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What Kind of Rural Digital Configurations Contribute to High County-Level Economic Growth? A Study Conducted in China's Digital Village Pilot Counties

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Abstract: The digitalization of rural areas has emerged as a crucial strategy for promoting economic development, yet the phenomenon of "digital suspension" poses a challenge, where the lack of digital integration in certain sectors may hinder economic progress. This study delves into this issue by identifying multiple configurations that drive county-level economic growth. More specifically, this study aims to explore how rural digitalization contributes to county-level economic growth through different combinations of environmental and subject-level factors. To address this issue, this study applies the fuzzy-set qualitative comparative analysis method, guided by systems thinking and ecological systems theory. The analysis is based on 89 case samples selected from China's digital village pilot counties, using data from the China County-level Digital Rural Index Research Report jointly released by Peking University and Ali Research Institute, published in 2022, and other county-level statistical data. The study explores the complex causal mechanisms and configuration paths through which rural digitalization empowers county-level economic growth. This study found that (1) the conditions necessary to generate high county-level economic growth do not exist in the process of rural digitalization (at least not within the digital village pilot); (2) four configurations facilitate high county-level economic growth: digital governance-led configuration, dual promotion of digital governance and digital infrastructure, dual promotion of digital life and digital infrastructure, and dual promotion of digital life and digital economy; and (3) two configurations yield non-high county-level economic growth and exhibit asymmetrical relationships with those configurations conducive to high growth. These research findings not only broaden the application of systems thinking and ecological systems theory in the realm of rural digitalization but also offer practical insights into strategies for enhancing county-level economic growth.

Keywords: systems thinking; ecological systems theory; rural digitalization; fuzzy-set qualitative comparative analysis; county-level economic growth

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1. Introduction

As the basic unit of rural revitalization in China, the county level is known as the "rice bag" and "vegetable basket" of China's development and is the main carrier of agricultural production and industrial manufacturing, playing a key role in the process of integrating towns and villages [1]. Counties are primarily composed of townships (which are generally

responsible for the administration of several surrounding administrative villages) and rural areas, and they hold a pivotal position in terms of land area, the total number of households and permanent residents, and the proportion of the county's economic aggregate in the national economic aggregate. The economic development of counties therefore has a bearing on the national economy and people's livelihoods and an important impact on the country's economic development [1,2]. However, compared to cities or urban areas, county-level economic development faces many challenges. The vast rural and township areas under the "urban–rural" dichotomy are characterized by "thin institutions", poor infrastructure [3,4], and a complex institutional environment [5], with a large outflow of young labor [6] and a relative lack of knowledge, skills, and wealth resources among local workers [7]. These factors have long hindered business innovation and development at the county-level and contributed to the vulnerability of the county-level economy.

In recent years rural digitalization has opened up new opportunities for county-level economic development. Rural digitalization generally refers to the application of digital technologies in rural areas, centered on big data and internet technologies [8]. As a framework concept, it usually encompasses the modernization of agriculture and rural areas, the digital literacy of farmers, and the endogenous dynamics of rural development [9]. In 2018 China proposed the implementation of a digital countryside strategy in the central government's No. 1 document (which generally focuses on agriculture, rural areas, and farmers) [10]. Since then, the Chinese government has issued a series of planning and support documents. For example, the Ministry of Agriculture and Rural Affairs (2020) and other departments jointly issued a plan for the development of digital agriculture in rural areas (2019–2025) [11]. With the joint efforts of the government and all sectors of society, China's digital village construction has achieved certain results. For example, the national digital village development level reached 39.1 per cent in 2021, indicating that new modes of the rural digital economy, such as rural logistics, rural e-commerce, and rural digital-inclusive financial services, have emerged and become well established [12].

Rural digitalization is also of great interest to researchers, who have examined topics such as the impact of the digital economy on rural–urban income inequality [13], digital inequalities faced by remote rural household enterprises [14], the mechanism of digital platforms in enhancing rural resilience [15], the endogenous mechanisms of digital economy for empowering rural human settlement [8], the impact of digital economy on rural–urban integration [16], the simulation of agricultural digital economy development and policy support system [17], the mechanism of digital rural construction in influencing the high-quality growth of agricultural economy [18], the mechanism of rural digitalization in raising rural households' income [19], the potential interrelationships between information and communication technologies (ICTs) and rural transformation [20], and the impact of digital countryside construction on industrial upgrading in counties [2]. However, research on rural digitalization and county-level economic growth (CEG) has received little scholarly attention. In addition, the majority of studies explored the linear relationship between a single antecedent variable and the outcome through empirical [2,8,16] and simulation methods [17], while a few studies qualitatively analyzed the causal mechanism through case study methods [14,15]. None of the above methods consider the possible pathways through which combinations of multiple factors influence outcomes from a combined quantitative and qualitative perspective [21,22]. Indeed, rural digitalization is a multifaceted process of digital convergence. Examples may include rural digital infrastructure construction, smart agriculture construction, the exploration of new modes of digital economy, digital governance effectiveness enhancement, rural cyberculture development, digital benefit services, and smart green village construction [12]. The conclusion that digital technology fuels rural development has been confirmed by many scholars [2,18,23]. It is clear that an

approach that considers a combination of rural digitalization factors that affect county-level economic growth is more relevant to the current state of development.

This study therefore aims to address the following questions:

RQ1: How does rural digitalization affect county-level economic growth?

RQ2: What are the various combinations of factors influencing county-level economic growth?

RQ3: Which pathways can more efficiently promote county-level economic growth, which configuration paths constrain county-level economic growth, and what connections exist between these opposing pathways?

Specifically, this study employs a fuzzy-set qualitative comparative analysis (fsQCA) method to analyze the aforementioned questions, aiming to reveal the complex causal impact mechanisms of various combinations of factors on county-level economic development in the context of rural digitalization. It seeks to clarify the possible matching pathways and address the limitations of existing research and methods. Building upon ecological systems theory [24,25], we investigate the relationships between different configurations of antecedent and outcome variables from both the subject and environmental aspects. Through this investigation, we aim to uncover the causal and complex mechanisms and configuration paths through which rural digitalization empowers county-level growth. The environmental aspect encompasses two factors: rural digital infrastructure and rural economic digitalization. The subject participation aspect includes two antecedent variables: rural life digitalization and rural governance digitalization. The four antecedent variables selected in this study meet the configuration requirement of 4–7 conditions in the qualitative comparative analysis (QCA) method [21,22]. In fact, the QCA method does not advocate exhaustively considering all relevant antecedent variables; instead, using this method, researchers should identify the consistency of the important variables under the proposed theoretical model through an in-depth analysis of case data, and then analyze the underlying causes leading to the observed phenomena [21].

This article contributes to the study of digital rural areas by identifying four configuration pathways leading to high county-level economic growth in particular, as well as two potential pathways leading to not-high[1] county-level economic growth. The findings of this study contribute new theoretical insights for the development and enhancement of county-level economies under the current trend of rural digitalization. Additionally, this study extends the application of systems thinking and ecological systems theory to a wider range of phenomena. Our research has implications for stakeholders involved in the implementation and promotion of rural digitalization. Furthermore, it offers practical recommendations for facilitating the synergistic interaction between "subjects" and "the environment" in providing digital ecosystem services and products.

The remaining sections of this paper are structured as follows: Section 2 reviews the relevant literature; Section 3 elaborates on the theoretical framework; Section 4 introduces the research methodology and describes the preprocessing of the data; Section 5 presents the configuration analysis and reports the research findings; Section 6 discusses the research findings, and presents the theoretical and practical implications; Section 7 summarizes the research conclusions; and Section 8 objectively discusses the research limitations and suggests future research directions.

2. Literature Review

In recent years, rural digitalization has been widely recognized as a crucial strategic approach to promoting coordinated regional development, particularly in large developing countries like China. With the gradual expansion of digital infrastructure in rural areas, the academic community has increasingly focused on its role in bridging the urban-rural

divide and stimulating local economic growth. For instance, research has demonstrated that investments in digital infrastructure can elevate the level of rural digitalization, and they can also promote rural entrepreneurship and enhance market accessibility [27]. Furthermore, the catalytic role of digital infrastructure in rural revitalization has also been corroborated [28,29]. However, such studies often rely on macroeconomic indicators or linear regression models, thereby overlooking the specific contextual dependencies and the combinatorial effects among various factors that underpin digital development in different regions.

The significance of digital governance has also been increasingly emphasized in recent research studies. Research indicates that the digital transformation of rural public service systems contributes to enhancing governance efficiency (e.g., by offering more expedient services) [30], as well as improving community satisfaction and the resultant creation of public service value [31]. However, most existing studies are conducted from a top-down, government-led perspective [32], overlooking the notable disparities in institutional capabilities and technological application levels among different county governments. In regions with weaker grassroots governance capabilities, digital platforms may exist in form but be absent in substance, resulting in the failure to truly materialize the effectiveness of "digital governance."

Apart from the infrastructure and governance dimensions, farmers' digital participation capabilities are increasingly recognized as a pivotal force driving the endogenous development of rural digitalization. Digital lifestyle applications such as mobile payments, unmanned supermarkets, intelligent health stations, and rural e-commerce play a crucial role in activating the economic potential of rural areas [33]. However, studies often assume that farmers possess adequate digital literacy or willingness to participate, while overlooking practical issues such as "digital exclusion," intergenerational differences, and cultural conservatism that may hinder farmers' effective engagement in digital life [34]. The rise of the digital economy has also sparked academic interest in topics such as digital transformation and rural industrial upgrading [35], as well as digital-inclusive finance and rural digital entrepreneurship [36]. Despite offering opportunities for transformation, the lack of corresponding capacity-building and institutional safeguards may exacerbate farmers' dependence on digital technologies and the digital economy, along with their livelihood instability.

