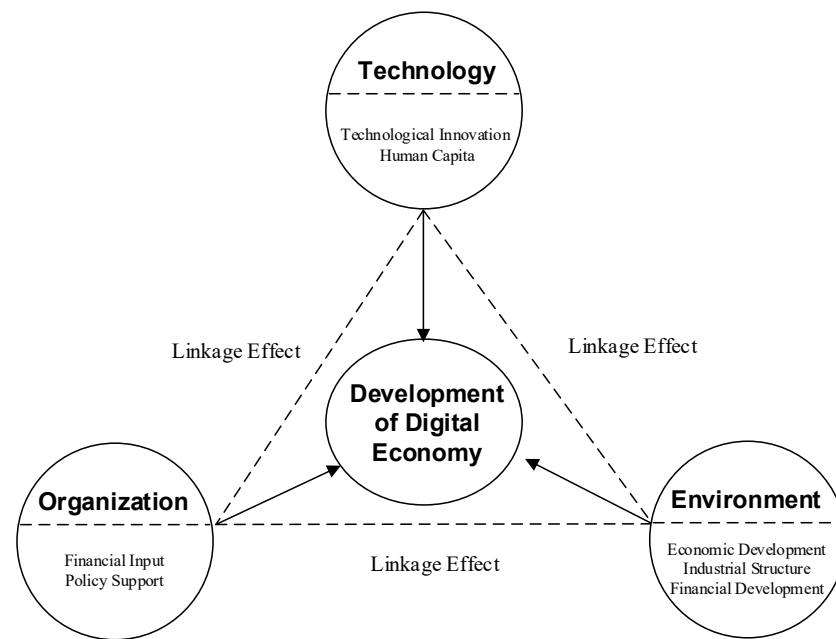


Figure 1. Research Framework.

3. Data Sources and Data Calibration

3.1. Data Sources

This article collects data from 227 cities in China as samples, with initial data sources including the “China Urban Statistical Yearbook” for 2021–2023, the Peking University Legal Database, and the “Urban Digital Development Index” for 2021–2023 released by the Digital China Research Institute of New H3C Group. Among these data sources, the variable of policy support level is standardized using the utility value method, with a value range of [0, 1]. The closer the utility value is to 1, the higher the legal effectiveness of the policy and the greater its impact on the digital economy. The specific data sources and assignment methods are detailed in Table 1.

Table 1. Variable Measurement and Data Sources.

Variable	Dimension	Specific Variables	Metrics	Data Sources
Outcome variable		Development Level of Digital Economy	Digital Development Index	Urban Digital Development Index (China)
Antecedents	Technology	Technological Innovation	Average number of patent authorizations per 10,000 people in each city from 2021 to 2023	China Urban Statistical Yearbook
		Human Capital	Average number of college students per 10,000 people in each city from 2021 to 2023	China Urban Statistical Yearbook
	Organization	Fiscal Investment	The average proportion of government science and technology expenditure to total fiscal expenditure in each city from 2021 to 2023	China Urban Statistical Yearbook
		Policy Support	Number of policy documents related to digital economy development in each city as of June 2023	pkulaw.com
	Environment	Regional Economic level	Average per capita GDP of each city from 2021 to 2023	China Urban Statistical Yearbook
		Industrial Structure	The average ratio of the added value of the tertiary industry to the added value of the secondary industry in each city from 2021 to 2023	China Urban Statistical Yearbook
		Financial Development	Balance of deposits and loans from financial institutions in various cities at the end of 2021–2023	China Urban Statistical Yearbook

3.2. Data Calibration

The original dataset needed to be calibrated prior to using the fsQCA software 3.0 [25], and the membership relationship between variables and variable fuzzy sets needed to be established through the anchor points of each factor [26]. Using the direct calibration method to calibrate each variable, establishing three calibration anchors first was necessary, where 1 represents complete membership, 0.5 represents the intersection point of complete non-membership, and 0 represents complete non-membership. Finally, statistical methods were employed to convert each data point into membership scores between 0 and 1 based on three calibration anchors [27]. Table 2 presents the specific values.

Table 2. Calibration anchor points for antecedent and outcome variables.

