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Original Research

Analysis of Driving County Innovation Capability Enhancement: Based on fsQCA

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Abstract

County-level innovation capability is a key link in promoting the deepening development of the national innovation system. Although there has been extensive research on the factors that affect county-level innovation capabilities, most studies have a mismatch between theory and methods. In theory, it is most appropriate to explain the reasons for improving county-level innovation capabilities from the perspective of complex systems. However, research methods lack the ability to capture the complex interactive effects between various conditions that affect innovation capability. In addition, it is necessary to seek new explanatory perspectives for the many conflicting findings in the literature. This study is based on the theories of complex systems and regional innovation systems, utilizing relevant data from 52 counties in Zhejiang, China, and using the fsQCA method from a holistic configuration perspective to study the multiple paths and mechanisms that promote synergy between the government and the effective market, attract factors to "reverse flow," and drive the improvement of county innovation capabilities. Research has found that a single factor is not a necessary condition to enhance the high county innovation capacity. The configuration that generates high county innovation capabilities can be summarized into four types: the joint driving model of innovative entities and responsible government; the joint driving model of collaborative production factors and responsible government; driven by the traditional industrial upgrading model; and the joint driving model of traditional industrial upgrading and responsible government. The research conclusion also reveals that the business environment plays an important role in the process of enhancing county innovation capabilities, but the innovation main body is the new force in enhancing county innovation capabilities. The various elements that affect the innovation capacity of the county adapt to each other, co-evolve, and evolve into different ecosystems, forming a diversified and differentiated driving path.

Keywords: county innovation capability, regional innovation system, fsQCA

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Introduction

"County innovation capability" is a concept derived from "national innovation capability" [1], and its connotation research mainly focuses on innovation foundation (Romer's endogenous growth theory) [2], innovation environment (Porter's industrial cluster theory) [3], industry university research connection, and technology spillover (Nielsen's national innovation system theory) [4]. Enhancing the innovation capability of counties can reduce the negative impact on the environment by improving production efficiency, developing clean energy technologies, green manufacturing processes, and developing circular economy models. Create innovative opportunities that contribute to sustainable development and achieve economic, social, and environmental well-being in counties [5, 6]. Therefore, it is receiving increasing attention from scholars and policymakers [7].

Despite extensive research on county-level innovation capabilities, little is known about which specific conditional configurations lead to higher levels of county-level innovation capabilities [8, 9]. The first reason is that the literature on county-level innovation capabilities is scattered and lacks a comprehensive framework [10]. Most studies only cover a small portion of the innovation conditions that are considered important [11]. In fact, county capacity improvement is the result of complex, multi-factor interaction, which requires the use of a holistic perspective to study the cause-and-effect relationship between multiple factors and county innovative capacity.

The second reason is that there is a mismatch between theory and methods in research on enhancing county-level innovation capabilities [12]. Theory suggests that the explanation for enhancing county-level innovation capabilities is best explained from the perspective of complex systems. The research method mainly uses the "independent" condition of empirical analysis to explain [9]. Many studies have failed to capture the complex interactive effects between various conditions that affect innovation capability [9].

To address this gap in the literature, we used the overall perspective of the national innovation system [10] and combined it with the fuzzy set qualitative comparative analysis method (fsQCA) to analyze the configuration conditions that lead to high-level county-level innovation capabilities under the influence of factor "reverse flow" [13, 14]. We try to answer the following questions: What are the core and marginal conditions affecting the innovation capacity of the county? Which paths can enhance county innovation capabilities more effectively? What are the paths that will restrict the innovation capacity of the county, and what are the links between them?

Our research is novel in that it proposes a perspective based on complex innovation systems and a holistic approach based on fsQCA to determine the configuration of conditions that guide a county to achieve high-level innovation capabilities. From a theoretical perspective, our research is expected to narrow the gap between the aforementioned theories and methods and be able to analyze in detail the sufficient and necessary conditions for achieving high innovation capabilities. Provide new ideas for empirical research on enhancing county-level innovation capabilities. From a practical perspective, our research has good decision-making reference value for exploring diversified paths of county-level innovation-driven development and how to improve high-quality development at the county level.

In the next section, we conducted a literature review on the factors that affect county-level innovation capabilities, proposed our theoretical framework, and proposed the fuzzy set qualitative comparative analysis method (fsQCA) as the theoretical background for empirical analysis. Section 3 is the research design and data sources, introducing the research methods and data sources. Section 4 introduces the results of the fsQCA method. Section 5 is the discussion, and section 6 is the conclusion.

Literature Review and Research Framework

Factors Affecting County-Level Innovation Capability

Innovation intensity and innovation efficiency are commonly used as standards to measure regional innovation capability. The basic conditions of regional innovation affect the intensity of innovation, such as GDP level and R&D activity investment. Innovation efficiency is related to specific regional factors, such as the industrial cluster environment, industry university research, external technology spillovers, etc. [15]

The innovation capacity of counties is influenced by the transformation of achievements, innovation entities, spatial position [16], innovation investment [17, 18], innovative talents, innovative resources, and local unique resource endowments. The transformation of achievements and the cultivation of innovative entities are difficulties and priorities that require the creation of a good county-level innovation environment [19], the integration of scientific and technological resources, the support of county-level characteristic industrial clusters [20], and the cultivation and introduction of innovative scientific and technological talents [21, 22].

