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Research on Innovation Capability of Regional Innovation System Based on Fuzzy-Set Qualitative Comparative Analysis: Evidence from China

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Abstract: Building regional innovation systems (RISs) has become an important measure for China to implement an innovation-driven development strategy, but a moderately complex way to describe the characteristics of the RISs is needed for aiding the implementation of this strategy. Based on the subject-resource-environment (SRE) framework with five secondary conditions, this study takes 31 regions in China as cases, and studies the innovation capability of the RISs by using the fuzzy-set qualitative comparative analysis (fsQCA) approach. The findings are as follows: (1) Different combinations of the five conditions have generated two high and one low innovation capability configurations of RISs. (2) The two configurations of high innovation capability are the independent-investment type and the independent-open type. (3) The configuration of low innovation capability is the core-resource-deficiency type. This study has simplified the complexity of the RISs to a certain extent and revealed that the matching effect among core conditions is the key to obtaining high innovation capability. The conclusions provide practical implications for the RISs in China to acquire appropriate innovation capabilities according to their resource endowment conditions.

Keywords: regional innovation system; innovation capability; SRE framework; matching effect; fuzzy-set qualitative comparative analysis

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1. Introduction

As a combination of regional economy and technological innovation, the regional innovation system (RIS) is a complex system that creates, stores and transfers knowledge, skills, and artifacts formed in a particular region [1]. A competitive RIS is considered to effectively enhance the innovation capability of the country, such as boosting regional industries and developing regional new knowledge economies [2,3]. Therefore, building an RIS has become an important measure for China to implement an innovation-driven development strategy. However, because of the differences in R&D investment, policies, and the market access among local governments, the innovation capability in different regions of China has large gaps, which affects the sustainable development of China's overall innovation capability. Therefore, studying the characteristics of different RISs will help each region to explore appropriate ways to enhance its innovation capability according to the resource endowment conditions.

Studies on the development paths of RISs in existing literature are mainly conducted based on three aspects:

(1) Linear assumptions. These studies mainly simplify innovation activities into economic variables under given assumptions and test the impact of specific variables such as social capital [4], scientific talents [5], regulation factors [6], etc., on RIS. However, the linear effect of single or multiple factors cannot comprehensively depict the features of an RIS, and the interactions among various elements in the region also make in-depth analysis difficult.

(2) System metaphor. These studies mainly apply the theory of ecology, psychology, chemistry, etc., to study RISs, using concepts such as innovation population structure [7], neuropsychology and neural evolution theory [8], B-L reaction model [9], etc. This places the study of RISs in the category of complex system research through system metaphor. However, this metaphorical approach complicates the analysis of regional innovation system, which weakens the possibility of dialogue between theory and reality.
(3) System evaluation. These studies mainly measure the effect of innovation resource input in different regions by evaluating the innovation performance or innovation efficiency of RISs based on the entropy method [10], dynamic network SBM model [11], coupling evaluation model [12], etc. However, these analyses fail to fully consider the differences among regions and tend to focus on the investment model of successful regions, which does not inspire the innovation vitality of different regions.

Configuration analysis based on the qualitative comparative analysis (QCA) approach provides a solution to the limitations of existing research. First of all, the configuration analysis adopts a holistic and systematic analysis approach, while QCA based on a set-theoretic approach applies to the configuration problem rather than the traditional net effect problem resolved by regression-based approaches [13]. Second, the QCA approach can directly analyze the interdependence among variables [14], so there is no need to analyze the regional innovation system by making a metaphor. Last, the QCA approach considers the case as a whole composed of causal conditions, so it pays attention to the complex causal relationship and causal asymmetry between the condition configuration and the result [13]. For example, different configurations may produce a high or low RIS innovation capability, which meets the demand of this study to describe the features of different regional innovation systems in China.

Therefore, this study applies the QCA approach to research the innovation capability of China's RISs to solve the following questions: What are the core and marginal conditions that affect the innovation capability of an RIS? What are the specific configurations that promote the innovation capability of an RIS? What practical implications can this study bring to improve the innovation capability of China's RISs? By answering these questions, this study will contribute in the following two aspects: (1) In theory, based on the SRE framework, this study builds a configuration model of RISs that simplifies the complexity of the regional innovation system; (2) In practice, it reveals the features of the independent-investment type, independent-open type, and core-resource-deficiency type of China's RISs and provides differentiated regional innovation system construction strategies for government decision-makers.