Variable	Specific Variables	Calibration		
		Full Membership	Intersection	Not Affiliated at All
Outcome Variable	Development Level of Digital Economy	76.06	51.50	38.51
Antecedents	Technological innovation level	94.22	12.02	2.99
	Human Capital	0.10	0.02	0.01
	Fiscal Investment	1,017,108.20	76,542.33	9248.93
	Policy Support	9.10	1.00	0.00
	Regional Economic Level	142,940.10	63,090.67	34,944.00
	Industrial Structure	2.14	1.19	0.70
	Financial Development	5.33	2.58	1.64

4. Data Analysis and Empirical Results

4.1. Integrated Application of Qualitative Comparative Analysis and Necessary Condition Analysis

The QCA method takes a holistic analysis perspective, considers the research objective as the configuration of different combinations of conditional variables, integrates the advantages of case and variable studies, and obtains the set relationship between element configurations and results through set analysis. This helps to solve causal complexity problems such as multiple concurrent causal relationships, causal asymmetry, and the equivalence of multiple solutions [25]. Alternatively, the NCA is a novel method based on complex causal relationships [24]. Compared with QCA, it can identify the necessary conditions for the outcome variable and quantitatively assess its effect along with the bottleneck level as a necessary condition [25]. Therefore, this article employs a combined approach of NCA and QCA to analyze the degree of necessity and distribution characteristics of various antecedent variables across different levels of digital economic development, as well as the configuration paths for the development of the digital economy in Chinese cities. The analysis process is shown in Figure 2.

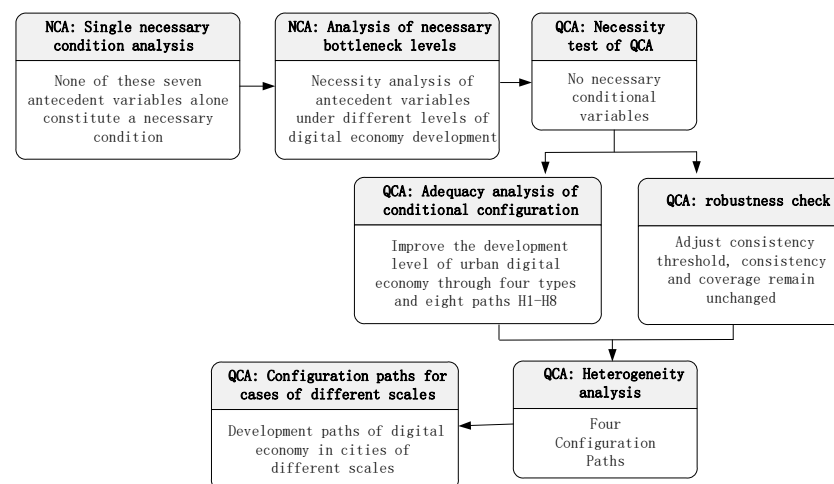


Figure 2. QCA+NCA Configuration Analysis Process Diagram.

4.2. Analysis of Necessary Conditions

(1) Single Necessary Condition Analysis

This study examines the distribution characteristics of the necessity of various antecedent conditions across different digital economy development levels. While analyzing the necessary conditions, this study also investigates the degree of necessity of each antecedent variable at varying stages of the digital economy's development.

This article employs two different estimation methods, ceiling regression (CR) and ceiling envelopment (CE), to calculate the effect sizes. Following the research recommendations of Dul (2020), the results of the NCA analysis should also consider the significance level, specifically with a p -value greater than 0.5 [28]. Upon comprehensive examination, both methods indicate that the p -values for human capital are above 0.5, demonstrating significant impact on the development of the digital economy. However, the effect sizes suggest a low-level influence. While the levels of technological innovation (CR method d -value of 0.03, CE method d -value of 0.00), economic development (CR method d -value of 0.01, CE method d -value of 0.00), fiscal investment (CR method d -value of 0.00, CE method d -value of 0.02), and policy support (CR method d -value of 0.02, CE method d -value of 0.00) have some necessary impact on the results, their significance levels are low ($p < 0.1$). Therefore, none of these seven antecedent variables alone constitute a necessary condition for the development level of the digital economy. The specific results are detailed in Table 3 below.

Table 3. NCA single necessary condition analysis results.