Innovation efficiency is also a specific factor in measuring regional innovation. Xiao et al. (2024) [23] used research methods such as the DEA-BCC efficiency model, kernel density, and spatial exploration to measure the efficiency of science and technology innovation in Chinese counties and identified the main factors affecting county innovation efficiency using a barrier degree model. They found that the development of high-tech industries, the construction of innovation platforms, the investment of enterprises in innovation, and the endowment of scientific and technological human resources are key factors restricting the improvement of county-level scientific and technological innovation efficiency.

The Impact Mechanism of Factor Flow on County-Level Innovation Capacity

The study of the relationship between production factors and regional economic development began with neoclassical economics. From neoclassical location theory (Weber and Lösch), growth pole theory (Perroux), cyclic cumulative causality theory (Myrdal), imbalanced growth theory (Hirschman), to "core periphery" theory (Friedman), etc., all are characterized by the spatial agglomeration of production factors affecting regional economies. There is currently no consensus on whether factor mobility promotes or hinders economic development. Some scholars believe that factor mobility is beneficial to the development of regional economies and have demonstrated the direct or indirect contribution of factor mobility to regional economic development from the perspectives of resource endowment [24], industrial structure [25], allocation efficiency [26], and spillover dividends [27]. However, scholars who hold the opposite view believe that only the economy of the inflow region can benefit from the flow of factors, while the economy of the outflow region will have a negative and hindering effect on its development due to the outflow of factors [28].

The degree of spatial agglomeration of innovative elements and resources affects the level of innovation-driven economic development. In order to explore the laws and processes of innovation, Lundvall first proposed the theory of innovation systems in 1985 [29]. It found that in order for different entities within an innovation system to achieve specific innovation goals, the flow of factors must form an organic whole through collaboration. With the rise of Silicon Valley in the United States and the development of industrial agglomerations, Cooke proposed the Regional Innovation System Theory in 1992, which studies the innovation network and administrative institutional support arrangements that frequently and closely interact with the innovation investment of regional enterprises within a certain geographical range [30]. The basic impact mechanisms include: 1. Limited regional space but open boundaries; 2. Diversified innovation entities (covering industry, academia, research, government, and service institutions); 3. Deeper interaction among innovative entities, forming a social ecosystem [31, 32]; 4. The institutional environment and governance play an important role in the formation, utilization, and diffusion of knowledge; 5. The utilization of various resources, social relationships, institutional norms, and values by regional innovation entities can enhance regional innovation capabilities, efficiency, and competitiveness [33-35].

In summary, most of the current research focuses on the "factor flow—industrial agglomeration—urban development—urban innovation" formed by the agglomeration of production factors into cities, while there is relatively little research on the impact of the "reverse flow" of production factors from cities to rural areas on county-level innovation capabilities, resulting in significant deficiencies in research on county-level innovation capabilities from this perspective.

Secondly, in terms of research methods, existing research mainly focuses on quantitative analysis (statistical techniques based on one-way linear relationships and causal symmetry). However, the same influencing factors have different effects on different counties, and different counties rely on different innovation conditions, making it difficult to imitate the successful experience of county innovation capabilities and provide specific guidance for the development characteristics of different counties [36]. In fact, the difference between the impact mechanism of county-level innovation capability and the innovation capability between counties involves multiple concurrent causal relationships, causal asymmetry, and the equivalence of multiple solutions, which require a holistic configuration perspective.

Research Framework

Study the impact mechanism of the collaborative mechanism between government, market, and factors on the formation of county-level innovation capacity under the reverse flow of production factors. Krugman explains the reasons for the formation of industrial clusters in a certain region using "an accidental historical event" [37]. Shi (2022) believes that regional economics involves the interaction of natural endowments, scientific and technological levels, and government systems [38]. Zhao (2019) summarized the success of the "massive economics" in Zhejiang counties as two major processes: industrialization—industrial agglomeration; and "forced" institutional evolution. Ultimately, a regional development model that is efficient market, responsible government, and beneficial society will be formed [39].

The impact mechanism of factor "reverse flow" on county-level innovation capability includes multiple concurrent causal relationships (resource endowment, economic level, social culture, technological progress, government governance, factor inflow, innovation efficiency, etc.), causal asymmetry, and multiple equivalent schemes, among other causal complexity issues. So, it is necessary to adopt a holistic configuration perspective and use qualitative comparative analysis (QCA) to treat the research object as a configuration of different combinations of conditional variables [13,14]. Through set analysis, the relationship between element configuration and results is discovered in order to explore the dominant factor configuration that affects the innovation capacity of counties. The specific research analysis elements and the theoretical model of linkage effects are shown in Fig. 1.

