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Navigating High-Quality Economic Growth: An Examination of Regional Innovation Ecosystems in China Through Fuzzy-Set Qualitative Comparative Analysis

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Abstract: From the perspective of the innovation ecosystem, this study investigates the specific paths through which regional innovation ecosystems drive high-quality economic development in 31 mainland provinces and cities in China, using the fuzzy-set Qualitative Comparative Analysis (fsQCA). It was discovered that: (a) Within regional innovation ecosystems, multiple concurrent causal relationships characterized by interlocking alignments exist among innovation agents, resources, and environments, leading to asymmetrical configurational outcomes between high-quality economic and non-high-quality economic development. (b) On the basis of different configurations of system elements, four paths driving high-quality regional economic development were revealed, each demonstrating a "many paths, one destination" characteristic. These include the innovation agent-aggregated regional innovation ecosystem, the diversified development integrated regional innovation ecosystem, the human resource-supported regional innovation ecosystem under market environment dominance, and the economic resource-driven regional innovation ecosystem under market environment dominance. (c) Under specific conditions, substitutive relationships between conditions of innovation agents and the innovation environment within the system were observed. The findings enrich the research perspective on high-quality economic development and offer path references and empirical evidence for regions aiming to construct effective innovation ecosystems to drive high-quality economic development.

Keywords: Regional innovation ecosystem; Fuzzy-set qualitative comparative analysis; High-quality economic development; New development concept

1. Introduction

High-quality development is identified as the paramount task in comprehensively constructing a modern socialist country. The report from the 20th National Congress of the Communist Party of China underscored to accelerate the innovation-driven development strategy and enhance the overall efficacy of the national innovation system. The economic development of China has entered a new normal, changing from factor and investment-driven to innovation-driven growth. Innovation is recognized as the basic force to drive the high-quality economic development under this new normal (Yang et al., 2023). The innovation ecosystem, as a higher-order organizational form for conducting innovation activities, not only aligns with the requirements of the innovation-driven development strategy but also epitomizes the implementation of the five new development concepts. The economic prosperity of a region benefits from a robust innovation ecosystem, which carries the crucial task of deeply implementing the nation's major development strategies and building an innovative country. Therefore, constructing a benign regional innovation ecosystem and coordinating the elements within the system to form mutually beneficial symbiotic relationships are deemed essential safeguards for regions to overcome the "middle-income trap" and achieve high-quality economic development.

Current research on the relationship between innovation ecosystems and high-quality economic development primarily focuses on two aspects. On one hand, studies have holistically examined the impact of innovation ecosystems on high-quality economic development from perspectives such as ecologization and economic growth

theory, addressing operational efficiency (Ke, 2021), evolution (Duan, 2020), and construction of innovation ecosystems. On the other hand, scholars have used panel data to study the relationship between innovation ecosystems and high-quality economic development through empirical analyses (Liu & Chen, 2021). Further literature review reveals that existing research, from the angles of innovation agents, resources, and environments, has analyzed the impact of innovation ecosystems on high-quality economic development (Shangguan & Ge, 2020), enriching the study on how the aggregation of innovation elements drives high-quality economic development. In fact, based on the theory of collaborative innovation, regional innovation ecosystems are viewed as open and organically unified wholes formed through the interaction between various innovation participants and their environments. The interconnection, interdependence, and synergistic coexistence among innovation agents, environments, and resources within the system are key to maximizing overall system benefits and value creation (Adner & Kapoor, 2009; Jacobides et al., 2018). Therefore, the coupling and coordination relationships among internal elements of the innovation ecosystem have facilitated rapid regional economic growth, becoming a new impetus for high-quality regional economic development. Studies have been undertaken on the synergistic coexistence, interconnected matching, and coordination mechanisms within innovation ecosystems, revealing that various combinations of elements can promote the development of innovation ecosystems in multiple ways (Hu & Hou, 2023; Tang et al., 2021). However, there is currently a lack of discussion on how the interconnected effects among internal elements of regional innovation ecosystems drive high-quality economic development. Additionally, due to the frequent interactions among elements constituting regional innovation ecosystems, traditional regression models have struggled to adequately explain the complex relationships between multiple elements (Ragin, 2008). As a method based on set theory and configurational analysis, fsQCA matches well with the complex dynamics of innovation ecosystem research. It effectively handles the multiple concurrent relationships of complex variables and identifies potential substitutive relationships among elements, making it suitable for the studies in this paper. Consequently, based on the innovation ecosystem perspective, this study constructs an analysis framework for innovation ecosystems using the fsQCA method, delving into the complex causal relationships and multiple equivalent configurational paths that drive (or inhibit) high-quality economic development.

This study makes the following contributions: Firstly, from the perspective of the innovation ecosystem and using the collaborative innovation and new economic growth theories, this study identifies factors influencing high-quality regional economic development, and unearths specific pathways leading to that development, thereby enriching the research perspective on high-quality economic development. Secondly, diverging from traditional research methods, such as regression, factor and cluster analyses, the fsQCA method is selected to explore the "different paths, same destination" characteristic of various condition configurations driving high-quality economic development within regional innovation ecosystems. This study emphasizes uncovering the multifaceted concurrent relationships and multiple configurational pathways driving high-quality economic development, further extending the application of configurational analysis in the realm of high-quality economic development. Lastly, through the fsQCA method, five specific pathways driving high-quality economic development have been identified, providing path references and empirical evidence for provinces and cities in China to construct innovation ecosystems that drive high-quality economic development with their own resources. This study principally addresses the following questions: First, whether the various constituent elements of China's innovation ecosystems are necessary conditions for driving (or inhibiting) high-quality economic development in regions. Second, what types of regional innovation ecosystem configurations can drive high-quality regional economic development, and what equivalent substitutive relationships exist among combinations of elements.