From a theoretical perspective, the integration of systems thinking and ecological systems theory provides a robust analytical tool for understanding the multi-layered and interactive nature of the rural digitalization process. Systems thinking emphasizes holism, nonlinearity, and the interdependence among system elements [37], making it particularly suitable for analyzing the co-evolution of the digital economy, digital infrastructure, digital governance, and human behavior within the specific context of a particular county. Ecological systems theory, on the other hand, incorporates the influence of environmental factors on individual behavior into a systematic framework through its hierarchical structure of microsystems, mesosystems, exosystems, and macrosystems [24,25]. However, most existing empirical studies remain confined to a single level (e.g., infrastructure investment [27]), with limited efforts to organically integrate the relationship between the macro-policy environment and micro-level behavioral agents, thus constraining their theoretical explanatory power.

In terms of research methodologies, most of the current literature employs empirical and simulation approaches, assuming independent and linear relationships among variables [16,17]. This mode of thinking often struggles to unveil the causal complexity and path diversity inherent in real-world development. In recent years, an increasing number of scholars have begun advocating for the incorporation of configurational methods, such

as fsQCA, to identify complex mechanisms such as "equifinal multiple pathways" and "causal asymmetry" [38,39]. However the empirical application of fsQCA in the field of rural digitalization remains relatively limited, and few studies have systematically integrated it with systems thinking or ecological systems theory.

Against this backdrop, the present study comprehensively integrates systems thinking with ecological systems theory, and employs the fsQCA method to explore how environmental and agent-related factors, through different configurations, jointly impact CEG during the process of rural digitalization. This not only broadens the understanding of the diversity in rural digitalization pathways but also offers a valuable theoretical and methodological complement to current rural development research, which predominantly adopts a linear perspective.

3. Theoretical Foundation and Research Framework

3.1. Systems Thinking

Systems thinking is a cognitive framework that helps understand complex phenomena by analyzing the interrelatedness, dynamics, and holism of various elements within a system [40,41]. It emphasizes analyzing issues from a holistic, dynamic, and interactive perspective rather than a fragmented, static, and isolated one. This approach is particularly suitable for studying complex systems characterized by interactions among multiple elements, time-lag effects, feedback loops, and nonlinear relationships [40–42].

In fact, the co-evolution of rural digitalization and economic growth embodies the multi-dimensional interactive characteristics of systems thinking. Firstly, within the system framework, digital technology, as a core element flow, restructures the rural economic system through three mechanisms: (1) "structural coupling" (e.g., integrating digital infrastructure with industrial systems), (2) "functional emergence" (e.g., creating new occupational groups via e-commerce platforms), and (3) "feedback regulation" (e.g., data-driven production and transportation decision-making). Secondly, nonlinear associations exist among subsystems. For instance, the expansion of the logistics network (at the hardware level) and the penetration of digital finance (at the service level) form a positive feedback loop, driving exponential improvements in the efficiency of agricultural product circulation. More importantly, systems thinking reveals critical leverage points. When the synergy between digital governance platforms (information hubs) and entrepreneurial entities (organizational carriers) exceeds a certain threshold, it triggers a "system phase transition," transforming dispersed resources into economies of scale. This dynamic equilibrium process necessitates moving beyond single-element optimization towards a multi-dimensional collaborative model that encompasses rural digital infrastructure, rural economic digitization, rural governance digitization, and rural living service digitization, ultimately achieving resilient growth in the rural economic system.

3.2. Ecological Systems Theory

Bronfenbrenner [43] pioneered ecological systems theory (EST), which employs a lifespan approach to understand how development occurs through the increasingly complex interactions between individuals and their environment [43,44]. From the outset EST garnered significant attention from scholars and has been applied in various interdisciplinary research fields (e.g., education [45] and psychology [46]). Bronfenbrenner's [43] EST is one of the most widely adopted theoretical frameworks for studying the interaction between subjects and their ecological environments to date [47]. A notable case in the business field is highlighted by Iansiti and Levien [48], who argue Microsoft and Walmart excel in modern commerce due to their positioning within an ecosystem, where the organizations themselves play only a partial role. Thus, the interaction between "individuals (or subjects)

and environment" is largely real according to the EST and such interactions have implications for external factors. Although not drawing upon EST directly, researchers in the EU adopted an ecosystem approach in developing the AURORAL ecosystem, a digital services platform designed to meet the needs and contexts of rural areas which focuses on smart communities and rural digital transformation [49]. This provides important insights into the use of ecosystems to analyze rural digitalization in this paper.

We draw upon EST to develop our theoretical framework for three reasons. Firstly, this theory is widely applied in interdisciplinary academic research, possessing the maturity of theoretical application and the advantage of being readily understandable to readers. Secondly, rural digitalization is a process of "subject–environment" interaction and mutual influence. In other words, if there is only investment and construction of external environments such as digital infrastructure, without the interaction and participation of villagers or outsiders (individuals), digital rural development will remain in a "suspended state", unable to harness the technological efficiency of digitalization, and villagers will also be unable to derive convenience and benefits from it [50]. Therefore, the perspective of "subject–environment" interaction advocated by EST aligns with the level of division of the antecedent variables in the theoretical model of this article. Lastly, the external influence perspective of "subject–environment" interaction advocated by EST aligns with the actual phenomenon of rural digitalization affecting local economic growth [18].

3.3. Model Construction

Both systems thinking and the configurational perspective underscore the principles of holism and dynamism. While systems thinking emphasizes the interplay among constituent elements and the evolution of the system as a whole, the configurational perspective elucidates disparities in outcomes through the specific combinations of these elements, thereby reflecting the inherent complexity of causal relationships. In essence, both paradigms reject linear and isolated modes of analytical inquiry. Therefore, the significant concepts within systems thinking, encompassing the interactions and synergistic relationships among factors, nonlinear relationships, and the dynamic equilibrium of ecosystems (which gives rise to path diversification) [40], have provided intellectual inspiration for this study to explore the causal and complex relationships between digital rural construction and county-level economic growth based on EST.

EST emphasizes the "subject–environment" interaction of various factors that jointly influence a certain external outcome. Similarly, rural digitalization requires, on the one hand, the establishment of digital infrastructure and the improvement of external conditions for digital economic development in traditional and technologically lagging rural areas, aiming to construct a sustainable external environment. On the other hand, it is necessary to encourage, attract, and train local villagers to participate in and use digital facilities, applying digital governance and digital services to daily life [50]. Therefore, in the process of rural digitalization, achieving the prerequisite role of the "subject–environment" interaction is essential to further unleash its role in functional knowledge economy, ultimately driving the growth of county-level economies [15].

Therefore, based on systems thinking and the adoption of EST, this study investigates the relationship between different configurations of four antecedent variables of rural digitalization and county-level economic growth from the "subject–environment" perspective, aiming to uncover the enhancement path of rural digitalization in empowering county-level economic growth. According to the primary indicators of the Chinese County-level Digital Rural Index (2020) research report [51], this study identifies two key elements from the environmental aspect—rural digital infrastructure and rural economic digitalization—and two important factors from the subject aspect—rural life digitalization

and rural governance digitalization. This is because rural digital infrastructure and rural economic digitalization mainly reflect the degree of investment and implementation of general technologies, with information, communication, and logistics networks as the core in traditional rural infrastructure and rural economy, while rural life digitalization and rural governance digitalization mainly reflect the coverage of people's acceptance, participation, and use of digital platforms or tools in daily life and government affairs. The former emphasizes the importance of constructing a rural digital environment, while the latter highlights local residents' interactive participation in such a rural digital environment. Based on this, we constructed a theoretical mechanism model of rural digitalization in empowering county-level economic growth, as shown in Figure 1.