2. Literature Review and Model

2.1. Regional Innovation System and Innovation Capability

Existing research on evaluation of the innovation capability of RISs is often based on the resource-based view, that is, the innovation capability of RISs originates from resources that are difficult to imitate and replace [15]. However, innovation capability is mainly measured by the number of innovation resources owned by the system [10–12]. Although these studies have contributed to understanding the innovation capability of regional innovation systems, the analysis of the relationship between resources and capabilities is insufficient be-cause of the emphasis on proving the importance of resource.

We followed the study of enterprise technology capability, that is, if technological progress is to have an effect on economic development, it must take the form of products [16]. In other words, if a regional innovation system is to have a practical effect, it will eventually be reflected in the products produced by the system. Analyzing the innovation capability of RISs from the perspective of products, we found that although all kinds of resources (such as R&D personnel or specific assets) related to the innovation capability reflect the innovation potential of an RIS, each resource is not a sufficient condition alone to trigger high innovation capability [17]. Thus, for the innovation capability of an RIS, we did not use the traditional resource-based measurement method but used the production quantity of new products as the innovation capability measurement indicator. Specifically, the innovation capability of an RIS was measured by the new product sales revenue of industrial enterprises above a designated size in different regions.

2.2. Subject–Resource–Environment Framework and Configuration Modle

The use of the QCA method places certain constraints on the number of conditional variables. If too many conditional variables are selected, the number of configurations will increase exponentially, which is difficult for researchers to explain [18]. For a medium-sized sample, the number of ideal conditions is generally between 4 and 7 [19]. In this study, 31 provinces of China were selected as the sample, making it a medium sample. How to select conditional variables within the number of constraints was the key to using the QCA method in this study.

Selecting conditional variables based on existing research frameworks is an important method in the application of QCA [20]. Based on the common goal, the innovation subject cooperatively integrates the innovation resources in the system in an environment suitable for innovation, thus promoting the improvement of regional innovation capability [21–24]. On the basis of the SRE framework, we built a configuration model containing five conditional variables derived from the subject, resources, and environment of the regional innovation system (see Figure 1).