2. Literature Review and Research Framework

The regional innovation ecosystem is recognized as an open, dynamic equilibrium system existing within a certain spatial scope, and it is posited that this system achieves dynamic balance through the circulation of matter, exchange of energy, and flow of information. Subsequent scholars have defined the innovation ecosystem from environmental, network, and agent perspectives while also deriving other related theoretical concepts such as industrial, regional and technological innovation ecosystems (Heaton et al., 2019; Kolloch & Dellermann, 2018; Nambisan & Baron, 2013). As a meso-level manifestation of innovation ecosystems, the regional innovation ecosystem has been proposed based on an ecological perspective, where internal innovation activities evolve through self-organization driven by the coupling of elements, with the composition of these elements exhibiting both "bipartite" and "tripartite" structures. The bipartite structure refers to elements including innovation agents and the innovation environment, meaning the regional innovation ecosystem is complex, with technological innovation composite agents coexisting symbiotically with a technological innovation composite environment (Mei et al., 2014). However, the "bipartite" structure falls short in distinguishing the specific utility of innovation resources. Thus, some scholars, according to research needs, have further differentiated the environmental elements and proposed a "tripartite" structure comprising innovation agents, innovation resources, and the innovation environment. These elements form a mutually beneficial and synergistic relationship and have garnered widespread support in the academic community. Therefore, based on the perspective of the innovation ecosystem

and from the dimensions of innovation agents, environment and resources, this study constructs a model to drive high-quality economic development.

(a) Innovation agents

Innovation agents consist of individuals and populations within the innovation ecosystem that drive and support innovation (Li & Zhang, 2018). The impact of innovation agents on high-quality regional economic development is contingent upon their number and quality, as well as their continuously unleashed creative vigor. These include knowledge and technology innovation agents (Ren & Song, 2020; Tang et al., 2021). In particular, first, knowledge innovation agents refer to entities capable of actively participating in knowledge innovation activities, possessing certain knowledge innovation capabilities and resources. They engage in original, foundational research using widely acquired knowledge, providing scientific research outcomes to other agents, with universities and research and development (R&D) institutions being the core carriers (Liu & Chen, 2021). Universities and research institutions drive regional economic development through scientific research and the cultivation of high-quality talents (Chen & Yang, 2012; Liu & Chen, 2021); Second, technology innovation agents, entities innovating in technology and products, with enterprises as the core carriers (Liu & Chen, 2021). Technology innovation agents possess professional knowledge and experience in their technological fields, understand market demands and trends, and can transform research outcomes into actual productive forces and commercial applications, playing a pivotal role in innovation activities and serving as a fundamental force in driving high-quality economic development.

(b) Innovation resources

Innovation resources are primarily the various resources inputted to support innovative activities within the regional innovation ecosystem. The resource-based theory highlights resources as the cornerstone for organizations to achieve competitive advantages. It has been observed that innovation resources aggregate through continuous competition among subjects, positively effecting high-quality economic development (Xiang et al., 2014). Moreover, innovation resources are considered foundational conditions and the most critical elements for conducting regional innovation activities, comprising human and economic resources (Lu & Zhou, 2013). In particular, first, human resources refer to individuals directly involved in scientific activities or providing direct services to such activities, serving as vital carriers of skills and knowledge (Xiao & Fan, 2019). As an element of the innovation ecosystem, human resources are deemed a determining factor in enhancing regional competitiveness and achieving prosperous development (Lu & Zhou, 2013). Second, economic resources refer to funds invested by enterprises, governments, or other institutions in scientific research and technological innovation. Economic resources propel scientific and technological innovations, bringing new scientific achievements and applications to society, advancing industrial restructuring, and optimization, thereby fostering high-quality economic development. As for resource allocation, the innovation ecosystem acts as a leader in economic resource allocation, with the optimization of financial structures to enhance the efficiency of economic resource allocation increasingly becoming a significant direction and strategy for achieving high-quality economic development (Jing & Sheng, 2022; Liu, 2019).

(c) Innovation environment

The innovation environment encompasses the network system of continuous exchanges established by various actors in a region based on innovation elements and policy mechanisms. It constitutes a fundamental element of the regional innovation ecosystem, representing the sum of various internal and external factors affecting the vitality of innovation agents (Jing & Sheng, 2022). Scholars have found that a conducive innovation environment enhances technological innovation capabilities and continuously provides a driving force for high-quality economic development (Li et al., 2022). The innovation environment includes both the infrastructure environment and the market environment (Tang et al., 2021). In particular, first, the infrastructure environment reflects the level of the region's hard innovation environment (He et al., 2012). A well-developed infrastructure not only guarantees the operation of the innovation ecosystem by providing energy, talent, and technology but also lays a solid foundation for further industrial upgrading. Additionally, it helps reduce trade and transportation costs, promotes the flow of resources and elements, and is conducive to high-quality economic development (Gu & Zhu, 2022). Second, the market environment refers to the socio-economic environment factors surrounding business activities, including political, legal, economic, technological, socio-cultural, natural geographic, and competitive factors (Liu & Wu, 2020). The market environment promotes the formation and evolution of the innovation ecosystem (Reinartz et al., 2011). It is crucial in the innovation ecosystem and facilitates the flow and matching of elements within the system, promotes product and technological innovation, and a stable market environment is foundational and a prerequisite for sustaining healthy, high-quality economic development (Adner & Kapoor, 2009).

In summary, from a configurational perspective, the impacts of innovation agents, environment and resources on high-quality regional economic development are not independent of each other. Instead, they exert their effects through a coordinated and interconnected mode of combination. Therefore, this study, grounded in the configurational perspective, integrates six antecedent conditions affecting high-quality regional economic development, delving into the synergistic mechanisms and innovation elements' interrelationships, as illustrated in Figure 1.