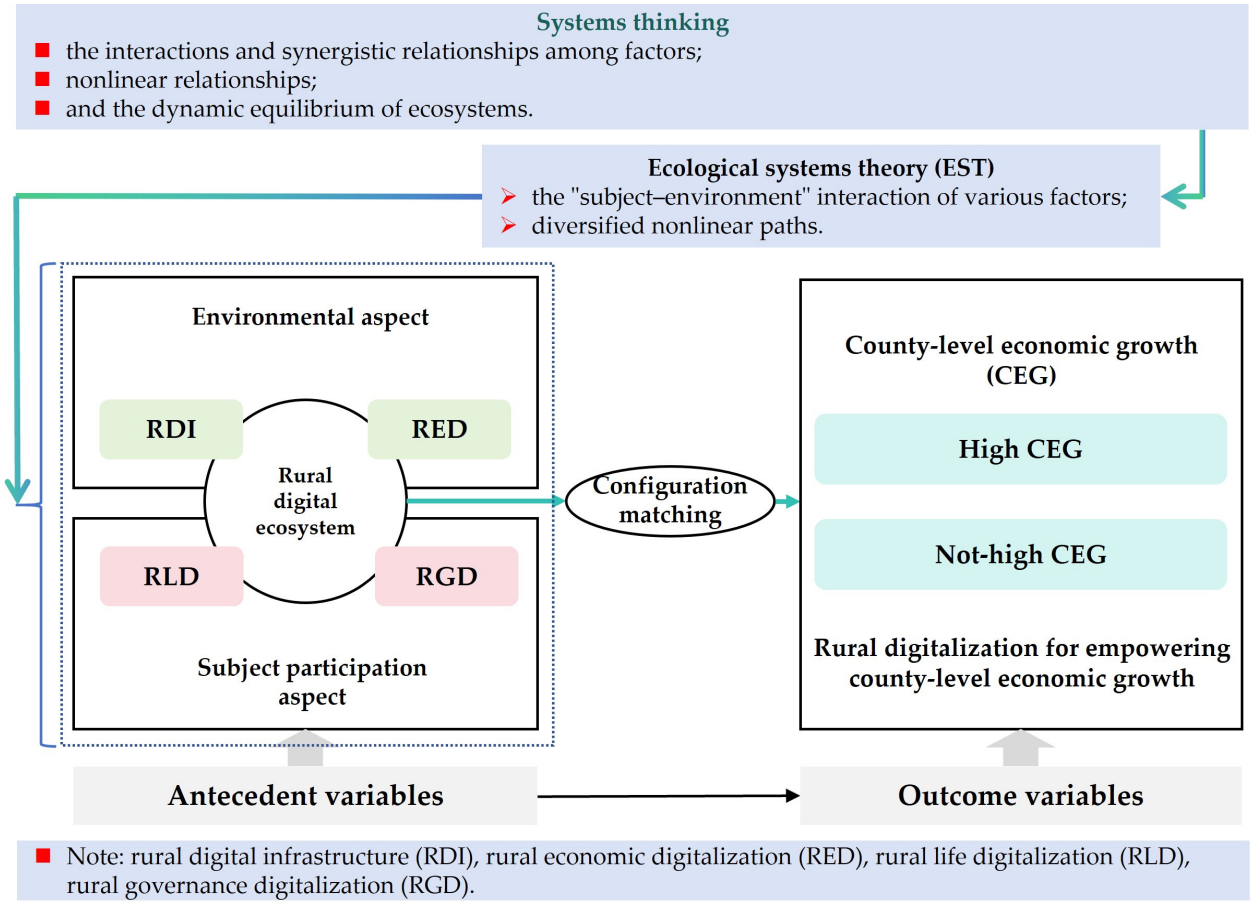


Figure 1. The theoretical mechanism model of rural digitalization for empowering CEG.

3.4. Definition of Variables

3.4.1. Environmental Aspect

Rural digital infrastructure typically refers to the basic facilities and technical support needed to provide digital services and management for rural areas, including broadband networks, mobile communications, data centers, digital platforms, and smart terminals [14,52]. Rural digital infrastructure is a key factor in promoting rural economic growth [18], enhancing the efficiency of public services and the level of rural governance [53], strengthening rural community resilience [15,54], and narrowing the urban–rural digital divide [14]. Conversely, inadequate digital infrastructure may hinder the endogenous development capacity of rural areas [55], exacerbating the development risks of falling behind in the digital era [56]. In some developing countries and regions, collaboration between governments and other stakeholders (such as non-governmental organiza-

tions, international organizations, and the private sector) to build rural digital infrastructure has become an important approach to promote multifaceted rural development [57].

The concept of rural economic digitalization actually evolved from the term "digital economy" proposed by Tapscott [58]. Rural economic digitalization typically refers to the comprehensive transformation and upgrading of the rural economy through the use of digital technology, informatization, networking, and intelligent means, aiming to enhance the level of rural economic development, optimize industrial structure, strengthen the agricultural industry's chain coordination, and improve production and living conditions [2,8]. The mechanisms of rural economic digitalization include but are not limited to smart agriculture [59], electronic commerce [60], and digital-inclusive finance [61]. Relevant studies indicate that rural economic digitalization plays a positive role in broadening market channels, improving production efficiency, promoting agricultural industrial upgrading, enhancing logistics supply chains, increasing farmers' income, and promoting the high-quality and sustainable development of county-level economies [2,18,62,63].

3.4.2. Subject Participation Aspect

Rural life digitalization relies first and foremost on having relatively sound digital infrastructure, a decent level of economic digitalization, and other external conditions. Under the operation modes of digital services, digital production, and digital management, rural life digitalization aims to enable local residents to handle their shopping/consumption, daily affairs, and cultural, tourism, educational, and health-related activities intelligently, easily, and conveniently through digital platforms, applications, mobile internet, and other media [51]. Research indicates that digitalization contributes to improving human settlement areas from three aspects: production, life, and ecology [8]. Furthermore, rural life digitalization helps to expand the scope of rural digital life within limited rural resources, reduce time and space constraints, enhance community participation, improve villagers' quality of life, narrow the urban–rural life gap, and protect and promote rural natural resources and culture [64–66]. However, it cannot be denied that the integration of the external environment and the participation of the subjects need continuous improvement during the process of rural life digitalization [50]. In particular, the experience of vulnerable groups in rural areas should be promoted [67]. For example, it is necessary to provide ongoing digital training and to promote digital technology to the vast rural elderly population in order to enhance their digital literacy and enable them to participate in and enjoy the convenience and benefits brought by digitalization [68].

Rural governance digitalization refers to the process of informatization and networking in rural governance, using digital technologies as modern rural governance means and digital platforms (e.g., e-government platforms) as carriers to enhance villagers' digital literacy, digital skills, and participation in digital governance [51,69,70]. Scholars have pointed out that the introduction of digital governance requires attention to the humanistic aspect of governance concepts [71]. On the one hand, this emphasizes the importance of people's participation as "subjects," while, on the other hand, it implies that rural areas may exhibit "digital divides" and differences in digital literacy and perception among different groups. Especially in governance related to people's well-being, if the relationship between the "introduction of digital governance" and "subject participation" is not handled well, it may cause concerns among villagers about the security of digital governance, thereby triggering collective "digital exclusion" [58]. Similarly, Misra and Mittal [72] pointed out that clear, transparent, and citizen-friendly rural digital governance creates a more attractive government and brings villagers closer to the government. Rural governance digitalization is expected not only to play a role in promoting rural sustainable development through digital technology but also to indirectly stimulate the development of the social economy [73].

4. Research Methods and Data Analysis

4.1. Methods

Fuzzy-set qualitative comparative analysis (fsQCA), first proposed by Ragin [74], is an asymmetric data analysis technique. On the one hand, it embodies the logical and experiential strength of qualitative methods in handling rich contextual information; on the other hand, it is a quantitative method capable of handling large numbers of cases [74,75]. Unlike correlation-based quantitative methods, fsQCA attempts to identify paths formed by combinations of multiple antecedent variables within a causal logic framework that can lead to the occurrence of the outcomes. In other words, the possible paths leading to the outcomes are diverse, meaning different combinations of the antecedent variables can lead to the same results [26,76]. In recent years, the application of fsQCA in the social sciences has shown a progressively increasing trend [77], especially in areas related to rural digitalization [78,79]. The logical framework of this research method aligns well with the research questions envisaged in this study, namely identifying the causally complex mechanisms through which rural digitalization influences county-level economic growth; exploring the combinations of various factors that influence county-level economic growth; and clarifying the configuration pathways facilitating or constraining county-level economic growth, alongside the connections between these opposing pathways. This strong alignment, together with the fact that fsQCA is a relatively mature application in this disciplinary field, made it logical to employ this method for data analysis.

The fsQCA approach encompasses three core steps: variable calibration, the necessity analysis of single conditions, and the sufficiency analysis of conditional configurations [74,75]. Of these, variable calibration involves transforming raw data into values ranging from 0 to 1, which indicate the degree to which a case belongs to a set under a certain condition. This step serves as the foundation of fsQCA. Necessity analysis of single conditions is employed to determine whether a condition is present in all cases that produce a particular outcome; if it is, then the condition is deemed necessary. Sufficiency analysis of conditional configurations, on the other hand, assesses whether combinations of multiple conditions are sufficient to lead to the occurrence of an outcome. Generally, when these conditions coexist, the outcome tends to manifest as well [74,75]. These three steps follow a sequential order, as illustrated in Figure 2:

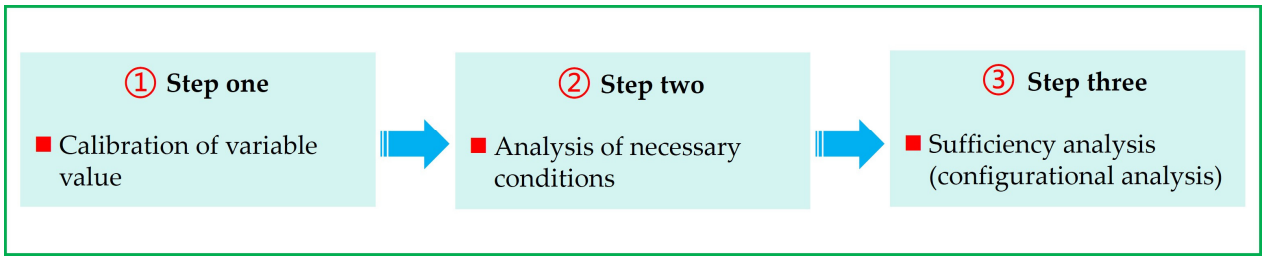


Figure 2. A simplified diagram of the three core steps in the fsQCA.

4.2. Selection of Cases

This study followed the theoretical sampling principle [80] and selected the pilot areas (county-level) chosen for digital rural development in China in 2020 [81] as the research cases. Among the listed pilot areas, a total of 117 cases are at the county level. Due to missing data, 28 counties were excluded, leaving 89 cases for data analysis. This meets the requirement for the number of cases when the number of antecedent variables is four [75]. The selected cases are representative cases in the context of implementing digital rural development in China, thus meeting the requirement for the typicality of research cases. In addition, the selected case samples cover 28 provincial-level regions of China,

spanning across the eastern coastal, central, and western regions, as well as the northern and southern regions. This ensures the selected cases not only meet the requirements for homogeneity and similarity but also exhibit heterogeneous characteristics internally [82]. The geographical distribution of the case samples is detailed in Figure 3. Additionally, the detailed names of the counties have been provided in Table A1 of the appendix.