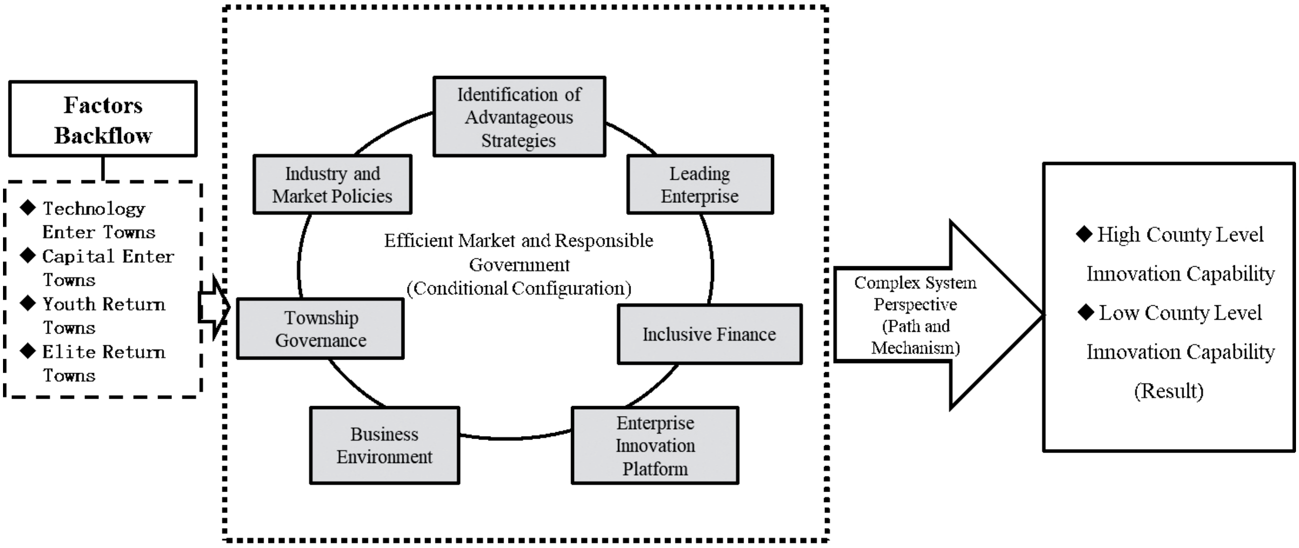

Fig. 1. The impact mechanism of county innovation capability from the perspective of configuration.

Research Design and Data Source

Research Methodology

This study adopted a qualitative comparative analysis (QCA) method based on a holistic perspective [13, 14]. Firstly, this method is suitable for small sample data analysis and requires a smaller sample size. This study takes the innovation capabilities of 52 counties in Zhejiang Province as samples, and the sample size meets the requirements of this method. Secondly, enhancing the innovation capability of counties is a process that involves numerous factors and is full of complexity. Due to the interdependence between various factors, there is not always a clear linear logical relationship between causality but rather a comprehensive manifestation of the interweaving of numerous elements. By analyzing the combination patterns of different conditional factors, we can identify the key factor combinations and core elements required to achieve high-level county-level innovation capabilities, which provides useful guidance for counties with different development characteristics to enhance innovation capabilities. Finally, when constructing the theoretical framework through literature reviews, it can be found that there is currently no definite conclusion to measure the impact of internal and external factors on the improvement of county-level innovation capabilities and the driving mechanisms behind them. In contrast, the QCA method provides a more practical analytical approach. QCA is based on set operation logic, such as AND, OR, and NOT, allowing researchers to consider different combinations of multiple variables as the cause of the results, thus breaking through the limitations of causal symmetry.

QCA is suitable for analyzing configurations with 4–7 conditions. The purpose of the QCA method is not to list all conditions but to approach or find the cause of the phenomenon by analyzing the consistency of important conditions [40]. That is, to identify the combination of conditions and core conditions for high county innovation capabilities, providing references for counties with different development characteristics to enhance their innovation capabilities.

Sample Selection and Data Source

This article collects data from 52 counties (counties, county-level cities, and autonomous counties) in Zhejiang, China, and the sample size meets the requirements of the QCA method. Zhejiang Province is a strong economic province in China. In 2022, its GDP reached $1.12 trillion, close to Saudi Arabia. The data used in the article comes from the annual statistical yearbooks of various counties in Zhejiang, annual government reports of each county, statistical monitoring data of scientific and technological progress in each county, the "County Digital Rural Index Report" (jointly released by Peking University's New Rural Development Research Institute and Alibaba Research Institute), and the "China Business Environment Index Blue Book (2022)" (jointly released by the China International Science Exchange Foundation, China Development and Reform Newspaper, Tsinghua University Institute of Social Governance and Development, and other institutions), the China County-level Digital Inclusive Finance Index Report (2022) released by the Institute of Rural Development of the Chinese Academy of Social Sciences, and the Evaluation Report on the Development Level of Regional Informatization and Digital Integration in Zhejiang Province (2022) released by the Zhejiang Provincial Department of Economy and Information Technology. In addition to the above information, qualitative analysis of typical county cases also comes from official media reports.

Measurement and Calibration

Precedent Conditions

This article summarizes the indirect factors that affect the innovation capacity of counties (policies, systems, grassroots governance, etc.) as responsible government factors. Including the identification and introduction efforts of advantageous strategic emerging industries by county governments in Zhejiang Province (measured by the proportion of added value of strategic emerging industries to regional GDP); the promotion of industrial and market policies (measured by the proportion of income tax reduction to enterprise income tax payable); innovation in township governance (measured by the county-level digital rural index); and improvement efforts in the business environment (measured by the Business Environment Index). Summarize the direct factors that affect county-level innovation capabilities (such as human capital, funds, technology, etc.) as effective market factors. This includes the leading strength of leading high-tech enterprises (measured by the proportion of high-tech industry added value to industrial added value), the investment in inclusive finance (measured by the Digital Inclusive Finance Index), and the construction of enterprise innovation platforms (measured by the Integrated Development Index of Informatization and Industrialization).