Condition	Method	Accuracy (%)	Upper Limit Area	Range	Effect Size (d)	p -Value
Technological Innovation	CR	99	989.76	16,321.06	0.06	0.03
	CE	100	826.48	16,321.06	0.05	0.00
Human Capital	CR	100	0.01	7.74	0.00	0.63
	CE	100	0.01	7.74	0.00	0.62
DVE. Level of Digital Economy	CR	74	32,286,960.58	238,368,016.08	0.14	0.01
	CE	100	21,953,288.11	238,368,016.08	0.09	0.00
Industrial Structure	CR	100	18.84	1051.08	0.02	0.00
	CE	100	37.68	1051.08	0.04	0.00
Fiscal Investment	CR	100	1,585,667.06	9,391,897.68	0.17	0.01
	CE	100	1,635,399.52	9,391,897.68	0.17	0.00
Policy Support	CR	97	21.68	253.37	0.09	0.02
	CE	100	22.02	253.37	0.09	0.00
Financial Development	CR	97	59.41	420.99	0.14	0.01
	CE	100	54.92	420.99	0.13	0.00

Note: $0 < d < 0.1$ is a low-level impact; $0.1 \leq d < 0.3$ is a moderate level impact; $0.3 < d$ is a high-level impact.

The data in Table 4 further demonstrate the bottleneck effect sizes of necessary conditions, indicating the minimum level that conditional variables must meet to achieve a given level of the outcome variable y within the observed range [29]. From Table 4, it can be seen that for the development of the digital economy at levels ranging from 10% to 90%, the highest level of economic development is required. However, to achieve a 100% level of digital economic development, the highest level of fiscal investment needed is 64%. In the context of non-high digital economic development, industrial structure is an unnecessary condition, but it becomes a highly necessary condition variable for digital economic development above 70% levels.

Table 4. Analysis of NCA necessary condition bottleneck level.

DEV. Level of Digital Economy	Technological Innovation Level	Human Capital	Fiscal Investment	Policy Support	Economic Development	Industrial Structure	Financial Development
0.0	NN	NN	NN	NN	NN	NN	NN
10.0	NN	NN	NN	NN	NN	NN	NN
20.0	NN	NN	NN	NN	NN	NN	NN
30.0	NN	NN	NN	NN	2.4	NN	NN
40.0	NN	NN	0.4	NN	8.6	2.3	NN
50.0	1.6	NN	7.8	NN	14.8	6.2	6.0
60.0	5.8	NN	15.2	NN	21.0	10.2	14.7
70.0	10.0	NN	22.6	1.3	27.2	14.2	23.4
80.0	14.2	NN	30.0	4.3	33.3	18.1	32.2
90.0	18.3	NN	37.3	7.4	39.5	22.1	40.9
100.0	22.5	21.4	44.7	10.5	45.7	26.1	49.7

Notes: (1) The analysis method is CR; (2) NN stands for ‘unnecessary’.

(2) Necessity test of Qualitative Comparative Analysis

To further investigate the necessity of various antecedent conditions for the development of the digital economy and to assess the robustness of the findings, we employ the QCA method to perform a necessary condition analysis on each individual condition. Table 5 presents the results. The consistency level of a conditioning variable with the outcome reveals the degree of membership of that condition. Scholars generally consider a consistency level above 0.9 to indicate that the conditioning variable can be considered a necessary condition for the outcome variable. As presented in Table 5, the consistency values of five antecedent conditions are all less than 0.9. According to the QCA necessity test criteria proposed by Ragin [27], the necessity of each individual condition is at a low level, signifying the absence of necessary conditions impacting the digital economy development level in the cities.

Table 5. Analysis of necessary conditions.

Conditional Variable	Consistency of Outcome Variables			
	High Level of Digital Economy Development		Non-High Level of Digital Economy Development	
	Consistence	Coverage	Consistence	Coverage
Technological innovation	0.74	0.85	0.42	0.52
~ Technological innovation	0.58	0.48	0.88	0.78
human capital	0.73	0.79	0.48	0.56
~ Human Capital	0.60	0.52	0.82	0.77
Fiscal Investment	0.71	0.86	0.42	0.54
~ Fiscal Investment	0.62	0.50	0.89	0.77
Policy Support	0.55	0.77	0.36	0.55
~ Policy Support	0.68	0.50	0.85	0.67
Economic Development	0.76	0.80	0.44	0.50
~ Economic Development	0.53	0.47	0.83	0.79
Industrial Structure	0.65	0.66	0.59	0.65
~ Industrial Structure	0.65	0.60	0.69	0.68
Financial Development	0.70	0.71	0.51	0.56
~ Financial Development	0.57	0.52	0.74	0.72

Note: ‘~’ represents the ‘not’ of a logical operation.