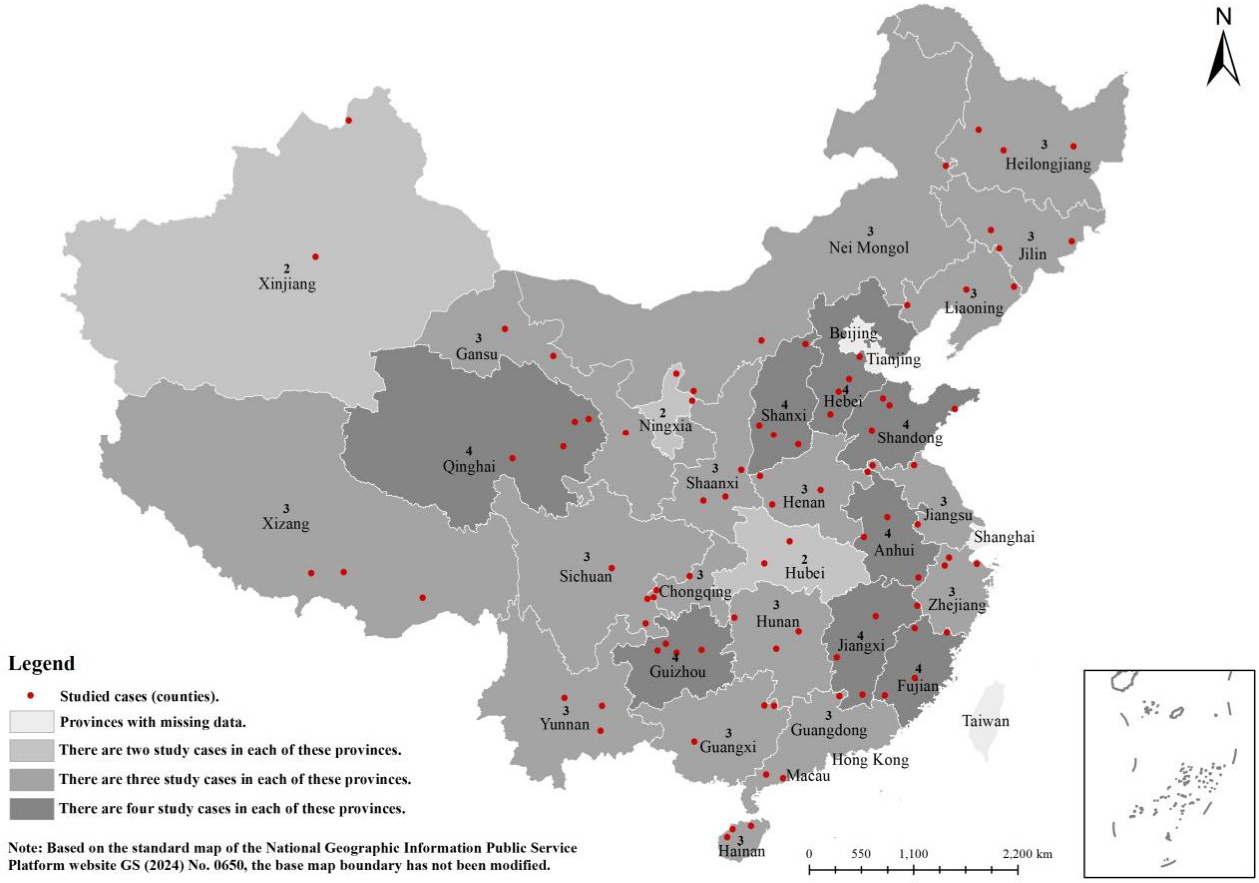


Figure 3. Regional distribution of the studied county-level case samples.

4.3. Data Sources

The measurement data of the four antecedent variables used in this study were all obtained from the China County-level Digital Rural Index (2020) research report [51], while the measurement data of the outcome variable, CEG speed, were obtained from the China County-level Statistical Yearbook published in 2022 (County-level Volume) [83] and 2021 [84]. Table 1 reports the descriptive statistical results of all the variables used in this paper.

Table 1. Descriptive statistics.

Variables	Mean	SD	A	B	C	D	E
RDI	79.051	18.093	1				
RED	50.949	22.201	0.460 **	1			
RGD	50.216	17.385	0.421 **	0.389 **	1		
RLD	52.847	18.780	0.498 **	0.508 **	0.424 **	1	
CEG	0.121	0.116	0.000	−0.010	0.171	0.036	1

Note: ** Correlation is significant at the 0.01 level (2-tailed). Rural digital infrastructure (RDI), rural economic digitalization (RED), rural governance digitalization (RGD), rural life digitalization (RLD), and county-level economic growth (CEG).

4.4. Variable Measurement

4.4.1. Measurement of Antecedent Variables

The four antecedent variables in this study are all primary indicators from the China County-level Digital Rural Index (2020) research report [51] published in 2022. This research report provides a detailed list of the secondary and tertiary indicators under each primary indicator. Table A2, Appendix shows the measurement indicators for these four antecedent variables. Studies have already used these indicators in academic research on rural digitalization, as the measurement data of the antecedent variables selected in this study possess both matching and feasibility characteristics [85].

4.4.2. Measurement of Outcome Variables

The outcome variable of county-level economic growth was measured using the GDP growth rate from 2020 to 2021 in the sample areas. GDP growth rate has been used by many scholars to measure the economic growth speed of a region [86], providing the reference for this study.

4.5. Calibration of Variable Value

Drawing on previous studies [75,87], this study used the 0.95th percentile, 0.5th percentile, and 0.05th percentile as the calibration anchor points for complete membership, crossover point, and complete non-membership, respectively, to calibrate the data of the variables. This percentile-based calibration approach is commonly used when theoretical thresholds are unavailable and data-driven calibration is necessary. It helps ensure that the calibration reflects the distributional characteristics of the data while avoiding arbitrary cutoffs [74,80]. For not-high outcome variables, we set the calibration anchor points opposite to those of high outcome variables [82]. Furthermore, following the research of [26,88], to prevent case loss, when the calibrated value appeared as 0.5, it was replaced with 0.501. The calibration anchor points for each variable are detailed in Table 2.

Table 2. Calibration anchor points for each variable.

Variables	Set of Objectives	Anchor Points		
		Full Membership	Crossover Point	Full Non-Membership
Antecedent variables	RDI	99.34	81.43	44.71
	RED	101.69	46.07	27.20
	RGD	78.43	51.79	22.80
	RLD	89.56	48.74	26.85
Outcome variables	CEG	0.2926	0.1004	0.0315
	~CEG	0.0315	0.1004	0.2926

Note: "~" indicates the "not" of logical operation. Rural digital infrastructure (RDI), rural economic digitalization (RED), rural governance digitalization (RGD), rural life digitalization (RLD), and county-level economic growth (CEG).

5. Research Findings

5.1. Analysis of Necessary Conditions

We analyzed whether the individual antecedent variables constitute the necessary conditions for the outcome variable, as shown in Table 3. The results show that the maximum consistency of the influence of each antecedent variable on the outcome variable is 0.75, with all values being less than 0.9, indicating that each of the four individual antecedent variables has a relatively weak explanatory power for CEG (only when the consistency value is greater than or equal to 0.9 is it considered to show strong explanatory

power) [89]. Therefore, we included these four antecedent variables in the subsequent configurational analysis to further analyze the configurations that lead to high CEG.

Table 3. Results of analysis of necessary conditions.

Antecedent Variables		Outcome Variables			
		High CEG		Not-High CEG	
		Consistency	Coverage	Consistency	Coverage
Environmental aspect	RDI	0.750	0.702	0.695	0.629
	~RDI	0.604	0.672	0.671	0.722
	RED	0.655	0.728	0.642	0.690
	~RED	0.721	0.675	0.747	0.677
Subject participation aspect	RGD	0.710	0.733	0.617	0.617
	~RGD	0.629	0.629	0.733	0.710
	RLD	0.693	0.713	0.642	0.640
	~RLD	0.650	0.652	0.712	0.692

Note: "~" indicates the "not" of logical operation. Rural digital infrastructure (RDI), rural economic digitalization (RED), rural governance digitalization (RGD), rural life digitalization (RLD), and county-level economic growth (CEG).

5.2. Configurational Analysis

When conducting data analysis using the fsQCA 3.0 software, we adopted the parameter setting method proposed by Ding [90] and set the frequency threshold to 1, consistency to be above 0.8, and PRI consistency to be above 0.6. Ultimately, three types of results were obtained: complex solution, parsimonious solution, and intermediate solution. When an antecedent variable appears in both the parsimonious and intermediate solutions, it is marked as a core condition; when an antecedent variable only appears in the intermediate solution, it is marked as a peripheral condition [26]. However, in this study, the computed complex, parsimonious, and intermediate solutions are exactly the same. This occurred because all logically possible configurations of the causal conditions are empirically represented in the data (89 cases cover all 16 (2^4) possible configurations), resulting in no logical remainders for the algorithm to simplify [80]. In such cases, the Quine–McCluskey algorithm cannot further distinguish between essential and inessential causal paths, and thus the solution is already fully reduced. Therefore, no peripheral conditions are presented in Table 4, and all conditions included in the solution are equally treated. This is similar to the use of intermediate solutions to analyze research findings by Poorkavoos et al. [91]. Thus, we calculated four configurations (S1a, S1b, S2, and S3) that lead to high CEG.