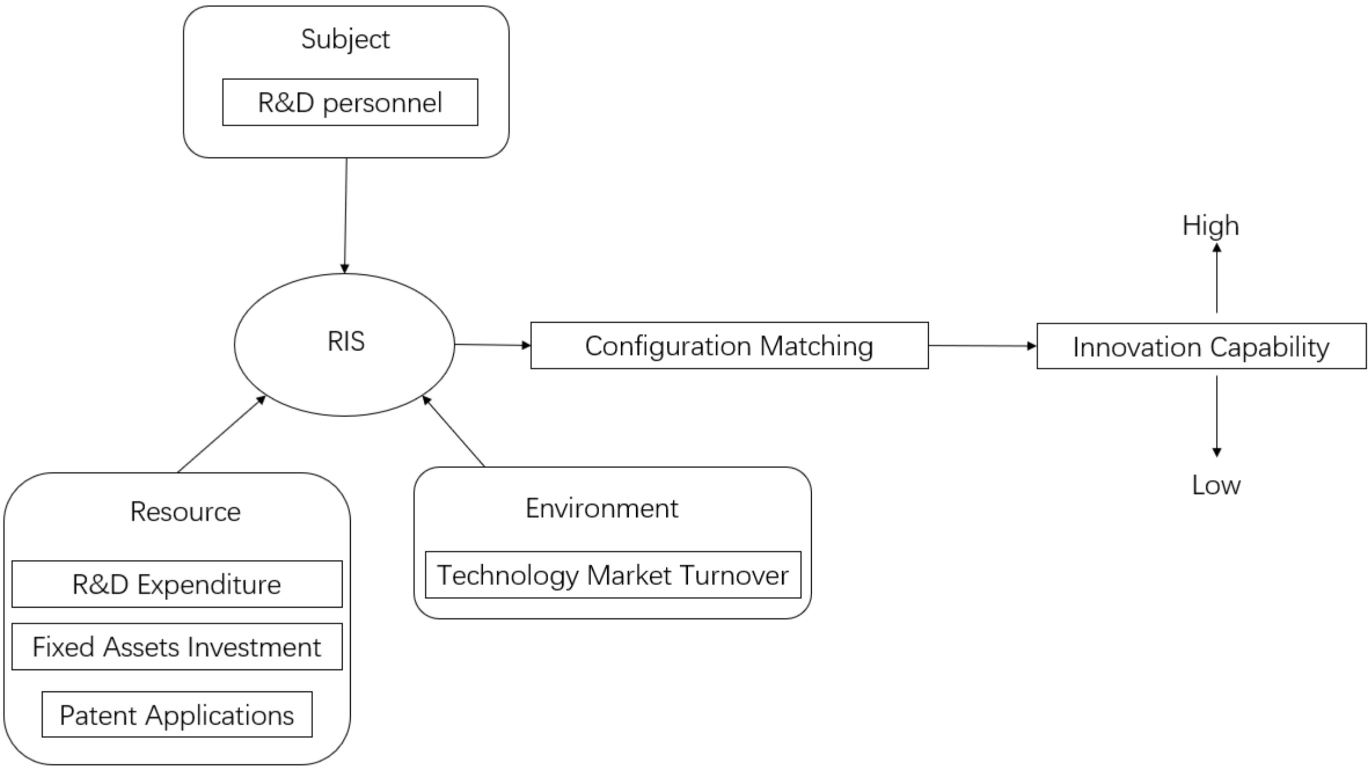

Figure 1. Configuration model of the RIS.

The five conditions were as follows:

(1) The subject condition of RISs was R&D personnel. The interaction between innovation subjects is an important source of knowledge sharing, interactive learning, and regional innovation [22]. The existing research tends to view innovation subjects from the organizational perspective, that is, innovation subjects generally refer to technology innovation subjects represented by enterprises and knowledge innovation subjects represented by universities and R&D institutions [25,26]. However, if we only see the technological change from the perspective of the organization, we may

overlook the fact that technological innovation can cross organizational boundaries, that is, understanding the innovation capability improvement mechanism by analysis units such as enterprises, universities, or scientific research institutions is still too vague [27]. Therefore, this study took the R&D personnel in the RIS as the innovation subject to highlight the innovation activities supported by human beings and used the "full-time equivalent of R&D personnel" as the measurement indicator.

(2) The resource conditions of the regional innovation system included three secondary conditions: R&D expenditure (RE), fixed asset investment (FA), and patent applications (PA). First of all, RE refers to the expenditures actually used for basic research, applied research, and experimental development, reflecting the importance and support of a region to innovative activities [15]. RE is an important indicator of innovation resources in the RIS and an important driving factor to promote the transformation of innovation achievements and improve system output [28]. Second, the innovation infrastructure reflects the RIS as a supporting platform used to ensure the normal conduct of innovation activities and encourage the continuous development of innovation activities, and it is an important material basis for the national and regional innovation systems [29]. However, it is difficult to accurately distinguish innovation infrastructure from traditional infrastructure at present. This study used FA to approximately measure the construction of innovation infrastructure. Finally, the literature often regards scientific papers as a part of innovation resources [30]. However, scientific discovery and scientific papers are not "innovation" in Schumpeter's sense. In contrast, patents form preliminary technical solutions that are encoded technical knowledge. In the past, academia has recognized that empirical knowledge is tacit knowledge [31,32]. As empirical knowledge is a valuable intangible innovation resource, scientific researchers and research organizations will save it by various means, which are reflected in their efforts to encode empirical knowledge. On the macro scale of RISs, a patent is the main coded form of empirical knowledge. Therefore, we used regional RE, FA, and PA to measure the above secondary conditions.

(3) The environmental conditions of the regional innovation system take the technology market turnover as the secondary condition. In the context of globalization, the innovation system must absorb knowledge, technology, capital, etc., outside the system to promote sustainable development. The product development of regional innovation systems, especially complex products, often requires the support of an external innovation network [33]. The more open the RIS is, the more conducive it is to carrying out collaborative innovation activities and improving the efficiency of resource integration [34]. The existing research mainly uses the market environment to refer to the degree of openness of the system environment [35]. In other words, in an open regional innovation system, it can obtain external innovation support and enhance the innovation capability through market transactions. This study focused on investigating the innovation capability of the RIS from the perspective of technology. Therefore, the technology market turnover (TM) [36] was used to measure the system-opening environment.