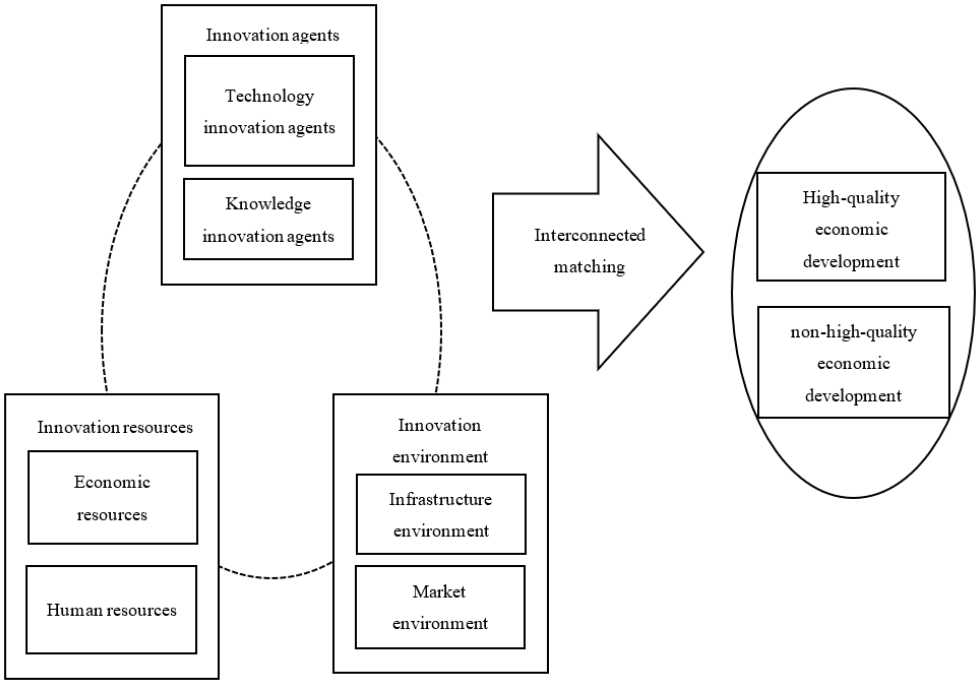

Figure 1. Configuration model

3. Research Method

3.1 Method Selection

The fsQCA method is utilized to investigate the "synergistic effects" and "interactive relationships" among antecedent variables in driving high-quality economic development within regional innovation ecosystems. The selection of this method is primarily due to the following considerations:

Firstly, as a complex dynamic whole composed of various elements, the regional innovation ecosystem facilitates the exploration of "synergistic effects" and "interactive relationships" among multiple elements, aligning well with the research questions of this study. In particular, the drive towards high-quality economic development in regional innovation ecosystems results from the synergistic interaction and collective action of multiple elements, which cannot be fully explained by a single element. Hence, a systematic analysis and interpretation of the specific pathways and modes of action driving high-quality economic development are required. Traditional linear regression struggles to study the impact of three or more elements on the dependent variable. The fsQCA method can identify combinatory relationships among multiple elements, thereby effectively addressing the complexity, non-linearity, and equivalence issues between innovation ecosystems and high-quality economic development (Shang et al., 2021), which is aptly suited for the research questions of this study.

Unlike traditional configurational analysis methods, the fsQCA method can reveal the matching relationships between condition elements, aiding in uncovering potential substitutive and complementary relationships among innovation elements.

The fsQCA method is capable of precisely identifying the cases covered by each equivalent configuration, recognizing potential differences in innovation strategy selection across different regions, and contrasting the asymmetric antecedents of high-quality economic development and non-high-quality economic development. It can present the complexity of regional innovation, thereby facilitating a comprehensive and systematic understanding of the specific driving mechanisms. Furthermore, the fsQCA method is particularly suitable for studying medium-sized samples with 15 to 50 cases, and the sample size of this study, which includes 31 cases, fits within the medium-sized sample study range.

3.2 Sample and Data

The 31 Chinese provinces, municipalities, and autonomous regions were chosen as the subjects for study. Considering the availability of data, the year 2019 was selected for conducting empirical research. The primary data sources include the "China Science and Technology Statistical Yearbook," "China Statistical Yearbook," "China Regional Innovation Capability Evaluation Report," and the "China Regional Economic High-Quality Development Research Report." Details on variable selection and data sources are presented in Table 1.

Table 1. Variable selection and data source

Selected Variable	Specific Indicator	Indicator Content	Data source	Reference
High-quality economic development	High-quality economic development index	Market mechanism, government role, technological innovation, ecological resources, social harmony, and globalization	China Regional Economic High-Quality Development Research Report	(Ragin, 2008)
Innovation agents	Technology innovation agents	Number of high-tech enterprises	China Science and Technology Statistical Yearbook	(Zhang, 2001)
	Knowledge innovation agents	Total number of universities and research institutions	China Science and Technology Statistical Yearbook	(Ou et al., 2018)
Innovation resources	Human resources	Full-time equivalent of R&D personnel	China Regional Innovation Capability Evaluation Report	(Xiao & Fan, 2019)
	Economic resources	R&D investment	China Regional Innovation Capability Evaluation Report	(Zhang et al., 2022)
Innovation environment	Infrastructure environment	Telecommunications, Internet information, and incubation conditions	China Regional Innovation Capability Evaluation Report	(Tang et al., 2021)
	Market environment	Market openness, technological services, and consumer spending level	China Regional Innovation Capability Evaluation Report	(Tang et al., 2021)

3.3 Measurement and Calibration

In this study, high-quality economic development at the regional level serves as the outcome variable for configurational path analysis, with secondary indicators set for antecedent variables. The weights for the secondary indicators were determined using the entropy weight method. In addition, they were calculated for the regional primary indicator scores through linear weighting. The study employed a direct calibration method to calibrate the outcome variables and condition variables, categorizing them into three calibration anchors, namely, full membership, crossover point, and full non-membership. In reference to existing research, the sample data for the three calibration points were set at the 95th percentile, 50th percentile, and 5th percentile, respectively. Utilizing the fsQCA 3.0 software, the outcome variable and antecedent condition variables were calibrated.

4. Empirical Analysis

4.1 Analysis of Necessary Conditions

In the empirical analysis, the necessity analysis conducted through Qualitative Comparative Analysis (QCA) involves calculating consistency and coverage to determine sufficient and necessary relationships. Consistency serves as a crucial basis for identifying necessary conditions, with a consistency value greater than 0.9 indicating the necessity of antecedent conditions. According to the analysis results of individual conditions' necessity presented in Table 2, it can be seen that among the six antecedent conditions, none is a necessary condition for driving high-quality economic development. The lack of technology innovation agents, human resources and market environment are identified as inevitable conditions of non-high-quality economic development.