The innovation capacity of counties is measured using the innovation index from the statistical monitoring report of scientific and technological progress in counties (cities, districts) in Zhejiang Province. This innovation index evaluates five aspects: technological investment, technological innovation, technological output, transformation and upgrading, and innovation environment, comprehensively reflecting the overall situation of technological progress, technological innovation capabilities, and innovation and entrepreneurship ecology in various regions (cities, districts, and counties) of Zhejiang Province.

Calibration

Calibration of antecedent conditions and results is a prerequisite for necessity analysis. There are no established measurement standards for defining high and non-high county innovation capabilities, responsible governments, and effective markets. The evaluation of county-level innovation capability, the level of responsible government, and the effectiveness of the market between counties is also relative. This article is suitable for using sample-based relative position calibration [13, 41]. Using the direct calibration method, the percentiles of the sample data are set as anchor points for full membership, crossover point, and non-membership, with "full membership" selecting 95% of the sample data, "non-membership" selecting 5% of the sample data, and "crossover point" selecting digits. To avoid ignoring cross-values, Fiss (2011) used the approach of adding 0.001 to the value of 0.5 [42]. The

Table 1. Collection, calibration, and descriptive statistics.

Collection	Fuzzy set calibration			Descriptive Analysis			
	non-membership	crossover point	full-membership	Mean	SD	Min.	Max.
Innovation Capability	75.945	134.65	199.41	0.523	0.303	0.01	0.99
Township Governance Innovation	62.855	89.45	109.555	0.487	0.347	0.03	0.99
Inclusive Finance	124.676	128.367	132.173	0.495	0.322	0.01	1
Identification of Strategic Industries	0.9025	5.86	19.816	0.487	0.310	0.03	0.99
Industry and Market Policies	7.473	43.47	62.688	0.528	0.308	0.03	0.98
Leading Enterprises	33.641	62.52	81.171	0.527	0.314	0	1
Enterprise Innovation Platform	61.34	90.71	111.055	0.549	0.323	0.01	0.96
Business Environment	62.528	70.325	77.966	0.514	0.319	0.01	0.97

calibration anchor points and descriptive statistics for the antecedent conditions and results are shown in Table 1.

Analysis Results

Analysis of Necessary Conditions

The QCA method first needs to analyze the necessity of individual government and market conditions. As shown in Table 2, the consistency of the necessity of individual government and market conditions for high/non-high county innovation capabilities is generally low (all<0.9), indicating that there are no necessary conditions for the government and market to generate high/non-high county innovation capabilities.

Configurations Analysis

This article uses the fsQCA method to analyze the configuration of responsible government and efficient market synergy that generates high (or non-high) county-level innovation capacity under the reverse flow of production factors to the county. The asymmetric causal relationship is discovered, and the discovered configuration is qualitatively analyzed and named to deepen the configuration theory [43].

Government and Market Configuration for Generating High County Innovation Capability

Considering that the number of cases in this article is 52 and all of them are important, when conducting configuration adequacy analysis, following the approach of Du (2022), the frequency threshold of cases is set to 1, the original consistency threshold is set to 0.8, and the PRI consistency threshold is set to 0.7 [13]. When it comes to counterfactual analysis, it is assumed that the presence or absence of a single antecedent condition can contribute to the county-level high innovation capacities (due to the lack of evidence and literature on the exact direction of the results influenced by antecedent conditions). As shown in Table 3, this article finds that four configurations of government market collaboration (specifically the seven sub-configurations of M1a, M1b, M2a, M2b, M2c, M3, and M4) can generate high innovation capabilities at the county level. According to the core conditions, M1a and M1b can be classified as one, and M2a, M2b, and M2c can be classified as one, forming a second-order equivalent configuration [42].

When naming configurations, follow the key points proposed by Furnari et al. (2020): simplicity, capturing the whole, and extracting uniqueness [44]; Referring to the approach of Du et al. (2022), combined with data from typical counties for further qualitative analysis, the selection of typical counties is based on two criteria: (1) The membership degree in the corresponding antecedent configuration and results is greater than 0.5; (2) The membership degree in the corresponding antecedent

Table 2. fsQCA necessity test for individual conditions.

Antecedent condition	Result	
	High county innovation capability	Non high county innovation capability
High Township Governance Innovation	0.726	0.502
Non-high Township Governance Innovation	0.526	0.775
High Inclusive Finance	0.745	0.523
Non-high Inclusive Finance	0.530	0.778
High Identification of Strategic Industries	0.807	0.509
Non-high Identification of Strategic Industries	0.533	0.864
High Industry and Market Policies	0.810	0.562
Non-high Industry and Market Policies	0.502	0.781
High Leading Enterprises	0.836	0.538
Non-high Leading Enterprises	0.484	0.813
High Enterprise Innovation Platform	0.861	0.545
Non-high Enterprise Innovation Platform	0.448	0.794
High Business Environment	0.806	0.517
Non-high Business Environment	0.489	0.806

configuration is less than or equal to its membership degree in the result, indicating that the county meets the sufficiency requirements [13].

This article takes the identification of advantageous strategic industries, business environments, and enterprise innovation platforms as the "anchor" for configuration naming that takes into account both integrity and uniqueness. The naming of the configurations reflects the synergy between a responsible government and an efficient market. The existence of a high business environment in all three configurations indicates that the business environment is a very important driving factor for improving the innovation capacity of grassroots counties. Therefore, all three configurations are named as a responsible government-driven model to achieve high county innovation capacity.