To identify configurations associated with not-high CEG, we used a slightly different PRI consistency threshold (0.5 instead of 0.6). This adjustment was made because the number of cases with not-high CEG was relatively small and unevenly distributed across condition combinations, which made it difficult to identify robust configurations under the more stringent threshold. This practice is consistent with the principle of causal asymmetry in fsQCA, which posits that the causal conditions leading to the presence of an outcome may differ from those leading to its absence [80]. Therefore, different parameter settings can be justified when analyzing positive (high) and negative (not-high) outcomes, particularly under conditions of empirical sparsity [92]. By setting the frequency threshold to 1, consistency to be above 0.8, and PRI consistency to be above 0.5 for computation [75,93], we generated two configurations (NS1 and NS2) that result in not-high CEG, as shown in Table 4. The analysis results indicate that the consistency values of the first four configurations are all above 0.8, demonstrating high consistency [94] and thus constituting sufficient conditions for high CEG. The overall consistency of the configurations resulting in not-high

outcomes exceeds 0.8, with a coverage of 0.584, indicating relatively good explanation for the reasons behind the not-high CEG [94].

Table 4. Configurations leading to high/not-high CEG.

Antecedent Variables	Outcome Variables					
	High CEG				Not-High CEG	
	S1a	S1b	S2	S3	NS1	NS2
Environmental aspect						
RDI		●	●	⊕		⊕
RED	⊕			●	⊕	
Subject participation aspect						
RGD	●	●	⊕		⊕	⊕
RLD		⊕	●	●	⊕	⊕
Consistency	0.840	0.914	0.889	0.914	0.813	0.811
Raw coverage	0.530	0.405	0.418	0.351	0.555	0.490
Unique coverage	0.101	0.022	0.048	0.019	0.094	0.029
Solution consistency	0.826				0.803	
Solution coverage	0.678				0.584	

Note: ● = core conditions exist, ⊕ = core conditions are absent. Where the entry is blank, this indicates that the conditions may or may not be present in the configuration. Rural digital infrastructure (RDI), rural economic digitalization (RED), rural governance digitalization (RGD), rural life digitalization (RLD), and county-level economic growth (CEG).

Based on the case coordinates output by the fsQCA 3.0 software, we plotted the graphical representations of the typical counties corresponding to each configuration, as shown in Figure 4. It can be noticed that the typical counties are concentrated in the upper triangular region of the plots. This indicates the sufficiency of the solutions (configurations) found in this paper [75,91].

5.2.1. Configurations Leading to High CEG

First, there is the digital governance-led type. This configuration (S1a) indicates that high rural governance digitalization and not-high rural economic digitalization are the core conditions that can lead to high CEG. We found that configuration S1a exhibits the characteristics of rural governance digitalization dominance, meaning that in situations where rural economic digitalization is not high and the roles of rural digital infrastructure and rural life digitalization in generating high CEG are unnecessary, high rural governance digitalization can lead to high CEG. Existing studies support the above findings; for example, it has been reported that rural governance digitalization can improve government service efficiency, enhance the rights of rural citizens, and bring government services to the doorstep of citizens, thereby bridging the urban–rural digital divide [95]. The efficiency of government services and the active participation of villagers will further promote local business and market environments [96], thus contributing to the generation of high CEG.

The typical county-level areas with configuration S1a include Hongtong, Yangxi, and Yushan, among others (see Graph A, Figure 4 for details). These counties demonstrate a high level of rural governance digitalization. From a geographical distribution perspective, these typical cases span across the southeastern coastal, central, northeastern, northwestern, and southwestern regions of China. There is therefore no significant regional concentration in geographical distribution. This indicates that the configuration dominated by digital governance possesses strong universality and adaptability in promoting CEG. This finding challenges the widely held view that only the developed eastern coastal regions can success-

fully drive digital transformation, suggesting that institutional execution capabilities (such as governmental capacity) can compensate for geographical or resource disadvantages, holding the potential to "bridge" the digital divide.

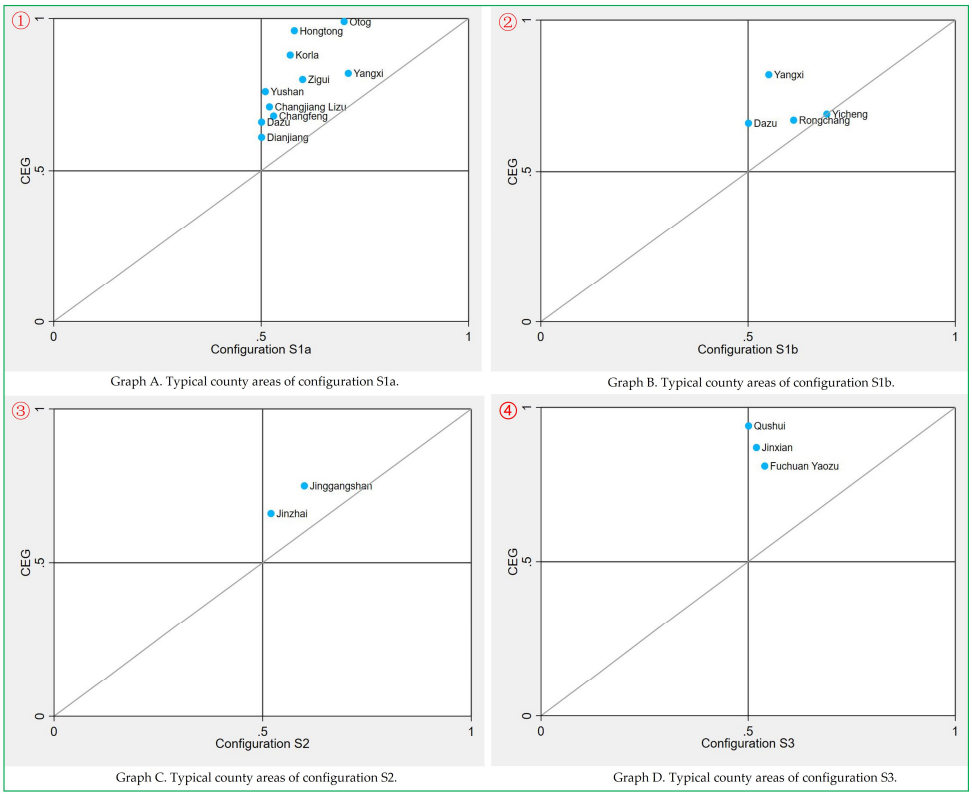


Figure 4. Typical counties corresponding to each configuration.

As an example, Yangxi County promotes government openness and information dissemination through platforms such as government portals, WeChat public accounts (12345) (a platform that provides one-stop demand services for enterprises and the public in terms of government counseling, requests for assistance, complaints, and suggestions), and Yuezhengyi (an application that provides instant messaging and government services) [97]. In government services, online processing is given priority. Relying on county and town (street) government service platforms and village (community) public service platforms, the county promotes and extends access to government services using the Internet, self-service terminals, and mobile terminals to the grassroots level, achieving the objectives of proximity, multi-point accessibility, and efficiency. By the end of 2019, the online processing rate of municipal and county-level government service matters reached over 80% [98]. Furthermore, the county has since achieved full coverage of government self-service machines at the village level, allowing residents to quickly complete over 170 services, such as provident fund inquiries, medical insurance inquiries, real estate information inquiries, and agricultural subsidy applications, by simply presenting their ID cards through these machines [99].

Second, there is the dual-promotion type of digital governance and digital infrastructure. This configuration (S1b) indicates that high rural governance digitalization, high rural digital infrastructure, and not-high rural life digitalization are core conditions that can generate high CEG. We found that configuration S1b enables the dual promotion of digital governance and digital infrastructure in promoting CEG; specifically, in situations where the level of rural life digitalization is low and the role of rural economic digitalization in generating high CEG is unnecessary, the combined effect of high rural governance digital-

ization and high rural digital infrastructure can generate high CEG. From the perspective of single factors, the continuous improvement of rural digital infrastructure provides "hard power" for county-level industrial upgrading and economic growth [14], while the enhancement of rural governance digitalization provides an indirect "soft environment" for CEG [100]. From the perspective of mutual promotion of factors, the continuous improvement of rural digital infrastructure provides more online functions and application scenarios for digital governance, while the enhancement of rural governance digitalization accelerates the demand development and work progress speed of digital infrastructure; under the joint action of the two, it shapes a good "software and hardware environment" for CEG. Furthermore, this software and hardware environment is continuously optimized through villagers' participation in digital governance, with their demands and applications evolving through feedback.

The typical counties with configuration S1b include Dazu, Rongchang, and Yicheng, among others, as shown in Graph B, Figure 4. These typical cases span across China's southeastern coastal, central, and southwestern regions. This demonstrates that the "dual-promotion pathway" does not rely on a single geographical condition or regional development level, but rather exhibits significant cross-regional adaptability. It indicates that the combination of digital infrastructure construction and digital governance capabilities constitutes a pathway that can be effective across diverse economic and geographical environments. Furthermore, this configuration is not an isolated example tailored to specific local conditions but rather a successful model that can be replicated and promoted in multiple regions. In other words, despite the disparities in developmental foundations among different regions, with the support of robust digital governance and appropriate infrastructure investments, synergistic effects can be achieved to drive economic growth.

Taking Dazu as an example, in terms of rural digital infrastructure, this area focuses on the construction of ten major characteristic demonstration parks for the agricultural industry and implements demonstration projects of digital agricultural comprehensive services in these characteristic industrial parks, promoting the construction of rural information infrastructure. The district also links the rural industry financial service capabilities of Ant Financial (an inclusive financial services company owned by Alibaba) to its digital rural platform, thereby providing convenient industry loan services for agricultural production and operation entities, and offers digital systems for agricultural production, operation, management, and service applications [101]. In terms of rural governance digitalization, the district is strongly promoting grassroots network social governance, creating a scientific, systematic, and innovative new mode of rural governance digitalization. For example, in important areas such as characteristic industrial bases, rural courtyards, and public places, intelligent cameras are installed, with PC+TV+Xiaoyi butler APP (an app launched by China Telecom for smart home, smart community, and digital village users) as the client; the purpose is to integrate various types of video resources to maximize the elimination of monitoring "blind zones", to protect the personal and property safety of villagers, and to provide public emergency command, community governance, and other services [102]. Through important means such as digital infrastructure construction and digital governance, new impetus has been added to the economic growth of Dazu.