4.2 Configuration Analysis

The analysis of antecedent condition configurations constitutes the core of the QCA method, aiming to examine the sufficiency of different combinations of antecedent conditions in the regional innovation ecosystem for the outcome variable. Drawing from set theory, the investigation determines whether certain combinations of conditions belong to a subset driving high-quality economic development. Initially, in setting parameters, the consistency threshold was established at 0.8, and the case frequency threshold was set at 1, to minimize potential contradictory configurations, with the Proportional Reduction in Inconsistency (PRI) consistency value also set at

0.8. The results obtained through QCA are presented in Table 3. It is observed that there are five configurations of high-quality economic development (Ha1, Hb1, Hb2, Hc1, Hd1), and two configurations of non-high-quality economic development (NHa1, NHa2), indicating that the conditions causing a specific outcome are not unique; thus, multiple pathways drive high-quality economic development. All five equivalent paths are the result of the combined action of multiple antecedent conditions, highlighting the importance of synergistic collaboration among innovation elements for regional economic high-quality development. Among the pathways driving high-quality economic development, Hb1 and Hb2 form equivalent second-order configurations, while in the configurations of non-high-quality economic development, NHa1 and NHa2 form equivalent second-order configurations. The consistency level of individual configurations and the overall solution is greater than 0.8, suggesting that all five pathways are sufficient conditions for the regional innovation ecosystem to drive high-quality economic development, with an overall coverage of 0.756, indicating that the combination of antecedent conditions has a strong explanatory power for regional economic high-quality development. There is no symmetrical relationship between the configurations driving high-quality economic development and those leading to non-high-quality economic development, hence the configurations of antecedent variables causing both outcomes do not exhibit symmetry.

Table 2. Analysis of necessary conditions

Condition Variable	High-Quality Economic Development		Non-High-Quality Economic Development	
	Consistency	Coverage	Consistency	Coverage
Knowledge innovation agents	0.804	0.822	0.542	0.555
Knowledge innovation agents	0.564	0.552	0.826	0.808
Technology innovation agents	0.763	0.945	0.391	0.485
Technology innovation agents	0.584	0.490	0.956	0.801
Human resources	0.810	0.963	0.412	0.490
Human resources	0.571	0.492	0.969	0.836
Economic resources	0.709	0.824	0.488	0.568
Economic resources	0.628	0.551	0.849	0.745
Infrastructure environment	0.737	0.740	0.601	0.603
Infrastructure environment	0.605	0.602	0.741	0.738
Market environment	0.878	0.922	0.515	0.541
Market environment	0.563	0.537	0.926	0.884

4.2.1 Configuration analysis of regional high-quality economic development

(a) Configuration Ha1: innovation agent-centric ecosystem. Under this configuration, technology innovation agents and knowledge innovation agents hold a central position, indicating that the presence or absence of economic resources does not affect regional high-quality economic development, provided that human resources play their supportive role effectively. Research has shown that various innovation agents, assisted by human resources, form a mutually dependent, interconnected, and collaboratively evolving innovation system, playing a significant role in regional high-quality economic development. Cases belonging to this configuration are primarily concentrated in the central regions of China, including provinces such as Jiangxi, Hunan, Henan, and Anhui. It is observed that the central region primarily achieves high-quality economic development through the innovation agent-centric strategy characterized by Ha1 configuration, with innovation agents at the core and human resources as support. However, due to geographical location, relatively weak development in innovation infrastructure, and market environment, the central region's approach to high-quality economic development appears relatively direct and simple, and the distribution of cases largely aligns with the actual situation.

Henan Province is a typical province of Ha1 configuration, ranking 9th in the national high-quality economic development index. As one of China's important economic areas and a typical agricultural province, Henan has gradually transitioned and upgraded through the issuance of policies such as "Several Fiscal Policy Measures to Support Scientific and Technological Innovation Development in Henan Province," "Opinions on Accelerating the Construction of a First-Class Innovation Ecology to Build a National Innovation Highland," and "Work Plan for Implementing Innovation-Driven, Science and Education Strengthening, and Talent-Powering Strategies." By guiding industry-academia-research cooperation, encouraging enterprises to increase R&D investment, and continuously enhancing support for universities, research institutions, and other innovation agents, Henan has attracted high-tech enterprises and talents. Through these measures, Henan Province has gradually formed an

innovation ecosystem with innovation agents at its core and human resources as support, becoming a strong driver for high-quality economic development in the region.

Table 3. Configuration analysis of achieving high-quality and non-high-quality economic development

Antecedent Variable	High-Quality Economic Development					Non-High-Quality Economic Development	
	Ha1	**Hb1**	**Hb2**	**Hc1**	**Hd1**	**NHa1**	**NHa2**
Technology agents	●		●	●	⊗	⊗	⊗
Knowledge agents	●	●	⊗	●	⊗	⊗	⊗
Human resources	●	●	●	●	⊗	⊗	⊗
Economic resources		⊗	⊗		●		⊗
Infrastructure environment	⊗	●	⊗	●	⊗	⊗	
Market environment	⊗	●	●	●	●	⊗	⊗
Consistency	0.996486	0.982935	1	0.977798	0.982143	0.968847	0.977542
Original coverage	0.365983	0.371661	0.297458	0.411623	0.354885	0.641982	0.701974
Unique coverage	0.0369725	0.0451666	0.0451666	0.220079	0.0625888	0.0677978	0.12779
Overall consistency			0.970121			0.97309	
Overall coverage			0.756291			0.769772	
Representative cases	Henan	Shandong	Fujian	Guangdong	Tianjin	Tibet	Ningxia

(b) Configuration Hb: human resources supported innovation ecosystem under market environment dominance. This pathway includes two scenarios. In the Hb1 configuration, human resources and the market environment play a central role, with knowledge innovation agents and the infrastructure environment serving supportive roles, indicating that the presence or absence of technology innovation agents does not impact the region's high-quality economic development. In the Hb2 configuration, human resources and the market environment are central, with technology innovation agents playing a supportive role. Leveraging the market mechanism and the spillover effects of human capital knowledge to optimize the business environment and establish a unified large market contributes to promoting regional high-quality development. Provinces that fit the Hb1 and Hb2 configurations include Hebei, Shandong, and Fujian.