4.3. Adequacy Analysis of Conditional Configuration

After performing the necessary condition test for individual conditions, further analyzing the sufficiency of the configuration of conditions is necessary. Based on relevant research by Ragin, the case frequency threshold was set to 1, and the original consistency

threshold was set to 0.8 [30]. Combining both the simple and intermediate solutions, this study identified eight result paths for cities with high levels of digital economic development. The RAGIN result presentation format was adopted, where “•” represents the presence of a core condition, “◦” represents the presence of a peripheral condition, “—” indicates that the condition may or may not be present, “⊗” represents the absence of a core condition, and “⊘” represents the absence of a peripheral condition [27].

The consistency and overall consistency of the various outcome paths for high-level digital economy development are both above 0.9, with an overall coverage rate of 0.60, indicating that the outcome paths cover most of the cases. This demonstrates that the cases selected in this article possess sufficient explanatory power. The specific configuration paths are presented in Table 6.

Table 6. Precondition configuration of provincial digital economy development level.

Antecedent Condition	High Digital Economy Level Configuration							
	Balanced Development Type			Talent-Funding Type			Financial Support Type	Technology-Funding Type
	H1	H2	H3	H4	H5	H6	H7	H8
Technological Innovation	•	•	•	•	•	— —	•	•
Human Capital	— —	•	— —	•	•	•	— —	•
Fiscal Investment	— —	•	•	•	•	•	•	•
Policy Support	•	•	•	•	— —	⊗	— —	— —
Economic Development	•	•	•	— —	— —	•	•	•
Industrial Structure	⊗	— —	— —	— —	•	•	⊗	⊗
Financial Development	⊗	— —	•	•	•	•	•	— —
Consistency	0.94	0.96	0.95	0.96	0.94	0.93	0.95	0.95
Original coverage	0.24	0.37	0.38	0.36	0.39	0.26	0.33	0.35
Unique coverage	0.03	0.00	0.01	0.00	0.02	0.01	0.01	0.03
Overall consistency					0.92			
Overall coverage					0.60			
Case City	Zibo	Guangzhou	Beijing	Wuhan	Nanjing	Changsha	Ningbo	Changzhou

Note: “•” represents the existence of core conditions, “◦” represents the existence of edge conditions, “— —” represents the presence or absence of such conditions, “⊗” represents the absence of core conditions, and “⊘” represents the absence of edge conditions.

From Table 6, it can be observed that the resulting path of generating a high level of digital economy development results from the combined effect of three-dimensional factors: technology and organizational environment. However, the organic combination of different factors in each dimension leads to different configuration paths of a high level of digital economy development. According to the various core conditions of each configuration path, the configuration paths of a high level of digital economy development are categorized into balanced development type and technical–organizational type.

(1) Balanced development type. The configuration paths that belong to this type include H1, H2, and H3. In paths H2 and H3, technological innovation, policy support and economic development are identified as critical influencing factors. This indicates that the high level of urban digital economy development under such paths is the result of the joint action of three levels of factors: technology, organization, and environment. The specific analysis is as follows:

H1. (Technological Innovation * Policy Support * Economic Development *~ Industrial Structure *~ Financial Development) A high level of scientific innovation means a strong driving force for the growth of urban digital technology. Strong policy support not only reflects the local government’s

attention and support for the development of urban digital economy, but also safeguards the healthy development of urban digital economy. A high level of economic development guarantees the demand for urban digital industry, which can better promote the deep integration of digital economy and real economy; thus, the digital development of cities is rapidly advancing under the combined influence of technology, organization, and environment.