From the perspective of configuration, the impact of the subject, resource, and environment conditions of the RIS on the innovation capability is not a simple linear relationship but occurs through linkage and matching. Thus, we empirically analyzed how subject, resource, and environment conditions affected the innovation capability of the RIS by using the fsQCA approach.

3. Method and Data

3.1. Fuzzy-Set Qualitative Comparative Analysis Approach

QCA was proposed by Ragin in the 1980s. Using the QCA approach, researchers can determine the logical relationship between matched patterns of different conditions and obtain results through cross-case comparison. That is, researchers can identify which configuration of variables can lead to the emergence of a result and which configurations cause the reduction in an outcome, to further identify the matching effects of multiple variables while acknowledging the causal complexity [19].

Compared with quantitative research based on regression analysis, QCA has the following advantages [19]: First, through cross-case comparison of large, medium, and small samples, researchers can identify the mechanism of action of variables reflecting conditions and ensure the external generalization of empirical results to a certain extent. Second, researchers can identify the equivalence of conditions and results, which can explain the mechanisms driving the results in different case scenarios so that they may further discuss the adaptation relationship between conditions. Third, researchers can further compare the results when the condition configuration disappears, thereby broadening the theoretical explanations of problems in specific research dimensions. Under the causal asymmetry premise, the variables representing the conditions and the "not set" conditions may not be the same.

Qualitative comparative analysis (QCA) includes three basic categories of analyses [19]: clear-set qualitative comparative analysis (csQCA), fuzzy-set qualitative comparative analysis (fsQCA), and multivalued set qualitative comparative analysis (mvQCA). Among them, fsQCA enables the QCA method to handle not only multicategory problems, but also the degree of change problems and the partial membership problem; that is, the case receives a membership score between 0 (non-membership) and 1 (full membership). Therefore, fsQCA has been widely used in relevant empirical studies in recent years.

We used the fsQCA approach for empirical tests. On the one hand, this study took 31 provinces in China as research samples, and the corresponding statistical data were quantitative data with continuous changes, which met the sample requirements and data characteristics of this approach. On the other hand, the purpose of this study was to analyze the causal relationship between the conditional configuration of the RIS and the innovation capability. The RIS is the result of the interaction of three conditional variables, namely, subject, resource, and environment, and the combination of secondary conditions from the three variables can produce different configurations. The fsQCA approach can properly handle the configuration problem.

3.2. Data Source

This study took 31 provincial administrative regions in China as research samples. The input of innovation elements and innovation development level of each province was highly heterogeneous, which could achieve a full comparison between the cases and external effectiveness of conclusions. Considering the time lag effect of the factor input of the regional innovation system on innovation capability, the lag period was determined as two years in this study. The result variables of this study were taken from the *China Statistical Yearbook 2020*, and the conditional variables were from the *China Statistical Yearbook 2018*. The introduction of each condition and result variable is shown in Table 1.

Table 1. Outcome and Conditions.

Measure	Index/Year	Abbreviation
Outcome	New Product Sales Revenue/2019	NP
Conditions	R&D Personnel/2017	RP
	R&D Expenditure/2017	RE
	Fixed Assets Investment/2017	FA
	Numbers of Patent Application/2017	PA
	Technology Market Turnover/2017	TM

3.3. Calibration

In fsQCA, each condition and result are regarded as a set, and each case has a membership score in these sets. Calibration is the process of assigning a membership score to a set for a case. Because of the lack of clear theories and external standards as the calibration basis for various conditional variables and result variable, this study calibrated the initial data (see Table A1 in Appendix A) based on descriptive statistics [37].

Referring to existing studies [37], we set the three points of complete membership, intersection, and complete non-membership in this study to the 95%, 50%, and 5% quantiles of the sample data, respectively. The measurement index description for each variable and the calibration points are shown in Table 2. We used fsQCA3.0 for analysis in this study. Because the value of the sample intersection point was exactly 0.5 after calibration, we adjusted 0.5 to 0.501 according to the partial membership of the value of the intersection point [37]. Fuzzy-set data of each variable after calibration can be seen in Table A2 in Appendix B.

Table 2. Result of calibration.