Shandong and Fujian are typical cases for the Hb1 and Hb2 pathways, respectively. Shandong Province, one of China's most economically developed provinces, boasts abundant innovation resources and a strategic geographical location, ranking 5th nationally in the high-quality economic development index in 2019. In recent years, Shandong has become one of the hotspots for global investment and talent attraction. The government has implemented various measures to promote talent discovery and cultivation, such as establishing innovation and entrepreneurship funds and providing professional skills training, which have shown significant effectiveness. According to data, Shandong's knowledge economy index ranks among the top nationally. While attracting talents, Shandong has also made significant progress in improving the market business environment. According to the "China Regional Innovation Capability Evaluation Report" released in 2021, Shandong's comprehensive market environment index climbed to 7th place nationally in 2019. Shandong has actively promoted the construction of a market marketing system by establishing market supervision regulations, strengthening market access management, optimizing the business environment for enterprises, and creating a fair competition market environment. Furthermore, the province has vigorously developed the information technology industry and built a number of modern information technology infrastructures, such as big data centers and cloud computing centers, providing enterprises with an excellent infrastructure environment. By constructing a complete "government-industry-academia-research" chain and fully utilizing the province's numerous knowledge innovation agents, Shandong promotes the docking of enterprises with universities and research institutions, enhancing the rate of technological achievement transformation. Geographically adjacent to Hebei, Shandong shares similar regional innovation strategies and development modes with Hebei. Both provinces achieve high-quality economic development through the Hb1-characterized strategy of focusing on human resources and the market environment, supported by knowledge innovation agents and the infrastructure environment.

Fujian Province is a typical example of Hb2 configuration. As one of China's regions with active economic development, Fujian ranked 7th nationally in the high-quality economic development index in 2019. For a long

time, Fujian has focused on enhancing talent cultivation levels, intensifying efforts to introduce and train high-level talents, and has established a series of talent projects, such as the "Minjiang Scholar" and "Overseas High-level Talent Introduction Plan," continuously promoting the introduction, training, and retention of talents. In terms of the market environment, Fujian has actively promoted reform and opening up, established open platforms like free trade zones and free trade ports, attracted a large amount of foreign investment, and strengthened connections with international markets. Furthermore, Fujian has actively engaged in "Belt and Road" cooperation to advance regional economic integration. While attracting talents and optimizing the business environment, Fujian introduced the "Six-Four-Five" modern industrial system, emphasizing the central role of enterprises as innovation agents. Industrial policies such as "doubling the number of high-tech enterprises" and "cultivating and strengthening leading enterprises" were formulated, extensively publicizing policies beneficial to enterprises to encourage them to increase R&D investment. The results indicate that Fujian achieves high-quality economic development through the Hb2 configuration, characterized by a strategy that places human resources and the market environment at its core, with technology innovation agents playing a supportive role, under the dominance of the market environment.

(c) Configuration Hc1: diversified development integrated innovation ecosystem. In this configuration, technology innovation agents, knowledge innovation agents, human resources, and the market environment play central roles, with the infrastructure environment serving a supportive role. The presence or absence of economic resources does not impact regional high-quality economic development. The provinces and municipalities that belong to this path are mainly concentrated in the eastern region, including Guangdong, Shanghai, Zhejiang, Jiangsu, Beijing, Shandong, Hubei, and Sichuan. It is observed that the eastern region primarily achieves high-quality economic development through the Hc1 configuration, characterized by innovation agents, human resources, and the market environment as cores, and the infrastructure environment as supportive. Results show that, with the advantages of strong innovation agents, a favorable innovation environment, and strategic geographical location, the eastern region of China exhibits a more balanced and synergistic approach to driving high-quality economic development compared to the central and western regions. The diversified development integrated strategy has become an important strategy for the eastern region to achieve high-quality development and maintain a sustainable competitive advantage. Therefore, the distribution of cases essentially aligns with the actual situation.

Guangdong Province is a typical representative of Hc1 configuration, ranking 1st nationally in the high-quality economic development index in 2019. Committed to promoting high-quality economic development, Guangdong has driven rapid economic progress through multiple forces. The province has made significant efforts to support high-technology enterprises, attracting a large number of high-tech firms through tax reductions, patent subsidies, and the establishment of national high-tech parks. In 2019, the number of high-tech enterprises reached 9,542, marking an increase of nearly 63% compared to 2013. Guangdong's universities and research institutions also lead nationally in both quantity and quality. These innovation agents have not only excelled in basic research but also made significant achievements in applied research and technology transfer, providing foundational support for innovation activities and substantially boosting the provincial economy. In terms of talent introduction, the government has implemented a series of policies to attract and cultivate high-end talents, such as the "Thousand Hundred Ten Project" and "Increasing Incentives for Talent Introduction," comprehensively improving talent services and providing continuous talent support for economic development. Guangdong has continuously advanced reform and opening up, accelerated marketization, optimized the business environment, and promoted enterprise innovation. The government has created platforms such as free trade zones and financial free ports, collaborated with foreign investment institutions and businesses, accelerated foreign trade and investment, and advanced the process of economic globalization, providing enterprises with superior production, sales, and innovation environments. Under good infrastructure support, the deep implementation of the innovation-driven development strategy has made Guangdong one of the most economically developed regions in China.

(d) Configuration Hd1: economic resource-driven innovation ecosystem under market environment leadership. In this configuration, economic resources and the market environment play central roles, collaboratively driving high-quality economic development. This conclusion validates existing research, which suggests that the aggregation of economic resources and the maximization of market vitality propel high-quality economic development. The provinces and cities belonging to this path are represented by Tianjin, a city with abundant economic resources as its foundation. As a coastal city with a relatively open market environment, Tianjin is one of the important foreign trade cities in the northern region, hence the distribution of cases fundamentally aligns with the actual situation. Tianjin primarily achieves high-quality economic development through the Hd1 configuration, characterized by a strategy focusing on economic resources and the market environment under market environment leadership.

Tianjin serves as a typical example of Hd1 configuration, ranking 8th nationally in the high-quality economic development index. As a municipality directly under the central government, Tianjin's development approach is somewhat unique compared to other provinces and cities. The relatively small geographical area makes it challenging for some innovation elements to aggregate. Additionally, its proximity to Beijing provides both convenience and opportunities for the city's economic development but also leads to issues such as talent outflow.