H2. (Technological Innovation * Human Capital * Fiscal Investment * Policy Support * Economic Development) In this type of path, cities possess strong technological innovation capabilities and a large pool of talents in the field of technological innovation, leading to a higher efficiency in the transformation of scientific and technological achievements into practical applications. Additionally, the higher fiscal expenditure in the field of science and technology provides a source of funding for research and development in regional technological innovation. Moreover, the high level of economic development in the region also ensures market demand for related digital economy industries.

H3. (Technological Innovation * Fiscal Investment * Policy Support * Economic Development * Financial Development) Similar to H2, this involves cities that jointly promote the development of the digital economy across the three dimensions of technology, organization, and environment. These cities enjoy good financial development, making it easier for enterprises to obtain funding. Additionally, they have a series of policy support measures for digital economy development, safeguarding and promoting the growth of the city's digital economy. There exists a certain substitution effect between Path H3 and Path H2, specifically in the substitution relationship between the core condition of policy support and fiscal expenditure.

(2) Talent-Funding Type. The configuration paths of this type are H4, H5, and H6. In this type of path, human capital, fiscal investment, and financial development emerge as core conditions. The concentration of talent in the field of technological innovation provides a solid technical development driving force for the digital economy development of cities. Significant fiscal investment and strong financial development also provide ample research and development funds and a development platform for technological innovation in the region, thereby steering the region's digital economy towards a better direction.

H4. (Technological Innovation * Human Capital * Fiscal Investment * Policy Support * Financial Development) In this pathway, regions with strong technological innovation capabilities and a large pool of talent in scientific and technological fields provide crucial technical support for the development of regional digital economy. Cities with significant fiscal investment in technological innovation attract the convergence of scientific and technological talents. Meanwhile, sound financial development provides financial support for local enterprises' transformation and upgrading, thereby promoting the development of urban digital economy.

H5. (Technological Innovation * Human Capital * Fiscal Investment * Industrial Structure * Financial Development) Compared to Path H4, cities on Path H5 possess a more favorable industrial structure, with a higher proportion of the tertiary industry. There exists a substitution effect between the industrial structure and policy support in these cities. A higher industrial structure is more conducive to the development of the digital economy in these cities. Therefore, the digital economy in these cities still maintains considerable vitality for growth.

H6. (Human Capital * Fiscal Investment * ~Policy Support * Economic Development * Industrial Structure * Financial Development) In this pathway, cities have less policy support related to digital economy development, but they possess a high-level industrial structure and economic development. Meanwhile, strong fiscal investment and advanced financial development provide powerful financial support for the development of digital economy in the region. Additionally, a superior development environment attracts talents in the field of science and technology, which enables the digital economy in these cities to develop rapidly.

(3) Funding Support Type. The configuration path under this type is H7. In this type of configuration path, fiscal investment, economic development, and financial development emerge as core conditions. The factors at the environmental and organizational levels are all closely related to funding, which underscores the significance of financial support for the development of the digital economy.

H7. *(Technological Innovation*Fiscal Investment*~Policy Support * Economic Development * Industrial Structure * Financial Development) For cities that belong to this type of path, despite the relatively limited policy support provided by local governments for digital economy development, the robust development of the regional economy and financial industry, coupled with the government's financial support for the technology sector, have offered solid financial backing for the growth of the regional digital economy.*

(4) Technology-Funding Type. The configuration path under this type is H8. In this type of configuration path, technological innovation, human capital, fiscal investment, and economic development emerge as core conditions. The technological aspects are relatively excellent, supported by significant financial investment from local governments and favorable economic development conditions, enabling the city's digital economy to achieve impressive results.

H8. *(Technological Innovation*Human Capital*Fiscal Investment*Economic Development * ~Industrial Structure) For cities that belong to this type of path, although they have a relatively poor industrial structure, they have a solid technological foundation. Additionally, the local government invests significantly in fiscal spending for technological innovation, providing strong momentum for the development of the city's digital economy. Furthermore, a favorable economic development level offers a good platform for the development of the regional digital economy, thereby continuously enhancing the level of digital economy development in cities of this path.*

4.4. Robustness Testing

The research results obtained through the QCA method are highly sensitive and random; therefore, a robustness test is necessary. Existing robustness testing methods primarily include adjusting the calibration threshold, case frequency threshold, and consistency threshold, adding new antecedent variables, and increasing or reducing cases. If the differences in overall consistency and coverage in the configuration path results do not lead to results with different interpretive meanings after adjusting the original consistency threshold and case frequency threshold in the truth table, then the configuration analysis results are robust. Additionally, if the additional configuration paths after adjusting the original consistency threshold and case frequency threshold in the truth table are subsets of the original configuration paths, it also indicates that the results are robust [24]. In this paper, by adjusting the consistency threshold of the truth table to 0.85, a consistency test of the results was conducted, and it was found that the consistency and coverage after adjustment did not change compared to before adjustment, thus indicating that the results have strong stability.