Outcome and Conditions	Complete Membership	Crossover	Complete Non-Membership
NP	352,491,893.200	42,118,322.000	653,340.400
RP	456,217.600	49,463.000	1160.200
RE	18,463,424.400	2,411,418.000	46,163.400
FA	54,047.280	17,537.000	3027.280
PA	154,705.200	13,855.000	273.800
TM	24,146,012.600	1,467,121.000	24,823.400

4. Results

4.1. Necessary and Sufficiency Analysis

We first tested whether a single condition (including its not-set) constituted a necessary condition for high innovation capability or low innovation capability. Consistency was an important criterion of the necessary conditions. When the consistency level was greater than 0.9, this condition was considered necessary for the result [20]. According to Table 3, the consistency of RD, RE, and PA was greater than 0.9, which meant that these three conditions were necessary for generating a high innovation capability. The consistency of ~RD, ~RE, and ~PA was greater than 0.9, which meant that these three conditions were necessary for a low innovation capability.

Table 3. Results of necessary condition analysis.

Conditions	NP (High Innovation Capability)	~NP (Low Innovation Capability)
	Consistency	Consistency
RP	0.961	0.433
~RP	0.635	0.950
RE	0.962	0.419
~RE	0.624	0.957
FA	0.842	0.454
~FA	0.543	0.793
PA	0.937	0.401
~PA	0.648	0.974
TM	0.763	0.451
~TM	0.681	0.834

Note: "~" represents Not in set operation.

Sufficiency analysis is the process of exploring whether the set represented by the configuration of multiple conditions is a subset of the result set. In parameter setting, in order to distinguish whether the configuration passed the consistency test of fuzzy-set theory, the consistency threshold was set to 0.8 [37]. Considering that the setting of the frequency threshold should include at least 75% of observed cases, while the total number of cases in this study was 31, this study set the case frequency threshold to 1 [20]. In order to reduce the potential contradictory configurations, this study set the PRI (proportional reduction in consistency) value to 0.7 [20].

When conducting a standard analysis program of high innovation capability, fsQCA 3.0 outputs two prime implications: "RP * PA" and "RE * PA". In this study, we chose to retain two prime implications. When conducting counterfactual analysis of high innovation capability, as the necessary conditions, we selected the "present" option for RP, RE, and PA in fsQCA 3.0. When conducting a standard analysis program of low innovation capability, as necessary conditions, we selected the "absent" option for ~RP, ~RE, and ~PA in fsQCA 3.0. The relationship among other conditions and the result did not reach an agreed conclusion or lacked a clear theoretical expectation, so we selected the "present or absent" option for them in fsQCA 3.0 [38].

At last, complex solutions, parsimonious solutions, and intermediate solutions were obtained through standardized analysis (see Table A3 in Appendix C). We took the conditions that appeared in both the parsimonious solutions and intermediate solutions as the core conditions and took the conditions that appeared only in the intermediate solutions and not in the parsimonious solutions as the supplementary conditions [20].

We adopted the form of QCA presenting results proposed by Ragin and Fiss [39], which clearly indicated the relative importance of each condition in the configuration (see Table 4).

Table 4. Results of the sufficiency analysis.

Conditions	NP (High Innovation Capability)		~NP (Low Innovation Capability)
	HC1	HC2	LC
RP	•	•	⊗
RE	•	•	⊗
FA	•		
PA	•	•	⊗
TM		•	
consistency	0.979	0.974	0.991
raw coverage	0.795	0.718	0.934
unique coverage	0.187	0.111	0.934
solution consistency	0.975		0.991
solution coverage	0.905		0.934

Note: • indicates the presence of the core condition, ⊗ indicates the absence of the core condition, • indicates the presence of the edge condition, and Blank indicates the presence or absence of the condition.

4.2. Configuration Analysis

Table 4 presents two configuration paths that explain the high innovation capability and one configuration path that explains the low innovation capability. Each column represents a possible condition configuration.

As to the configurations of high innovation capability, the solution consistency was 0.975, which meant that 97.5% of RISs had a higher level of innovation capability in all cases that met the two condition configurations; the solution coverage was 0.905, that is, the two configurations of conditions explained 90.5% of the cases of high innovation capability.

As to the configurations of low innovation capability, the solution consistency was 0.991, which meant that 99.1% of RISs had a low level of innovation capability in all cases that met this condition configuration; the solution coverage was 0.934, that is, this configuration explained 93.4% of the cases of low innovation capability.

Based on the configuration of conditions, we further identified the different matching relationships among subject, resource, and environment in influencing the innovation capability of the RIS.