However, as a city supported by industry, by the end of 2019, R&D investment by industrial enterprises above a designated size reached 21.343 billion yuan, and government R&D expenditure accounted for 0.54% of GDP, ranking 6th nationally. The steadily rising innovation capability provides strong support for Tianjin to become an autonomous innovation source in the Beijing-Tianjin-Hebei region. At the same time, by strengthening the top-level design of the business environment, coordinating innovative measures, advancing the "streamlining administration, delegating power, and improving government services" reform, continuously optimizing government services, and always prioritizing the optimization of the business environment, Tianjin has made great efforts to create a market-oriented, open, and standardized business environment, significantly improving the market environment. According to the "China Regional Innovation Capability Evaluation Report" released in 2021, Tianjin's comprehensive market environment index climbed to 5th place nationally in 2019. Leveraging its open market environment and economic resources, Tianjin has become one of the best-developing regions in North China.

4.2.2 Configuration analysis of regional non-high-quality economic development

This study also analyzed two configurations leading to regional non-high-quality economic development. Results indicate that the absence of technology innovation agents, human resources and market environment are necessary conditions for non-high-quality economic development. Furthermore, examining both pathways reveals that the absence of multiple elements in the regional innovation ecosystem contributes to non-high-quality economic development. That is, the lack of innovation agents, resources and environment in a region results in lower levels of economic development quality. In particular, NHa1 configuration includes provinces, such as Ningxia, Tibet, Gansu, Xinjiang, Guizhou, Jilin, Heilongjiang, and Liaoning. In this configuration, the absence of technology innovation agents, human resources, and market environment serve as core missing conditions, with the infrastructure environment and knowledge innovation agents as supplementary missing conditions. This suggests that low density of innovation agents, poor innovation environment, and insufficient human resource supply will lead to non-high-quality economic development. NHb1 configuration includes Tibet, Qinghai, Guizhou, Xinjiang, Ningxia, Inner Mongolia, Yunnan, and Heilongjiang. In this configuration, the absence of technology innovation agents, human resources, and market environment are core missing conditions, with knowledge innovation agents and economic resources as supplementary missing conditions. This indicates that low density of innovation agents, insufficient investment in innovation resources, and poor market environment lead to non-high-quality economic development. A comparison reveals that the configurations causing non-high-quality economic development are not the opposite of those driving high-quality economic development, meaning the antecedent condition configurations for driving high-quality economic development and causing non-high-quality economic development exhibit asymmetrical characteristics.

4.3 Analysis of Substitutive Relationship

Through the analysis and comparison of configurations driving high-quality economic development in regions, it was discovered that under specific conditions, there exists a substitutive relationship among the antecedent conditions. A comparison between the Ha1 and Hb1 pathways reveals that for provinces and cities with comprehensive knowledge innovation agents and abundant human resources, a combination of conditions involving technology innovation agents with the infrastructure environment and market environment can substitute for each other. In this scenario, technology innovation agents and the market environment serve as core conditions, with the infrastructure environment acting as a supportive condition (Figure 2). A comparison between the Ha1 and Hb2 pathways indicates that for provinces and cities with comprehensive technology innovation agents and abundant human resources, knowledge innovation agents and the market environment can substitute for each other, with knowledge innovation agents and the market environment as core conditions (Figure 3). Comparing the Hb1 and Hb2 pathways shows that for provinces and cities in a favorable market environment and possessing ample human resources, a combination of conditions involving knowledge innovation agents and the infrastructure environment can substitute for technology innovation agents, with knowledge innovation agents, technology innovation agents, and the infrastructure environment serving as supportive conditions (Figure 4).

The substitutive relationship between technology innovation agents and the combination of infrastructure environment and market environment conditions indicates that, within specific regional innovation ecosystems, technology innovation agents and the combination of infrastructure and market environment conditions have equivalent effects in driving high-quality economic development. When there are comprehensive knowledge innovation agents and abundant human resources, high-tech innovation agents can function similarly to a favorable infrastructure environment and high market environment element combinations, collaboratively driving regional economic high-quality development alongside other elements. This reflects the synergistic interaction between innovation agents and innovation resources within regional innovation ecosystems to drive high-quality economic development. The substitutive relationship between knowledge innovation agents and the market environment demonstrates that, under certain conditions, knowledge innovation agents and the market environment have the

same effect on driving high-quality economic development. This is because, in the presence of comprehensive technology innovation agents and abundant human resources, the coordination between agents and resource elements achieves effective collaboration, enabling regional economic high-quality development through various equivalent paths. The mutual substitution between knowledge innovation agents and the market environment suggests that, with sufficient investment in other elements, a well-developed knowledge innovation agent network and ample market environment elements can equivalently promote regional economic high-quality development. Both knowledge innovation agents and the market environment can match with other ecosystem elements. Furthermore, the synergy between knowledge innovation agents and the market environment is crucial, adapting to uncertain market demands through structural and efficacy integration to form a unique system of sustained development advantages, continuously driving regional economic high-quality development. The substitutive relationship between technology innovation agents and the combination of knowledge innovation agents and infrastructure environment conditions indicates that, with sufficient market environment and economic resource elements, the role of technology innovation agents in driving high-quality economic development is equivalent to the combination of knowledge innovation agents and infrastructure environment conditions. Knowledge innovation agents, supported by infrastructure conditions, can exchange knowledge with technology innovation agents, both acting as primary agents in driving high-quality economic development.