Among them, M1 and M2 represent high-advantage strategic industries and leading enterprises, while M3 and M4 represent non-high-advantage strategic industries and leading enterprises. Therefore, M1 is named the joint driving model of innovative entities and responsible government. M2 is named the joint driving model of collaborative production factors and responsible government. The characteristic of this model is to enhance county-level innovation capabilities through tax preferential subsidies, grassroots rural governance innovation, inclusive financial investment, and collaboration between enterprise innovation platforms and innovation entities. M3 is named the traditional industry upgrade-driven model. The characteristic of this model is that compared to other counties in the province, counties lacking geographical advantages and effective support for strategic emerging industries and high-tech industries can only rely on the upgrading and transformation of the integration of informatization and industrialization in the traditional manufacturing industry, as well as tax incentives,

Table 3.Configurations for achieving high/non-high county-level innovation capacity.

Antecedent condition	High County-level Innovation Capacity							Non-high County-level Innovation Capacity			
	M1a	M1b	M2a	M2b	M2c	M3	M4	NM1	NM2	NM3	NM4
1. Responsible Government											
Identification of Strategic Industries	•	•	•		•	⊗	⊗	⊗			⊗
Industry and Market Policies	⊗		•	•	•	•	•	⊗	•	⊗	⊗
Township Governance Innovation			•	•	•	⊗	•	⊗	⊗	⊗	⊗
Business Environment	•	•	●	•	●	⊗	•	⊗	⊗	⊗	•
2. Efficient Market											
Leading Enterprises		•	•	•	•	⊗	⊗	⊗	⊗	•	⊗
Inclusive Finance	•	•	•	•		•	⊗		⊗	⊗	•
Enterprise Innovation Platform	•	•		•	•	•	⊗	⊗	⊗	⊗	⊗
Consistency	0.942	0.974	0.998	0.99	0.998	0.986	0.979	0.997	0.959	0.974	0.99
Raw coverage	0.374	0.569	0.463	0.492	0.469	0.2	0.193	0.464	0.328	0.27	0.197
Unique coverage	0.022	0.039	0.006	0.024	0.013	0.008	0.015	0.198	0.091	0.059	0.045
Overall consistency	0.957							0.968			
Overall coverage	0.703							0.66			

Note: ● = core Core conditions exist; ⊗ = Missing core conditions; • = Auxiliary conditions exist; ⊗ = Missing auxiliary conditions inclusive finance injection, etc., to drive the improvement of county innovation capabilities. M4 is named as a joint driving model of traditional industrial upgrading and responsible government. The characteristic of this model is that, compared with other counties in the province, counties lacking geographical advantages and effective support for strategic emerging industries and high-tech industries can only rely on the integration, upgrading, and transformation of traditional manufacturing informatization and industrialization, as well as creating a good business environment, a rural governance environment, and increasing tax incentives, to drive the improvement of county innovation capabilities.

(1) A joint driving model of innovative entities and responsible government. The M1 configuration mode has two sub modes. Configuration M1a points out that government market collaboration with high strategic industry identification and a high business environment as core conditions and non-high industry and market policies, high inclusive finance, and high enterprise innovation platforms as marginal conditions can generate high county-level innovation capabilities. Configuration M1b points out that government market collaboration with highly advantageous strategic industry identification, a high business environment as core conditions, high leading enterprises, high inclusive finance, and high enterprise innovation platforms as marginal conditions can generate high county-level innovation capabilities. Comparing M1a and M1b, it can be found that both have the same core conditions. The edge conditions between the two have the same high inclusive finance and high enterprise innovation platforms. There is only a substitution relationship between the non-high industry and market policies in M1a and the leadership of high-leading enterprises in M1b.

It can be seen that an active and proactive government is the core condition for enhancing the innovation capacity of counties. Innovative entities such as advantageous strategic emerging industries, leading high-tech enterprises, and enterprise innovation platforms will continue to nurture innovative achievements, thus becoming the driving force for enhancing county-level innovation capabilities.

This article describes the ecological relationship between government and market collaboration as an innovative entity-driven and responsible government-driven ecosystem. Typical counties belonging to this type of ecology include Xinchang, Changxing, Haiyan, etc.

Taking Xinchang County as an example, its county innovation capability index ranks first among 52 counties in Zhejiang Province. In November 2018, it was designated as one of the first 52 innovative counties by the Ministry of Science and Technology of China. The approach is to continuously stimulate the vitality of innovative entities. For instance, boosting research and development spending, establishing extensive collaboration between industry, academia, and research, attracting innovative talent in science and technology, and creating a comprehensive service guarantee platform.

(2) A joint driving model of collaborative production factors and responsible government. The M2 configuration mode has three sub modes. Configuration M2a points out that the core conditions for generating high county innovation capabilities are a government-market collaborative mechanism with a high business environment, high identification of advantageous strategic industries, high industry and market policies, and high innovation in rural governance. The auxiliary conditions for generating high county-level innovation capability are a government-market collaborative mechanism with high inclusive finance and leading high-tech enterprises. Configuration M2b points out that the core conditions for generating high county-level innovation capabilities are a government-market collaborative mechanism with a high business environment, high industry and market policies, and high rural governance innovation. The auxiliary conditions for generating high county-level innovation capabilities are a government market collaborative mechanism with high inclusive finance, high-leading high-tech enterprises, and high enterprise innovation platforms. Configuration M2c points out that the core conditions for generating high county-level innovation capabilities are a collaborative mechanism between the government and the market with a high business environment, high identification of advantageous strategic industries, high industry and market policies, and high rural governance innovation. The auxiliary conditions for generating high county-level innovation capabilities are the government-market collaborative mechanisms of high inclusive finance and high enterprise innovation platforms.