4.5. Heterogeneity Analysis of Configuration Paths

After exploring the development paths of the digital economy in various cities from a configuration perspective, significant differences in the development paths of China's digital economy were observed. Therefore, this article will continue to be grounded in the configuration pathway of a high-level digital economy, incorporating the analysis results of the bottleneck level of NCA's singular necessary condition, along with the actual situation and inherent conditions of digital economy development in each respective city. The objective is to delve into the reasons behind the heterogeneity in digital economy development across these cities.

(1) **Balanced Configuration Path.** In this type of configuration path, there exists a certain substitution relationship between H2 and H3, specifically, a substitution relationship between the two antecedent variables of human capital at the technological level and financial development at the environmental level. As indicated by the results of the NCA necessary condition analysis, the necessity degree for human capital and financial development in cities with a moderate level of digital economy development is relatively low. This suggests that in cities with moderate development, the impact of human capital and financial development on the development of the regional digital economy is limited, which to some extent confirms the substitution relationship between fiscal investment and policy support.

(2) **Talent-Funding Type Configuration Path.** In this type of configuration path, there is a substitution effect between policy support in Path H4 and industrial structure in Path H5. Taking Wuhan, a city belonging to the talent-funding type configuration path, and Guangdong, a city belonging to the balanced configuration path, as examples for comparison, Wuhan has been increasing its attraction to technical talents in recent years. Leveraging its advantageous educational resources, Wuhan has accumulated a large pool of talents in the field of technological innovation. The “Policies of Wuhan to Support the Accelerated Development of the Digital Economy” released in 2022 further underscores the need to enhance support for digital economy talents. Wuhan encourages universities, research institutions, leading and backbone enterprises, as well as new R&D institutions, to recruit talents in the field of digital economy. Qualified talents will be given priority in being admitted to talent programs and will enjoy corresponding policy incentives. Furthermore, Wuhan supports key universities in strengthening the development of emerging disciplines in the digital economy, optimizing professional structures and teacher allocation, and enhancing the cultivation of interdisciplinary talents. By deepening industry–education integration and school–enterprise cooperation, Wuhan has established a number of digital economy industry–education integration alliances and talent cultivation bases. Through talent accumulation, a solid technical foundation has been laid for the development of Wuhan’s digital economy. Unlike Wuhan, which leverages its regional educational resources to vigorously stockpile scientific and technological talents, Guangdong promotes the healthy and efficient development of the city’s digital economy through policies related to the digital economy. On 1 June 2022, the first local regulation “Guangzhou Digital Economy Promotion Regulations” went into effect. The regulations depict a comprehensive blueprint for the development of Guangzhou’s digital economy, marking an important achievement in strengthening legislation in emerging fields for Guangzhou and providing strong legal protection for the city’s comprehensive construction of a digital economy-leading city. Sustainable development of the digital economy relies on supporting policies in areas such as finance, finance, talents, and intellectual property rights. The “Regulations” provide detailed implementation and norms for various aspects, including implementing financial and land support measures, strengthening talent introduction and cultivation, and establishing open and transparent market access and operational rules.

(3) **Funding-Oriented Configuration Path.** This type of configuration path is characterized by the presence of fiscal investment, economic development, and financial development as core conditions, all of which are closely related to funding. As indicated by the results of the NCA bottleneck level test, under the condition of high digital economy development, fiscal investment, economic development, and financial development all need to meet a relatively high level, far exceeding other factors. This finding confirms that the support of relevant funding is crucial for regions to make significant progress in digital economy development.