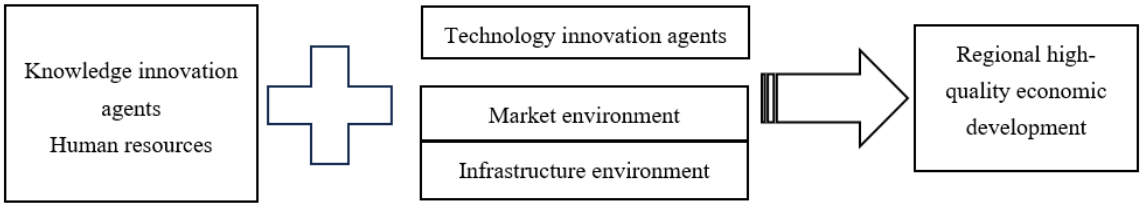

Figure 2. Substitutive relationship of the combination of technological innovation agents and innovation environment conditions

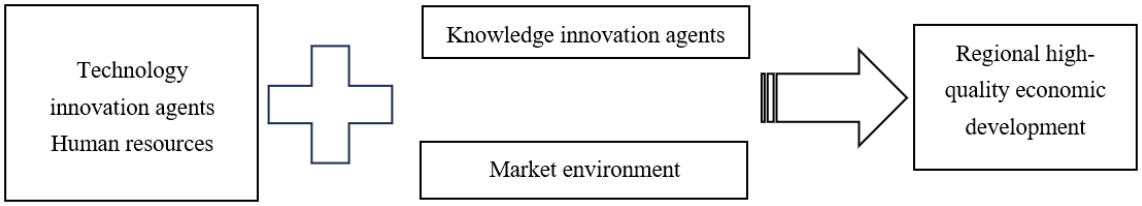

Figure 3. Substitutive relationship of knowledge innovation agents and market environmental conditions

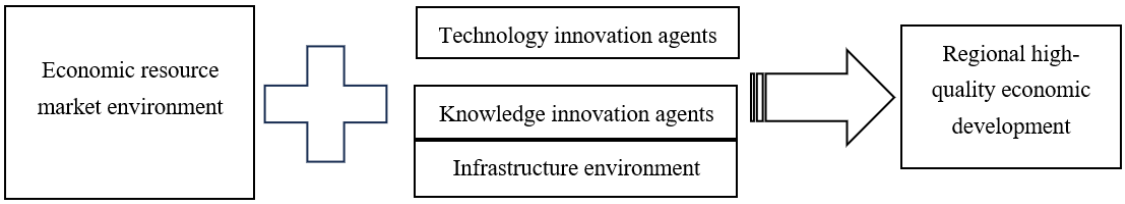

Figure 4. Substitutive relationship of the combination of technology and knowledge innovation agents and infrastructure environment conditions

4.4 Analysis of Regional Heterogeneity

The analysis of regional heterogeneity clearly reveals the differences between various areas. From the five pathways driving regional economic high-quality development through regional innovation ecosystems, it is found that innovation-driven high-quality economic development is mainly concentrated in the central and eastern regions, with the innovation agent-centric ecosystem approach primarily found in the central region. From a configurational relationship perspective, this belongs to a dual drive of agents and resources. Further analysis shows that, firstly, although the central region has solidified its position as a comprehensive transportation hub, the problem of uneven development remains prominent. Some areas, especially remote ones, suffer from inadequate transportation facilities, affecting the efficiency of goods and personnel flow. Secondly, as an inland area, the central region has a certain gap in openness compared to the eastern coastal areas, resulting in a slightly less developed market environment and education system than the eastern developed areas. Although the central

region is actively aligning with the "Belt and Road" initiative through the construction of integrated transportation networks, further efforts are needed to form a new high-level open system inland. Lastly, the central region's industrial structure has been "heavy" for a long time, with insufficient investment in innovation and a low rate of innovation transformation, hence the approach to high-quality economic development appears relatively direct and simple.

The human resource-supported innovation ecosystem under market environment leadership is mainly found in provinces with rapid development momentum in recent years. This pathway exhibits certain uniqueness, primarily reflecting the government's emphasis on talent introduction and market environment construction. From a configurational relationship viewpoint, it belongs to a dual drive of resources and environment. Although the driving methods conforming to this configuration can achieve regional economic high-quality development, due to historical reasons and other issues, the scale of innovation agents and the investment in economic resources still lack compared to the eastern developed areas. In the future, the government needs to increase support for universities and research institutions while maintaining existing advantages, and strive to introduce enterprises with innovative capabilities.

The diversified development integrated innovation ecosystem approach is primarily concentrated in the eastern region. Many cities in China's eastern region have developed economies with strong innovation capabilities. Coupled with several other factors, this has effectively driven high-quality economic development in the eastern region. As China's economic hub, the eastern region emphasizes innovation-driven development. By constructing a diversified development innovation ecosystem and strengthening scientific and technological innovation and industrial innovation, it promotes industrial upgrading and economic structure optimization, focusing on industrial structure adjustment, transitioning from traditional manufacturing to advanced manufacturing with high technology and high added value, and modern service industries, thus nurturing new economic growth points. The eastern region promotes regional integration, such as the coordinated development of Beijing-Tianjin-Hebei, the integrated development of the Yangtze River Delta, and the construction of the Guangdong-Hong Kong-Macao Greater Bay Area. Through optimizing regional economic layout and resource sharing, it achieves collaborative development and mutual benefits within the region.

From the four pathways driving regional non-high-quality economic development, it is observed that areas with non-high-quality economic development are mainly concentrated in the western region. It is apparent that the level of high-quality economic development in cities across China's western region is poor. If provinces in this region do not promptly follow national policies and respond to national calls, it may easily lead to non-high-quality economic development, causing the western region to fall further behind.

Overall, compared to the eastern region, the central region ranks second in terms of high-quality economic development levels, but mutual coordination of multiple factors can also drive regional high-quality economic development. The eastern region, located along the coast with convenient transportation, a robust industrial base, a more developed economy, and a more complete market system, is clearly superior to the central region and the relatively remote and isolated western region. Naturally, since the reform and opening-up, it has become the focus of China's gradient development strategy, followed by the central region. The digital content industry in the western region as a whole lags behind the central and eastern regions, leading to increasingly evident differences in high-quality economic development among the eastern, central, and western regions.

4.5 Robustness Check

To ensure the robustness of the conclusions drawn in this study, the robustness check was conducted. The consistency threshold was adjusted from 0.8 to 0.85 (Zhang & Du, 2019), and the PRI value was raised from 0.8 to 0.85, with the case frequency threshold set at 1. The results showed that the configurations produced by the antecedent condition variables remained unchanged. Therefore, it can be concluded that the above results possess robustness.