(1) Configuration HC1: Independent-Investment Type. When the RIS had sufficient RP, RE, PA, and FA, a high innovation capability could be obtained. In this path, we found that RP, RE, and PA were the core conditions, FA was a supplemental condition,

and TM was irrelevant for high innovation capability. Because this path depends on the subjects and resources independently owned by the RIS, we named this configuration path the independent-investment type. This means that the independent RP and innovation resources invested by the regional innovation system are important endowment conditions for achieving high innovation capability. This path explained approximately 79.5% of the cases of high innovation capability; approximately 18.7% of the cases of high innovation capability were only explained by this path.

(2) Configuration HC2: Independent-Open Type. When the RIS had sufficient RP, RE, PA, and a high level of TM, high innovation capability could be obtained. In this path, we found that RP, RE, and PA were the core conditions, TM was a supplemental condition, and FA was irrelevant for high innovation capability. Since this path depends on the RP and R&D resource input of the RIS itself and requires the system to be open, we named the configuration HC2 as the investment-open type. This means that while enhancing its own endowment conditions, the RIS can drive the improvement of the innovation capability of the system by promoting the opening of the system and strengthening the market connection and technology trading with external systems. This path explained approximately 71.8% of the cases of high innovation capability; approximately 11.1% of the cases of high innovation capability were only explained by this path.

(3) Configuration LC: Core-Resource-Deficiency Type. When the RIS was deficient in RP, RE, and PA, a low level of innovation capability could be obtained. In this path, we found that ~RP, ~RE, and ~PA were the core conditions, while TM and FA were irrelevant for the result, so we named the configuration LC the core-resource-deficiency type. This path explained approximately 93.4% of the cases of low innovation capability, the cases of which could only be explained by this path.

Table 5 shows the typical cases of each configuration.

Table 5. Typical cases of each configuration.

NP (High Innovation Capability)		**~NP (Low Innovation Capability)**
HC1	**HC2**	**LC**
Guangdong, Jiangsu Shandong, Zhejiang Fujian, Anhui Hubei, Hunan Sichuan, Henan Hebei, Chongqing	Guangdong, Jiangsu Shanghai, Shandong Zhejiang, Anhui Hubei, Hunan Sichuan, Beijing Tianjin	Qinghai, Hainan Xizang, Ningxia Xinjiang, Gansu Guangxi, Guizhou Jilin, Yunnan Neimenggu, Heilongjiang Shanxi, Shaanxi

5. Discussion

5.1. Equivalent Configuration and Substitution Effect

The research on RISs characterized by linear hypothesis often emphasizes the net effect of specific variables on innovation capability [4–6], which leads to the failure of in-depth analysis of the nonlinear effects and complex causal relationships among various conditions. This study used configuration analysis and the fsQCA approach to compare the similarities and differences between HC1 and HC2 (see Figure 2). It was found that: (1) HC1 and HC2 are equivalent configurations, both of which can explain why the RIS obtained high innovation capability; (2) FA and TM are mutually substituted. Therefore, when the RIS possessed the three core conditions of high-level RP, RE, and PA, the system improved the innovation capability not only by increasing investment in fixed assets, but also by strengthening system openness.

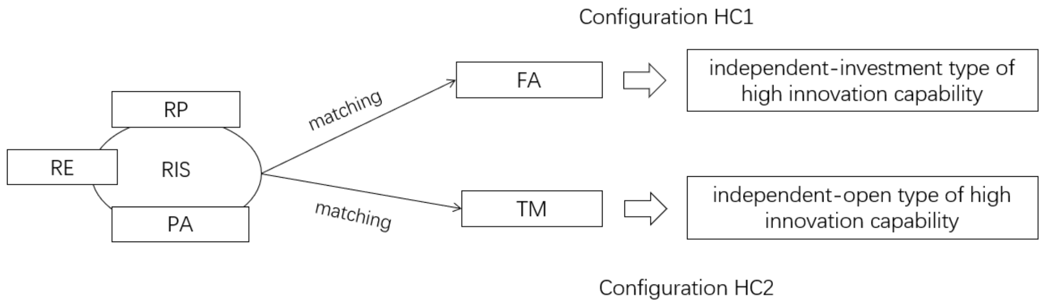

Figure 2. Equivalent configuration and substitution effect.