Third, there is the dual-promotion type of digital life and digital infrastructure. This configuration (S2) indicates that high rural digital infrastructure, high rural life digitalization, and not-high rural governance digitalization are the core conditions that can lead to high CEG. It demonstrates the dual promotion of CEG via rural digital infrastructure and rural life digitalization. Specifically, in situations where rural governance is not highly digitized and economic digitalization alone does not suffice to generate high CEG, the combined effect of the high digitalization of life and infrastructure can achieve this. This

finding is consistent with existing research. For instance, Liu [50] argues that unilateral efforts in digital infrastructure construction alone are unlikely to effectively promote rural economic development. It is crucial to extensively train the main subjects in rural digital construction, primarily farmers, to enhance their digital literacy and proficiency in information technology in order to effectively integrate digital services in rural life.

The typical county-level areas with configuration S2 include Jinggangshan and Jinzhai, as shown in Graph C, Figure 4. These two typical cases are located in the central region of China. This finding illustrates that, under certain conditions, even in the absence of systematic digital governance, a robust technological foundation and vibrant digital lifestyle scenarios can also drive CEG. This phenomenon suggests that we should pay attention to the differences and substitutability in the allocation of digital elements across different regions, as different pathways may yield similar output effects under varying contexts.

Taking Jinzhai as an example, in terms of infrastructure construction, the county focuses on information infrastructure, having built 365 5G base stations to achieve full coverage of 4G networks. Simultaneously, 220 beneficial organizations for agricultural, rural, and farmer development's information have been established, achieving full coverage in administrative villages [103]. In terms of digital life, the county leverages advantages in cloud computing, big data, IoT, AI, and other technologies. It has developed and launched multiple digital life-related application services such as smart healthcare, smart education, smart transportation, and smart tourism, actively promoting these digital services within its jurisdiction. For instance, in the smart tourism scenario, the county uses digital technology to support the development of comprehensive tourism, enabling real-time data access from multiple scenic areas and intelligent monitoring around the clock. Tourists can use their smartphones at anytime and anywhere to inquire about scenic spots, make reservations, or experience virtual reality tours to immerse themselves in the beautiful landscapes of Jinzhai [104]. These measures make life more convenient for residents, allowing them to better enjoy the pleasures of digital life.

Finally, there is the dual-promotion type of digital life and digital economy. This configuration (S3) indicates that high rural economic digitalization, high rural life digitalization, and not-high rural digital infrastructure are the core conditions that can lead to high CEG. It presents the characteristics of the dual promotion of CEG via digital life and digital economy. Specifically, in situations where rural digital infrastructure construction is not highly developed and rural governance digitalization is unnecessary for generating high CEG, the combined effect of the high digitalization of life and economy can achieve this. Existing studies support the aforementioned findings; for instance, research indicates that the digital economy facilitates long-term increases in farmers' income and serves as a significant driving force for rural economic development [105]. Rural digitalization provides opportunities to narrow the urban–rural digital divide; the construction of digital infrastructure not only facilitates digital life for rural families [106] but also plays a crucial role in promoting rural business activities [107].

The typical county-level areas with configuration S3 include Qushui, Jinxian, and Fuchuan Yaozu, as detailed in Graph D, Figure 4. These three typical cases are located in the central, southern, and southwestern regions of China. This phenomenon indicates that in certain regions, even with an incomplete rural digital infrastructure, counties can still achieve significant economic growth by leveraging vibrant digital lifestyle scenarios and robust digital economic activities. This configuration reveals the functional substitutability and regional embeddedness characteristics of the digital pathway. It also suggests that policymakers, in promoting rural digitalization, should place greater emphasis on cultivating digital application capabilities and economic embedding mechanisms.

Taking Jinxian as an example, in terms of rural economic digitalization, the county has leveraged rural e-commerce as a breakthrough to accelerate the development of rural digital economy. The county has established 164 e-commerce service stations and two county-level rural logistics centers, developed four rural delivery routes, and trained over 10,000 e-commerce personnel, indicating its strong momentum in the development of the e-commerce industry [108]. In terms of rural life digitalization, the county aims to benefit local people by promoting key application scenarios such as smart campuses and smart healthcare, which are continuously being extended into rural areas [109].

5.2.2. Configurations Leading to Not-High CEG

This study also examined configurations leading to not-high CEG and found two such configurations (see Table 4 for details). Configuration NS1 shows that in rural areas where digitalization of economy, life, and governance is lacking, CEG will not be high, regardless of the state of digital infrastructure. Configuration NS2 shows that in rural areas where digital infrastructure, governance digitalization, and life digitalization are all lacking, CEG will not be high regardless of the state of economic digitalization. Furthermore, this study found that configurations NS1 and NS2 exhibit the characteristics of "subject–environment" deficiency in the rural digital ecosystem, where there is a severe lack of rural digitalization-related factors at both the subject and environmental levels, making it difficult for factors within the system to synergize, thus resulting in a "suspended" state of rural digitalization for an extended period and a failure to mobilize subject participation [50], ultimately leading to not-high CEG.

5.2.3. Configuration Comparison Under Systems Thinking

In systems thinking, owing to the nonlinear interactions among elements, the phenomenon of multiple pathways leading to a single outcome frequently arises [40]. For example, system redundancy allows elements to attain equivalent results through diverse pathways. This study compared the four configurations of high CEG and the two configurations of not-high CEG, identifying four substitution relationships. See Figure 5 for details.

By comparing configurations S1a and S1b, it was found that under the condition where rural governance digitalization is a core presence factor, the single factor of "~rural economic digitalization" can be replaced by the combined factor "rural digital infrastructure*~rural life digitalization," both of which can promote CEG, as shown in Figure 5A. From an ecosystem perspective [43], this indicates a functional substitution among digital elements, wherein infrastructure and governance jointly stabilize the system when economic digitalization is absent.

Second, by comparing configurations S1b and S2, it was found that under the condition where rural digital infrastructure is a core factor, the combined factor of "rural governance digitalization*~rural life digitalization" can be replaced by the combination of "rural life digitalization*~rural governance digitalization," both of which can promote CEG, as shown in Figure 5B. This illustrates structural compensation, where the relative weight of digital life and governance can flexibly adapt, echoing the ecosystem's principle of resilience through diversity [15,34].

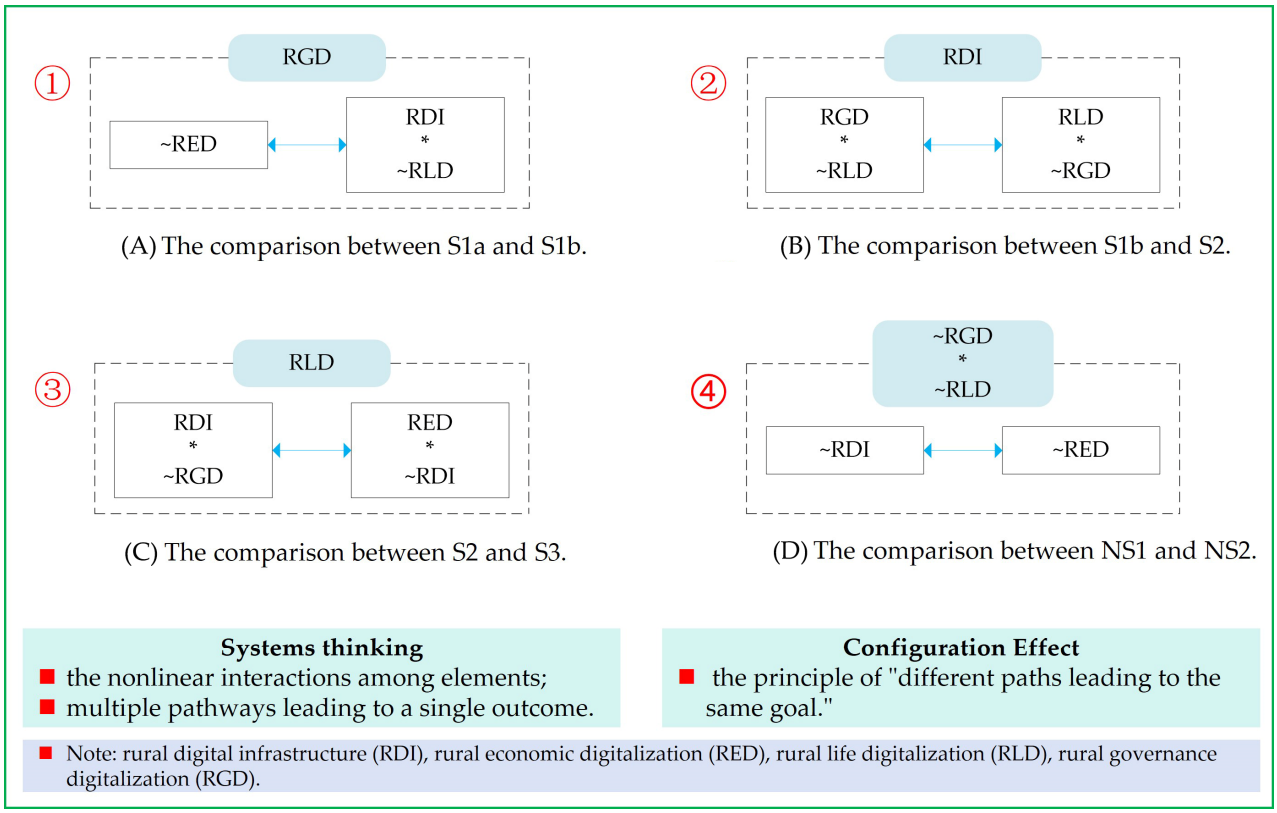


Figure 5. The substitution relationship between configurations.