5. Conclusions and Implications

5.1 Conclusions

From a configurational perspective, this study analyzes the antecedent configurations and characteristics driving regional high-quality economic development. The main conclusions are as follows:

(a) Individual system elements do not constitute necessary conditions for driving regional economic high-quality development; a synergistic effect is needed through the combination of different factors. Compared to other elements, the market environment plays a more universal role in driving high-quality economic development; the absence of technology innovation agents, human resources and the market environment are necessary conditions leading to non-high-quality economic development.

(b) Utilizing the fsQCA method, five pathways driving regional economic high-quality development were

identified, further categorized into innovation agent-centric innovation ecosystems, human resource-supported innovation ecosystems under market environment leadership, diversified development integrated innovation ecosystems, and economic resource-driven innovation ecosystems under market environment leadership. Two pathways leading to non-high-quality economic development were identified, exhibiting asymmetrical characteristics with the pathways driving high-quality economic development. This further verifies that the pathways through which regional innovation ecosystems drive high-quality economic development possess characteristics of "multiple concurrent", "divergent paths converging", and "asymmetry". Based on the development situations and resource ownership of different regions, a comparison of areas with similar innovation ecosystem environments among the five pathways to achieve regional high-quality economic development is sought, aiming for the rational allocation of limited resources and ultimately achieving innovative development.

(c) Under certain conditions, there exists a potential substitutive relationship among the elements composing the regional innovation ecosystem. Three types of mutual substitution relationships were identified in this study. With comprehensive knowledge innovation agents and abundant human resources, the combination of conditions involving technology innovation agents with the infrastructure and market environment equivalently drives regional economic high-quality development; with comprehensive technology innovation agents and abundant human resources, knowledge innovation agents and the market environment equivalently drive regional economic high-quality development; with a favorable market environment and ample economic resources, the combination of conditions involving knowledge innovation agents and the infrastructure environment equivalently drives regional economic high-quality development with technology innovation agents.

5.2 Theoretical Contribution

This study contributes to the literature in two main ways:

(a) Grounded in theories related to innovation ecosystems and new development concepts, and integrating the research findings of current scholars with the operational characteristics of regional innovation ecosystems in China's provinces and municipalities, this study has formulated a comprehensive analytical framework for driving high-quality economic development through regional innovation ecosystems. This framework includes three levels of conditions: innovation agents, resources and environment, identifying six antecedent conditions impacting high-quality economic development. The application of this analysis framework helps expand the research perspective on high-quality economic development.

(b) By employing the fsQCA method and based on a configurational perspective, this study empirically investigates the interactive matching effects and multiple concurrent relationships of innovation agents, environment and resources in driving high-quality economic development from an innovation ecosystem viewpoint. This further extends the application of the fsQCA research method in the innovation ecosystem field to explain "complex causal" relationships. The exploration of multi-pathway concurrent synergistic effects further enhances the understanding of the complex impact mechanisms of innovation ecosystems on high-quality economic development.

5.3 Managerial Implications

The regional innovation ecosystem, composed of multiple elements, is integral to driving high-quality economic development in regions. From a configurational perspective, multiple pathways to drive regional high-quality economic development have been identified. This suggests that the development potential and innovation potential of different regions vary, necessitating an adjustment in policy logic and an improvement in the symbiotic or leading relationships among system elements, to craft distinct elemental configurations for different regions. The main managerial implications are as follows:

(a) The synergistic effect among elements should be emphasized, leveraging the leading role of key elements. It is essential to perfect the coordination and interaction mechanisms among innovation agents, innovation resources, and the innovation environment, enhancing the efficiency of element flow and interaction within the system. Additionally, the "combination" of elements in various formulas should be closely managed, focusing on the interactive matching of innovation agents, innovation resources, and the innovation environment from a "holistic perspective" based on "configurational thinking". The regional innovation ecosystem possesses multiple pathways to drive high-quality economic development, embodying the concept of "many roads lead to Rome" with divergent paths converging to similar outcomes. Therefore, local governments should build an innovation ecosystem configuration that suits the regional development mode, based on an accurate assessment of local conditions, referring to the high-quality economic development configurational module. This aims to target limited innovation resources and forces towards the construction of core element configurations, forming differentiated pathways for driving high-quality economic development through regional innovation ecosystems.

(b) The driving force of the regional innovation ecosystem for high-quality economic development has been fully demonstrated in China's eastern regions and some central regions. However, many provinces and cities in the

western and northeastern regions should pay attention to the actual operation of local innovation ecosystems, deeply analyze the competitive advantages within the local innovation ecosystem and the coupling of system elements. They should formulate targeted long-term strategies for sustainable, high-quality development of the regional innovation ecosystem, igniting the engine of innovation ecosystems for high-quality economic development.

(c) The impact of the market environment on regional high-quality economic development deserves attention. The market environment element appears in all four combinational configurations. A sound market environment is fundamental to achieving high-quality economic development. It facilitates the rational allocation of resources, promoting a competitive mechanism for the rational distribution of resources to sectors and enterprises with competitive advantages and development potential, thereby enhancing the efficiency and quality of regional economic development. By focusing on prominent issues in the local market environment and establishing a cooperative mechanism between government and market, continuous optimization of a market-oriented, open business environment is encouraged. Establishing a robust market accountability mechanism, expanding communication channels between government and market, leveraging quality local resources and geographical advantages to enhance market openness, ultimately achieves high-quality regional economic development.

5.4 Deficiency and Prospect

This study has provided a theoretical elucidation of configurational forms, offering theoretical support for the research findings. However, like research employing the fuzzy set approach, it shares a common limitation: a lack of further qualitative analysis of the QCA results. This is particularly true regarding the theoretical discussion of pathways leading to non-high-quality economic development in regions, which has been almost entirely overlooked. Future research should analyze the driving mechanisms behind these pathways. Additionally, due to the difficulty in obtaining regional data, this paper focuses only on six antecedent conditions centered around "agent-resource-environment", without considering factors such as the governmental environment, which impacts the universality of the conclusions. Future studies could further enrich the research framework on regional innovation ecosystems, collect more data, and delve deeper into the forms of element combinations. Lastly, due to the availability of data, this study uses static data from a single year. Future research could collect data over time and use the longitudinal QCA method to explore how changes in the innovation ecosystem impact the evolution of regional high-quality economic development.

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Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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