(4) **Technology-Funding Oriented Configuration Path.** Unlike the funding-oriented configuration path, this type of path emphasizes technological innovation and human capital at the technological level as core conditions. This reflects the importance of a technological foundation for digital economy development. A strong capacity for digital

economy innovation and a robust pool of technological talents can provide a continuous source of development momentum for regional digital economy growth.

In summary, there is significant heterogeneity in the development of China's urban digital economy. The most prominent factors causing differences in the level of digital economy development are economic development, technological innovation, and human capital. Among them, the differences between developed regions of the digital economy mainly stem from fiscal investment, while the differences between underdeveloped regions and developed regions of the digital economy mainly come from technological aspects and economic development. Analysis of the above configuration path results indicates that the urban scale is the foundation for the development of the urban digital economy and one of the core factors causing differences in the level of digital economy development among cities. The level of digital economy development in cities of different sizes shows a trend of steady improvement, but the absolute differences between cities have expanded [30].

4.6. Further Analysis

Based on the “Notice on Adjusting the Criteria for Urban Size Classification” issued by the State Council of China in 2014, this article categorizes 227 cities into three size groups: megacities and megalopolises, large cities, and small and medium-sized cities. By exploring the heterogeneity of the configuration paths for digital economy development in different cities based on their size, this article aims to provide a reference for cities of different sizes to develop their digital economies.

As shown in Table 7, the paths of digital economy development among megacities and megalopolises in China are not uniform. Both technological innovation and fiscal investment emerge as core conditions in all the paths leading to a high level of digital economy development in these cities. This suggests that for megacities and megalopolises, when the local digital economy reaches a high level of development, significant fiscal investment in the field of technology ensures that the region has sufficient funds to build digital infrastructure, laying a solid foundation for the further development of the digital economy. Simultaneously, strong technological innovation capabilities provide a continuous endogenous driving force for the development of the regional digital economy.

Table 7. Configuration paths for digital economy development in cities of different sizes.

Antecedent Condition	Digital Economy Configuration of Super and Mega Cities					Digital Economy Configuration of Big Cities	
	S1	S2	S3	S4	S5	V1	V2
Technological Innovation	•	•	•	•	•	•	•
Human Capital	⊗	⊗	•	— —	•	— —	•
Fiscal Investment	•	•	•	•	•	•	•
Policy Support	•	⊗	•	•	•	•	•
Economic Development	•	— —	•	•	•	•	— —
Industrial Structure	⊗	•	•	⊗	— —	— —	•
Financial Development	— —	•	— —	•	•	— —	•
Case City	Suzhou	Shanghai	Guangzhou	Shenzhen	Hangzhou	Xiamen	Jinan

Note: “•” represents the existence of core conditions, “•” represents the existence of edge conditions, “— —” represents the presence or absence of such conditions, “⊗” represents the absence of edge conditions.

The results in Table 7 regarding the configuration of the digital economy in large cities reveal interesting patterns. In configuration path V1, technological innovation, fiscal investment, and economic development emerge as key conditions, similar to the paths observed in megacities and megalopolises. However, what distinguishes Xiamen from these larger cities is its robust economic development, which contributes significantly to its relatively advanced digital economy. This mutual reinforcement underscores the crucial role of funding in driving digital economy growth.

In configuration path V2, technological innovation, human capital, fiscal investment, and financial development take center stage. Unlike V1, cities following this path leverage their strengths in talent and finance to fuel the development of their digital economies. This approach demonstrates the diverse strategies that cities can adopt to nurture their digital economies, tailored to their unique resources and capabilities.

5. Conclusions and Recommendations

5.1. Conclusions

Based on the TOE framework for digital economy development, this paper integrates the NCA and QCA configuration analysis methods to qualitatively analyze the result paths leading to the level of digital economy development in various cities, and concludes that there is heterogeneity in the digital economy development of each city. The research findings are as follows. Firstly, the development of the digital economy in each city is the result of the combined effects of regional technology, organization, and environment. Among them, high-level technological innovation, fiscal investment, and economic development are the key factors for regions to achieve a high level of digital economy development. Secondly, generally speaking, the development paths of the digital economy in regions with high-level development are not consistent. The combined effects of economic development, technological innovation, and human capital have the greatest impact on the development of the digital economy in cities. Thirdly, there are significant differences in the development paths of the digital economy among cities of different sizes. For megacities and megalopolises, the combination of technological innovation and industrial structure has a significant impact on the development of the regional digital economy. For large cities that belong to the second tier in terms of digital and environmental conditions, the roles of policy support, economic development advantages, and talent attraction in promoting the development of the urban digital economy are more pronounced.