Meanwhile, by observing configurations S2 and S3, the substitution relationship shown in Figure 5C is derived. Specifically, under the condition where rural life digitalization is a core factor, the combined factor of "rural digital infrastructure*~rural governance digitalization" can be substituted with the combination of "~rural digital infrastructure*rural economic digitalization," both of which can promote CEG. This highlights the adaptive balance between physical infrastructure and economic capacity [28] in sustaining digital vitality in county-level ecosystems.

Finally, when comparing the NS1 and NS2 configurations of not-high CEG, the substitution relationship is as shown in Figure 5D. Specifically, under the condition where "~rural governance digitalization*~rural life digitalization" are the core factors, these can be substituted with "~rural digital infrastructure" and "~rural economic digitalization", both of which can generate not-high CEG. This reflects how deficiencies in key subsystems can propagate downward spirals, as suggested by both systemic fragility and ecological imbalance [110].

Overall, these substitution patterns illustrate the configurational diversity underlying rural digitalization of county-level regions. Furthermore, we found that the configurations generating not-high CEG exhibit an asymmetric relationship compared to those generating high CEG. The findings validate that different county-level regions construct and evolve their digital ecosystems according to local constraints and capacities, demonstrating the context-dependent adaptability and path multiplicity emphasized by both systems thinking [40,41] and EST [43,44].

5.3. Robustness Test

Robustness tests were conducted by adjusting the consistency threshold, case frequency, and calibration values for high CEG configurations [111]. In the first test, the consistency threshold for generating high CEG was raised from 0.8 to 0.85, while the case

frequency remained at 1, and PRI consistency remained at 0.6; this test resulted in the same configurations as before adjustment, with consistency and coverage similar to those before adjustment. In the second test, the case frequency was adjusted from 1 to 2, while the consistency threshold remained at 0.8, and PRI consistency remained at 0.6, resulting in configurations that were essentially consistent with those before adjustment. In the third test, we decreased the crossover point by 5% while maintaining the consistency threshold at 0.8 and the PRI consistency at 0.6. This test yielded the same configurations as those before the adjustment, with similar levels of consistency and coverage. The detailed results of the three robustness tests can be found in Table 5. Therefore, based on the results of these three robustness tests, the configurations can be considered to be relatively robust.

Table 5. Results of robustness tests for high CEG.

Antecedent Variables	**Outcome Variables**											
	High CEG (the Consistency Threshold Increased from 0.8 to 0.85)				**High CEG (the Case Frequency Threshold Increased from 1 to 2)**				**High CEG (the Crossover Point Decreased by 5%)**			
	S1a′	**S1b′**	**S2′**	**S3′**	**S1a″**	**S1b″**	**S2″**	**S3″**	**S1a‴**	**S1b‴**	**S2‴**	**S3‴**
Environmental aspect												
RDI		●	●	⊕		●	●			●	●	⊕
RED	⊕			●	⊕			●	⊕			●
Subject participation aspect												
RGD	●	●	⊕		●	●	⊕	⊕	●	●	⊕	
RLD		⊕	●	●		⊕	●	●		⊕	●	●
Consistency	0.840	0.914	0.889	0.914	0.840	0.914	0.889	0.894	0.858	0.926	0.891	0.920
Raw coverage	0.530	0.405	0.418	0.351	0.530	0.405	0.418	0.388	0.521	0.404	0.418	0.341
Unique coverage	0.101	0.022	0.048	0.019	0.103	0.030	0.020	0.007	0.098	0.024	0.049	0.018
Solution consistency	0.826				0.823				0.840			
Solution coverage	0.678				0.667				0.673			

Note: ● = core conditions exist, ⊕ = core conditions are absent. Where the entry is blank, this indicates that the conditions may or may not be present in the configuration. Rural digital infrastructure (RDI), rural economic digitalization (RED), rural governance digitalization (RGD), rural life digitalization (RLD), and county-level economic growth (CEG).

Additional robustness tests were conducted by adjusting the consistency threshold, case frequency, and calibration values for not-high CEG configurations. Specifically, firstly, we increased the consistency threshold from 0.8 to 0.85 while maintaining all other parameters consistent with the previous settings. As a result, we obtained two not-high configurations, both of which were subsets of the original not-high configurations. The solution consistency and coverage were also similar to those obtained previously. Secondly, we raised the case frequency from 1 to 2 while keeping all other parameters consistent with the previous settings. This test generated the same configurations as those before the adjustment, with identical levels of consistency and coverage. Finally, we decreased the crossover point by 5%, again maintaining all other parameters as before. Ultimately, we obtained a configuration that was a subset of the original result, and both the consistency and coverage of this configuration solution achieved satisfactory levels (with a solution consistency of 0.829 and a solution coverage of 0.453). The detailed results of the robustness test for not-high configurations are presented in Table 6.

Table 6. Results of robustness tests for not-high CEG.

Antecedent Variables	Outcome Variables				
	Not-High CEG (the Consistency Threshold Increased from 0.8 to 0.85)		Not-High CEG (the Case Frequency Threshold Increased from 1 to 2)		Not-High CEG (the Crossover Point Decreased by 5%)
	NS1′	NS2′	NS1″	NS2″	NS1‴/NS2‴
Environmental aspect					
RDI	●	⊕		⊕	⊕
RED	⊕	●	⊕		⊕
Subject participation aspect					
RGD	⊕	⊕	⊕	⊕	⊕
RLD	⊕	⊕	⊕	⊕	⊕
Consistency	0.869	0.883	0.813	0.811	0.829
Raw coverage	0.387	0.316	0.555	0.490	0.453
Unique coverage	0.142	0.072	0.094	0.029	0.453
Solution consistency	0.867		0.803		0.829
Solution coverage	0.459		0.584		0.453

Note: ● = core conditions exist, ⊕ = core conditions are absent. Where the entry is blank, this indicates that the conditions may or may not be present in the configuration. Rural digital infrastructure (RDI), rural economic digitalization (RED), rural governance digitalization (RGD), rural life digitalization (RLD), and county-level economic growth (CEG).

6. Discussion

Our research findings support the value of adopting the "subject–environment" interaction perspective from EST in analyzing rural digitalization. We found that factors from both the subject and environmental aspects jointly influence CEG, as shown by configurations S1b, S2, and S3. These findings are in agreement with the existing literature in some aspects, such as digitalization serving as a core factor in enhancing the overall economic development level of urban and rural areas [8,63,112]. However, what sets our study apart is that we explored and found multiple pathways of CEG driven by various combinations of factors from the perspective of configuration. Furthermore, we did not merely consider factors from the perspective of software and hardware infrastructure; we integrated the participatory role of villagers in the digital environment, thereby providing new insights into addressing the issue of suspension of rural digitalization. Based on these findings, we have made potential theoretical contributions and practical implications in several areas.

6.1. Theoretical Implications

First, based on the configurational perspective, we systematically integrated various factors of rural digitalization construction and identified multiple configurations leading to high CEG. Many existing studies explored the impact of single factors such as the digital economy [113] or digital governance [114] on regional economic development, without analyzing the causal relationship from the perspective of multifactorial combination. Our analysis of the complex causal mechanism of rural digitalization in driving CEG, based on a systematic and multifactorial combination perspective rather than a linear or purely qualitative research perspective, allowed us to identify multiple configurations leading to high CEG, namely, S1a, S1b, S2, and S3. These configurations can explain the differentiated impact of the digital development environment in different villages on CEG, reflecting the digital characteristics of different villages. Therefore, this study contributes to current research by identifying diverse rural digitalization configurations for promoting CEG,

responding to scholars' call for adhering to the principle of adapting measures to local conditions in rural and county development [115].

This study also provides new theoretical insights for alleviating or resolving the digital suspension issue in rural areas. China's rural digitalization is still in its early stages; although some digital infrastructure has been relatively well established, there are still many issues [50]. The majority of farmers are not actively engaged in rural digitalization; certain digital initiatives are not aligned with the digital development needs of agriculture, rural areas, and farmers, and farmers' digital technology application capabilities need improvement [50]. Moreover, data sharing, coordination, and integration among governments, enterprises, social organizations, and the public are difficult to achieve [116]. From the perspective of "environment–subject" interactive coupling, this study comprehensively considers the integration level of the environment and subject in rural digitalization, revealing potential pathways whereby environmental and subject factors jointly promote high CEG (e.g., S1b, S2, and S3). This study contributes substantially to the literature by providing a theoretical research framework for addressing or alleviating the digital suspension issue in rural digitalization.

Furthermore, our study demonstrates that EST provides a scientifically reasonable framework for analyzing the combination of antecedent variables driving CEG through rural digitalization. EST is commonly employed in fields such as education [44,45], psychology [46], and business [48], and its perspective on "subject–environment" interaction has also been extended to the entrepreneurial domain [117,118]. The application of this theoretical framework in our study enriches the relevant research on rural digitalization and expands its application in this field. This is a key point distinguishing our study from previous research.

Lastly, based on systems thinking, this paper breaks through the traditional linear analytical framework and research paradigm [119]. By revealing the nonlinear coupling mechanism between rural digital elements and county-level economic growth, it provides a new paradigm for research on the resilient growth of county-level economies within the context of digital development.

6.2. Practical Implications

Based on our findings, we identify six practical implications. First, it is possible to enhance the learning and exchange of information among typical rural digitalization cases in different counties. In terms of the mechanism of rural digitalization driving CEG, counties with the same configuration exhibit similarities (e.g., the four county cases in configuration S1b), and cases with different configurations can achieve the same result. This suggests that managers can promote the learning and exchange of rural digitalization construction modes among different counties, drawing from typical cases to borrow their digital construction methods.