Comparing M2a, M2b, and M2c, it can be found that the core conditions of the three are basically the same, and the auxiliary conditions are also the same for high-leading high-tech enterprises. It can be seen that the core condition for enhancing the innovation capacity of counties lies in the responsible and proactive efforts of the government. On the one hand, local governments can attract innovative entities, such as strategic emerging industries and high-tech industries, to settle in by creating a favorable business and rural governance environment. On the other hand, they need to increase tax incentives and exemptions, which is known as "releasing water to raise fish." By coordinating multiple factors, innovation entities can become the driving force for enhancing county-level innovation capabilities. This article names the ecological relationship between government and market synergy as a responsible government-driven model with collaborative production factors. Typical counties belonging to this type of ecology include Jiashan, Pinghu, Cixi, etc.

Taking Jiashan County as an example, it was designated by the National Development and Reform Commission of China as a demonstration county for high-quality development in November 2022.

They cultivate innovation platforms through regional collaboration. Enable collaborative innovation elements, optimize innovation ecology, and gather high-end innovation resources. For example, they have built a number of scientific and technological innovation carriers (such as the Zhejiang University Yangtze River Delta Smart Oasis Innovation Center, Jiashan-Fudan University Research Institute, etc.). Gathering a group of "high-level" talents (9 academicians and over 500 research and development personnel). "High innovation" entities have been formed, including leading enterprises in science and technology, small tech giants, high-tech enterprises, and technology-based small and medium-sized enterprises. An innovative "high-efficiency" policy support system has been developed. Enterprises can intuitively understand the matching degree with various policies through system modules, generate policy evaluation reports, and thus achieve the implementation of preferential policies.

(3) The traditional industry upgrade-driven model. Configuration M3 points out that the core condition for generating high county-level innovation capabilities is the mechanism of non-high rural governance innovation, high inclusive finance, and high enterprise innovation platforms. The auxiliary conditions for generating high county-level innovation capabilities are the government market coordination mechanisms of non-high advantage strategic industry identification, high industry and market policies, non-high business environment, and non-high leading high-tech enterprises.

(4) Joint Driving Model of Traditional Industrial Upgrading and Responsible Government.

Configuration M4 points out that the core conditions for generating high county-level innovation capabilities are a government-market collaborative mechanism of a high business environment, high industry and market policies, and high rural governance innovation. The auxiliary conditions for generating high county-level innovation capabilities are the government market coordination mechanism of the non-high advantage strategic industries identification, non-high inclusive finance, non-high leading high-tech enterprises leading, and non-high enterprise innovation platforms.

Comparing M3 and M4, it can be found that although they are different in core conditions, they both have non-high-advantage strategic industry identification and non-high-leading high-tech enterprise leadership in auxiliary conditions. It can be seen that if a county lacks effective support for strategic emerging industries and high-tech industries, it can only enhance its innovation capacity through tax incentives, inclusive financial investment, and the informatization and digitization transformation of traditional industries (M3). It can also enhance innovation capabilities through optimizing the business environment, innovating rural governance, and offering tax incentives (M4). Typical counties belonging to this type of ecology include Yuhuan, Wuyi, Pan'an, etc. Most of their counties are mountainous or island areas, lacking geographical advantages. But there are unique county-level pillar industries formed by traditional "massive economic".

Taking Yuhuan County as an example (M3 mode). Although it is an island county, it has consistently ranked in the top one-third of China's top 100 innovative counties. They are implementing the "Phoenix Nirvana" action in the traditional manufacturing industry. For example, carrying out renovation projects for old industrial parks to promote industrial transformation and upgrading. The second is to strengthen the implementation of industrial policies and financial service support. The third is to increase the deep integration of informationization and industrialization into enterprise innovation platforms and accelerate the intelligent transformation of traditional industries.

Taking Wuyi County (M4 mode) as an example. On the one hand, by creating a good business environment, innovative grass-roots rural governance, increased tax incentives, and other incentive policies to stimulate the innovation and innovation capabilities of the subjects. On the other hand, they accelerate the transformation and upgrading of traditional industries through innovation-driven, digital empowerment, advanced manufacturing, and modern service industries integration development. For example, they rely on "5G +", "big data", "cloud computing" and other technological innovations to advance the digital transformation of traditional pillar industries such as electric (garden) tools, smart door locks, and food contact containers. In addition, they have also started to develop new energy, high-end equipment manufacturing, fiber optic communications, and other high-tech, low-carbon industries. Thus driving the improvement of innovation capabilities in the county.

Because fsQCA software seeks maximum coverage by default, it may magnify subtle differences and form similar but different configurations. Further analysis reveals that the raw coverage of mode M1b is the largest among the seven modes that lead to high county-level innovation capability (mode M1a=0.374; mode M1b=0.569; mode M2a=0.463; mode M2b=0.492; mode M2c=0.469; mode M3=0.2; mode M4=0.193), which indicates that the explanatory power of mode M1b is greater compared to the other six modes.