5.2. Contributions of the Paper

The marginal contributions of this paper may be reflected in the following two points. Firstly, it expands the research cases of configuration analysis. Previous studies on the development of digital economy in various regions of China using the QCA method mainly focused on the provincial level, with a limited number of case studies. The results of relevant configuration paths cannot reflect the actual development status of different cities. This paper covers most cities in China with a case sample of 237 prefecture-level cities, enabling a better analysis of the development of digital economy in cities of different sizes and further exploring the status of China's digital economy development. Secondly, it introduces the standard of city size. In further analysis, by comparing the configuration paths of super cities, megacities, and large cities in China, it clarifies the configuration paths and key driving forces of digital economy development in cities of different sizes, thus providing a certain reference for cities of the same size but with relatively weak digital economy development.

5.3. Recommendations

Based on the above research conclusions, this article proposes the following three countermeasures and suggestions.

Firstly, the upgrading of digital technologies should be accelerated to promote the coordinated development of the digital economy. Cities with a higher level of digital economy development should enhance their innovation capabilities in digital technologies through policy support and standardized guidance, and gain the upper hand in cutting-edge technology. Cities with relatively backward digital economy development should strengthen digital infrastructure construction and implement preferential policies through fiscal investment, which will attract large-scale Internet platform enterprises to settle in, driving regional innovation capabilities and scientific research investment, and attracting digital technology talents. This will address the shortcomings in digital technologies, and,

through the combined efforts of technology, organization, and the environment, promote the coordinated development of the regional digital economy.

Secondly, we should give full play to the guiding role of policies to promote the cross-regional coordinated development of the digital economy. Due to differences in technological accumulation, resource endowments, and industrial structures, the development processes of digital industries and industrial digitization vary among different cities. Therefore, it is necessary to give full play to the guiding role of local policies in the development of regional digital economy, fully explore the potential of digital economy development, utilize the fact that digital technology is independent of geographical restrictions, promote the integrated development of digital industries and industrial digitization among different provinces and cities, guide the central regions to attract digital industries by leveraging their industrial needs and natural resources, facilitate the digital transformation of regional industries, further collaborate with and develop in tandem with the Western regions, and promote the circular development of the digital economy across the country.

Thirdly, the supply of funds for digital construction should be optimized to ensure the healthy development of the digital economy. Funds are the source of vitality for the development of the digital economy. Local governments' fiscal expenditures in the field of science and technology play a significant role in promoting the development of the regional digital economy. Therefore, governments at all levels should increase financial support for regional digital construction and development, optimize expenditure structures, coordinate budget arrangements, further improve the efficiency of fiscal funds, and actively support the construction of local digital infrastructure. In addition, it is necessary to establish a diversified investment and financing system and broaden funding channels for digital infrastructure construction, innovate in construction models, and flexibly utilize forms such as government purchase of services. Local governments are encouraged to cooperate with social capital in investment funds for digital projects and increase support for major projects in key areas of the digital economy, thereby laying a solid foundation for the healthy development of China's digital economy.

Fourthly, an inter-ministerial coordination mechanism should be established for the development of the digital economy, strengthen situation analysis, coordinate and solve major issues, and pragmatically promote the implementation of plans. Each region should take into account its own reality, improve the coordination mechanism for work promotion, enhance the ability to develop the digital economy, and promote the better integration of the digital economy into the new development pattern, as well as providing better services.

6. Research Prospects

Due to the limited data acquisition channels, the research cases in this paper do not cover all cities. Additionally, the system of indicator variables may not be comprehensive enough, such as digital infrastructure, digital industries, and so on. These indicators may also affect the development of the digital economy.

Future research can focus on the following aspects: firstly, other antecedent conditions should be further expanded for a multi-perspective configurationally analysis; secondly, micro-case studies should be conducted, targeting all city-level and specific regional samples to further increase the accuracy of the research; thirdly, incorporating factors such as information infrastructure, data foundation, and service digitization into the research framework should be considered.

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