Second, in terms of rural digitalization construction planning, the government can consider comprehensively promoting industrial, governance, and service digitalization. This study found that, in the process of rural digitalization construction, factors at the environmental and subject levels need to be balanced and coordinated (e.g., configurations S1b, S2, and S3). Therefore, in the planning of rural digitalization construction, the government can focus on local industrial development advantages and characteristics, strengthen the investment and construction of digital infrastructure, and improve the digitization level of relevant industries. The government can also establish online government service platforms, guide farmers to participate in government affairs online, and improve the level of rural digital governance, as well as focus on the goal of building convenience into rural life, promoting the digitalization of rural life, and improving the level of digital services in

rural areas. This will enhance the government's capability to provide services within the rural digital ecosystem, and boost villagers' sense of gain from digital services and their digital happiness index.

Third, the government, social organizations, and other entities need to actively guide farmers to participate in rural digitalization activities and encourage them to change their "digital exclusion" mentality. This study found digital factors from the subject aspect play a crucial role in driving CEG (e.g., configurations S1a, S1b, S2, and S3). Therefore, the government and social organizations can organize training activities to enhance farmers' digital literacy while also enhancing knowledge dissemination about the importance of rural digitalization construction and its positive impact on rural development. These measures aim to promote farmers' awareness of their subject status in rural digitalization construction.

Fourth, to promote the resilient growth of county-level economies, it is essential to harness the synergy between "subjects" and "the environment" within the digital ecological context by providing digital ecosystem services and products. For instance, social organizations can collaborate with villagers to establish public brands for rural agricultural products, implementing a "one item, one code" certification system through blockchain traceability technology to enhance the premium pricing potential of eco-agricultural products. Additionally, the government, enterprises, and rural communities can jointly develop a rural virtual reality (VR) cloud tourism system that incorporates digital twin models of ancient villages and VR teaching of intangible cultural heritage skills, thereby offering ecosystem services that combine cutting-edge technology with rural characteristics to customers.

Fifth, based on the multiple high configurations identified in this study, it is recommended that the government, when formulating digital policies, implement differentiated, region-specific, and pathway-based categorical guidance policies. Full consideration should be given to the differences among counties in terms of resource endowments, industrial structures, and governance capabilities, in order to identify digital advancement pathways suitable for each region and provide targeted policy and financial support. This approach will help avoid resource misallocation and inefficient development resulting from a "one-size-fits-all" promotion strategy.

Finally, it is recommended to establish a configuration logic-oriented mechanism for evaluating and providing feedback on the digital performance of rural areas within counties. By constructing a dynamic monitoring system, we should not only examine individual inputs but also pay closer attention to the synergistic effects of multiple factors. Combining the typical configuration models identified in this study, the government can conduct categorized and periodic assessments to accurately identify the progress of digital construction and make policy adjustments, thereby enhancing the flexibility and precision of policy implementation.

7. Conclusions

Rural digitalization is not merely a technological spillover from urban areas, but a transformative process that reshapes the economic and social fabric of county-level regions. While it requires continuous investment in digital infrastructure and services, its long-term success also hinges on the active participation of local residents as co-creators and beneficiaries of digital transformation.

Grounded in systems thinking and EST, and employing the configurational fsQCA method, this study provides novel insights into the complex causal pathways through which rural digitalization contributes to CEG. Unlike linear models, our approach reveals that there is no single necessary condition for high CEG, but rather multiple equifinal

configurations that can lead to successful outcomes. Specifically, we identify four distinct high-performing configurations:

(1) A digital governance-led pathway;

(2) A dual-promotion pathway of digital governance and digital infrastructure;

(3) A dual-promotion pathway of digital life and digital infrastructure; and

(4) A dual-promotion pathway of digital life and the digital economy.

These configurations reflect diverse yet effective strategies for driving economic development under varying local conditions. Moreover, two contrasting configurations are associated with not-high CEG, affirming the causal asymmetry principle of fsQCA and underscoring the risks of imbalanced or incomplete digital development.

These findings highlight that rural digitalization does not follow a "one-size-fits-all" model. Instead, targeted, path-specific strategies that are tailored to the interplay between environmental and subject-level factors are crucial. When comprehensive digitalization is constrained by local realities, focusing on key driving elements (e.g., governance capacity, infrastructure, digital engagement) can still yield significant gains. This study thus offers both theoretical advancement in understanding rural digital transformation and practical guidance for policymakers seeking adaptive, region-specific strategies to foster sustainable CEG.

8. Limitations and Further Research

We acknowledge some limitations in this study, which future research will need to address. Firstly, the case samples of this study were obtained from China's pilot counties for digital rural development in 2020, where digital construction was still in its early stages. Therefore, the research results may have stage-specific and regional characteristics, which limit the universality of the research findings. In the future, comparative studies can be conducted based on large case samples from different stages of digital rural development and different counties. Furthermore, conducting separate configurational analyses and comparisons based on geographical regional divisions, using nationwide county-level samples, is also a topic worthy of in-depth exploration. In particular, when data is accessible, it is important to examine the relationship between the effectiveness of digital village construction during its 1.0 and 2.0 phases, post-2021 and after its economic growth. Secondly, while our use of EST as the research framework proved useful, the adoption and application of different theories (e.g., synergy theory and value creation theory) may affect the selection of antecedent variables. Therefore, future research could consider causal relationship studies under different theoretical frameworks. Thirdly, this paper emphasizes the construction of a theoretical model based on the fsQCA method, drawing on systems thinking concepts (e.g., mutual influence and collaborative operation among factors, nonlinear causality relationships, and dynamic balance in ecosystems). In the future, causal analysis and multi-scenario simulation comparisons can be conducted to explore the relationship between digitalization and economic development resilience in different counties, utilizing research methods such as system dynamics models. Fourthly, with the relentless evolution of the QCA methodology, a growing cohort of scholars has increasingly turned to the dynamic QCA approach to elucidate intricate causal mechanisms [120,121]. This trend unequivocally offers a methodological vantage point that warrants meticulous exploration in our forthcoming research pursuits. Lastly, regardless of whether rural digitalization construction is successful, truly achieves the integration and synergy of environment and subject, and positively impacts CEG, the farmers living in these local areas have the most say. Therefore, future research can conduct survey studies based on counties, focusing on the perceptions of local farmers towards rural digitalization construction. This can

differentiate from the use of secondary data in this study, providing another perspective to demonstrate the feasibility of the proposed theoretical framework.

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Appendix A

Table A1. The studied county-level case samples.

Code	County-Level Name	Provinces	Code	County-Level Name	Provinces
C1	Yongqing	Hebei	C46	Zigui	Hubei
C2	Suning		C47	Yicheng	
C3	Nanhe		C48	Huayuan	Hunan
C4	Xinji		C49	Daxiang	
C5	Xi	Shanxi	C50	Shaoshan	
C6	Hongtong		C51	Nanxiong	Guangdong
C7	Yunzhou		C52	Yangxi	
C8	Gaoping		C53	Gaozhou	
C9	Toketo	Nei Mongol	C54	Gongcheng Yaozu	Guangxi
C10	Otog		C55	Fuchuan Yaozu	
C11	Jalaid		C56	Pingguo	
C12	Liaozhong	Liaoning	C57	Qionghai	Hainan
C13	Lingyuan		C58	Chengmai	
C14	Hengren Manzu		C59	Changjiang Lizu	
C15	Lishu	Jilin	C60	Dianjiang	Chongqing
C16	Helong		C61	Dazu	
C17	Dongliao		C62	Rongchang	
C18	Huanan	Heilongjiang	C63	Longchang	Sichuan
C19	Wangkui		C64	Dayi	
C20	Yian		C65	Xingwen	

Table A1. *Cont.*

Code	County-Level Name	Provinces	Code	County-Level Name	Provinces
C21	Feng	Jiangsu	C66	Xifeng	Guizhou
C22	Pukou		C67	Qianxi	
C23	Donghai		C68	Jinsha	
C24	Deqing	Zhejiang	C69	Yuqing	
C25	Cixi		C70	Shilin Yizu	Yunnan
C26	Linan		C71	Chuxiong	
C27	Changfeng	Anhui	C72	Kaiyuan	
C28	Dangshan		C73	Milin	Xizang
C29	She		C74	Qushui	
C30	Jinzhai		C75	Bailang	
C31	Shouning	Fujian	C76	Dali	Shaanxi
C32	Wuyishan		C77	Zhashui	
C33	Datian		C78	Foping	
C34	Shanghang		C79	Yumen	Gansu
C35	Anyuan	Jiangxi	C80	Gaotai	
C36	Jinxian		C81	Gaolan	
C37	Jinggangshan		C82	Guinan	Qinghai
C38	Yushan		C83	Huzhu Tuzu	
C39	Gaoqing	Shandong	C84	Maduo	
C40	Feicheng		C85	Huangyuan	
C41	Huimin		C86	Yanchi	Ningxia
C42	Haiyang		C87	Pingluo	
C43	Lingbao	Henan	C88	Korla	Xinjiang
C44	Xixia		C89	Jimunai	
C45	linying			/	

Table A2. Measurement indicators of antecedent variables [51].

Primary Indicator	Secondary Measurement Indicators	Primary Indicator	Secondary Measurement Indicators
Environmental aspect		Subject participation aspect	
RDI index	Information infrastructure index	RGD index	Governance means index
	Digital financial infrastructure index	RLD index	Digital consumption index
	Digital business landmark index		Digital cultural, tourism, education, and health index
	Basic data resource system index		Digital life service index
RED index	Digital production index Digital supply chain index Digital marketing index Digital finance index	/	

Notes

[1] Because of the nature of the dataset we follow Fiss [26] in using the terms "high" and "not high" rather than the simpler "high" and "low".

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