Government Market Synergy Mechanism for Non-High County Innovation Capability

In order to test the causal asymmetry, this article analyzes the government market synergy mechanism that generates non-high county-level innovation capabilities and finds that four configurations generate non-high county-level innovation capabilities.

Configuration NM1 shows that when all collaborative elements perform poorly, it is not possible to achieve high county-level innovation capabilities. According to the NM2 configuration, the lack of core conditions such as rural governance innovation, business environment, leading high-tech enterprises, and enterprise innovation platforms, as well as the lack of auxiliary conditions such as industrial and market policies and inclusive finance, will not generate high county-level innovation capabilities. It indicates that the government's investment in industrial and market policy factors (such as tax incentives) alone cannot effectively activate the innovation capabilities of innovation entities, thereby driving the improvement of county-level innovation capabilities. Configuration NM3 shows that without core conditions such as industrial market policies and enterprise innovation platforms, as well as auxiliary conditions such as rural governance innovation, business environment, and inclusive finance, even with the high leading high-tech enterprises, it cannot generate high county-level innovation capabilities. Even with leading enterprises, such as high-tech enterprises, leading the way, without a supportive innovation environment, it cannot effectively enhance the innovation capacity of the county. Configuration NM4 shows that without core conditions such as industrial market policies and enterprise innovation platforms, as well as auxiliary conditions such as identifying advantageous strategic industries, innovating rural governance, and leading high-tech enterprises, even with a high business environment and inclusive finance, there will not be high county innovation capabilities. Even though the business environment and financial support are good, the lack of innovative entities such as strategic emerging industries and high-tech enterprises still cannot enhance the innovation capacity of the county.

Robustness Testing

This article conducts a robustness test on the configuration of government-market synergy conditions that generate high-county innovation capabilities. QCA is a set theory approach where slight changes in operations may result in new subset relationships but does not alter the substantive explanations of research findings, indicating that the results of this study are robust [13]. Firstly, increase the threshold for case frequency from 1 to 2 to generate a configuration that is basically consistent with one solution in the existing configuration. Secondly, by reducing the PRI consistency from 0.7 to 0.65, the resulting configuration basically includes the existing configuration. The above robustness test shows that the results of this article are relatively robust.

Discussion

Scholars have conducted extensive research on county-level innovation capabilities, but the literature is relatively scattered [10]. Most studies only cover a small portion of innovation conditions that are considered important [8, 9, 11], such as innovation entities, innovation organizations [16], innovation investment [17, 18], and the innovation environment [19]. In fact, enhancing county-level innovation capabilities is the result of complex and multifactorial interactions. Furthermore, in research on enhancing county-level innovation capabilities, there is a mismatch between theory and methods [12]. The theory suggests that enhancing county-level innovation capabilities is best explained from the perspective of complex systems. In terms of research methods, empirical analysis of linear thinking (causal symmetry) is mainly used to explain [9].

We combine the perspective of complex innovation systems with qualitative comparative analysis methods to determine the condition configuration for enhancing high-level county-level innovation capabilities. Therefore, this paper addresses the problem of theoretical and research methodology fragmentation caused by the fragmentation of the literature on county-level innovation capabilities. Unlike previous studies, we found that there is no single condition necessary to enhance high-level county-level innovation capabilities. On the contrary, our study identified four conditional configurations for enhancing high-level county-level innovation capabilities. They respectively reflect that different counties have achieved high-quality development of county innovation through various paths based on their own conditions, including the joint driving model of innovative entities and responsible government; the joint driving model of collaborative production factors and responsible government; the model driven by traditional industrial upgrading; and the joint driving model of traditional industrial upgrading and responsible government. Reflecting the differences in resource endowments and development stages of counties, there are also differences in the driving mechanisms of their innovation capabilities, indicating that in addition to focusing on the business environment, it is also necessary to pay attention to the investment of other factors.

Firstly, this article finds that a single responsible government and effective market factors are not necessary conditions for generating high county-level innovation capabilities and require collaboration between responsible government and effective markets. The responsible government is mainly reflected in optimizing the business environment and cultivating innovative entities; the effective market is mainly reflected in the significant leading role of high-tech enterprises as innovation entities, coupled with the injection of inclusive financial elements and the digital transformation of enterprise innovation platforms. Effective collaboration between the two plays an important role in generating high county-level innovation capabilities.

Secondly, the four configurations of non-high county innovation capability reflect that when all collaborative elements perform poorly, it is impossible to achieve high county innovation capability. Secondly, even if the business environment and other factors, such as financial support, are well-invested, the lack of innovative entities such as strategic emerging industries and high-tech enterprises cannot enhance the county's innovation capabilities.

The business environment shaped by the government can achieve high-quality development of the regional economy [45], and effective innovation entities in the market are the driving force to enhance regional innovation capabilities. From the perspective of complex systems, the various elements that affect regional innovation capabilities are like species, constantly competing or adapting to each other, co-evolving, and may evolve into different ecosystems, forming diverse and differential driving paths [46].

Conclusions

The possible theoretical contributions of this article are reflected in the following aspects: Firstly, based on the theory of complex systems [46] and the fsQCA method [13, 14], the interrelationships between factors affecting county-level innovation capabilities were explored. The research mainly focuses on examining the impact of various factors on the innovation capability of counties from two dimensions: responsible government and efficient market. Research has found that the single-factor condition of government-market synergy is not a necessary condition for high county innovation capability. It is necessary to systematically analyze the substitution mechanisms between factors and the synergistic effects of these factors. This provides a comprehensive understanding of the enhancement of county-level innovation capabilities in complex contexts. Make marginal contributions to the research of the fsQCA method in the field of county-level innovation capability. Secondly, this article adopts a configuration perspective by extending the application of complex system theory to situations with complex asymmetric causal relationships. It means dealing with systems where causal relationships are not linear or directly traceable. The research results support the viewpoint of complex systems, that is, there are multiple paths to improve the innovation capability of counties rather than a single optimal balance [46]. Made marginal contributions to the theory of complex systems. The article reveals different ways to enhance county-level innovation capabilities in the complex and ever-changing Chinese environment. It provides a detailed analysis of successful experiences in enhancing county-level innovation capabilities and offers specific guidance for counties with different development characteristics. Similarly, county-level innovation capabilities in many other developing countries and regions also face similar environmental challenges. Therefore, the findings of this study not only provide valuable ideas for Chinese policymakers but also provide important reference value for policymakers in other developing countries and regions around the world. Thirdly, this study demonstrates a paradigm shift from symmetric thinking to asymmetric thinking in data analysis and theoretical construction, providing new explanations for many conflicting findings in the literature. Research has shown that a single factor is not a necessary condition for enhancing county-level innovation capabilities but rather requires the combined action of multiple factors. This provides a new perspective for explaining the differences in research results in the literature.

Policy Implications

This article provides three reference suggestions for policy-makers in China and other developing countries and regions. Firstly, the business environment shaped by the government is the core condition for improving the innovation capability of grassroots counties, indicating that local governments need to continuously optimize the business environment [45]. The business environment is the "wind vane" of local economic development, the "magnetic field" of gathering high-end factors, and the "fertile ground" of enterprise innovation and entrepreneurship. Even though Zhejiang Province has become a "top student" in China's business environment, it still regards optimizing the business environment as the "number one reform project." Zhejiang Province has implemented the "Regulations on Optimizing the Business Environment in Zhejiang Province" since March 2024. This regulation fully integrates into the latest standards of the World Bank's business environment assessment. This has provided legal protection for the construction of the business environment in Zhejiang Province.

Secondly, the innovation subject is a key driving factor in enhancing the innovation capability of counties. So, we need to vigorously develop the modern industrial system. On the one hand, we will continue to promote the transformation and upgrading of county-level industries. In the "physical space," gradually evolving from a "massive economic" form to a modern large-scale industrial cluster platform. In the "virtual space," relying on the industrial Internet, the manufacturing industry and the service industry are continuously integrated through the "data brain," and the application scenarios of digitally intelligent manufacturing are continuously enriched. On the other hand, efforts will be made to promote the development of independent innovation in counties. Build public service platforms such as industrial innovation service complexes. Gather various innovative carriers, innovative service institutions, and university research institutions within the comprehensive service system to assist cluster enterprises in scientific research and innovation. For example, the innovation consortium model of "top enterprises + universities (research institutes)" and the full-chain major scientific and technological innovation platform model of "cutting-edge leading technology - key common technology - major scenario applications".

Finally, the multiple configuration paths revealed in this study to enhance county-level innovation capabilities indicate that although there are differences in innovation capabilities among counties due to differences in development stages, industrial foundations, ecological functions, resource endowments, and factor aggregation abilities, they can all find suitable paths to enhance their own innovation capabilities. For counties with industrial clusters, innovative entities such as advantageous strategic emerging industries, leading high-tech enterprises, and enterprise innovation platforms should be established. This can continuously stimulate the vitality of innovation entities in terms of R&D investment, deep cooperation between industry, academia, and research, the leadership of scientific and technological innovation talents, and comprehensive service platform guarantee. For mountainous counties that are constrained by geographical environment and development space, as well as those with special ecological function responsibilities, it is necessary to promote the integrated development of "ecology + industry + technology" to enhance the innovation capability of the county. Therefore, they should focus on development strategies such as "one county, one policy" (promoting differentiated policies), "one county, one industry" (upgrading traditional characteristic industries), "one county, one product" (exploring historical and cultural products and tourism resources), "collaborative enclaves" (industrial enclaves and scientific and technological innovation enclaves), and "urban-rural integration" and continuously shift from mismatched competition to collaborative synergy, gradually deeply integrating into the urban agglomeration economy, to enhance the innovation capacity of the county.

Limitations and Future Directions

The limitations of this article are mainly reflected in: Firstly, the availability of data is relatively difficult, so we can only focus on analyzing the static relationship between government and market synergy and the impact of county-level innovation capacity under the factor of "reverse flow." In the future, researchers can further dynamically analyze how government-market synergy affects changes in county-level innovation capacity. Secondly, although this article has conducted some qualitative analysis using county-level cases and found different driving mechanisms, the depth and richness of qualitative analysis using QCA research are still lacking. In the future, researchers can further conduct in-depth county-level case studies on different driving modes, thereby revealing the process of promoting the evolution of county-level innovation capabilities. Finally, this article focuses on the counties in Zhejiang Province, and in the future, research on Chinese counties can be conducted, incorporating more indicators to stimulate the innovation vitality and motivation of innovation entities and promote the coordinated development of county innovation capabilities with low-carbon, high-quality, and sustainable economies.

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Conflict of Interest

The authors declare no conflict of interest.

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