5.2. Simplify the Complexity of Regional Innovation System

Adopting theories from ecology, physics, or chemistry to study RISs through metaphor is a common method to bring them into the study of complex systems [7–9]. However, the process and results of RIS analysis based on this approach are too complex, which may lead to a degree of separation between theory and reality. The fsQCA approach used in this study focused on the holistic and systematic perspective, with which we could analyze the interdependence among variables of the RIS without metaphor. Under the SRE framework, by examining the relationships among different combinations of five secondary conditional variables and innovation capability, we used the independent-investment type and the independent-open type to characterize the RIS with a high innovation capability and used the core-resource-deficiency type to characterize the RIS with a low innovation capability. Based on this, we simplified the complexity of the RIS, enhanced the dialogue between theory and reality, and made it easier for decision makers to derive useful implications from it.

5.3. Causal Asymmetry

The innovation capability evaluation of RISs based on the resource view mainly focused on the number of innovation resources owned by the RIS and the effect of innovation resource input in different regions [10–12]. However, this kind of analysis failed to fully consider the regional differences and over-focused on the input mode of successful regions. In this study, by comparing HC1, HC2, and LC, we found that the causes of high innovation capability and low innovation capability are asymmetric: (1) When the RIS is in a synergy state of RP * RE * PA, the matching of FA or TM can achieve high innovation capability; however, (2) when the RIS is in a synergy state of ~RP *~RE *~PA, the impact of FA and TM on the results is irrelevant. In other words, on the one hand, FA and TM are input variables of the RIS with a high innovation capability, but they cannot lead the RIS with a low innovation capability out of its predicament. On the other hand, decisionmakers should pay more attention to ensuring the matching among core resources than to how many innovation resources the RIS has.

6. Conclusions

This study took 31 provincial administrative regions in China as case samples, integrated five conditional variables of RISs based on the SRE framework, and studied the innovation capability configuration of China's RISs using the fsQCA approach to analyze the causal relationship between the condition configuration of RISs and innovation capability. Our main conclusions were as follows:

(1) High-level RP, RE, and PA are necessary conditions for the RIS to obtain a high innovation capability. Low-level RP, RE, and PA are necessary for the low innovation capability of RIS.
(2) There are two paths for the RIS to obtain a high innovation capability. The configuration with the conditions of RP, RE, PA, and FA forms an RIS with an independent-investment type of high innovation capability. The configuration with the conditions of RP, RE, PA, and TM forms an RIS with an independent-open type of high innovation

capability. The matching effect of high-level RP, RE, and PA is the core condition for the RIS to obtain a high innovation capability.

(3) There is one configuration path leading to the low innovation capability of the RIS. The matching effect of low-level RP, RE, and PA forms an RIS with a core-resource-deficiency type of low innovation capability.

This study offers two theoretical contributions:

(1) Based on the SRE framework, this study integrated the subject, resource, and environment conditions of the RIS and expanded the SRE framework by proposing five secondary conditions that affect the innovation capability. Based on the fsQCA approach, we simplified the complexity of the RIS and characterized the features of China's RISs as independent-investment type, independent-open type, and core-resource-deficiency type.
(2) We analyzed the matching effect of the subject, resource, and environment conditions on the innovation capability of the RIS. On the one hand, this study indicated that the RIS can obtain a high innovation capability through different combinations of various conditions and found that ensuring the matching among core resources is the key to obtain high innovation capability. On the other hand, we revealed that the causes of high innovation capability and low innovation capability are asymmetric, and failed regional innovation systems are worthy of attention as well as the successful ones.

This study presents the following practical implications for the improvement of the innovation capability of China's RISs:

(1) The existence of the triple conditions of the subject, resource, and environment of the RIS reveals the complexity of improving the innovation capability. Based on the existing conditional endowments of the RIS, policy makers can focus on matching the core conditions in the systematic perspective and seek a differentiated path to enhance the innovation capability.
(2) The matching effect of RP, RD, and PA should become the policy focus of the RIS. The RP is the main carrier of regional innovation knowledge, the RE reflects the degree of emphasis and support for innovation activities in a region, and the PA contains the tacit knowledge of the regional innovation system. However, the three do not spontaneously couple. Thus, decision makers who play the role of RIS integrators should focus on creating a policy environment conducive to the matching effect of the core conditions.

Finally, this study had limitations, and the following two aspects can be considered for improvement in subsequent research:

(1) Although the SRE framework used in this study covered the subject, resource, and environment factors of the regional innovation system, we omitted some factors owing to the limitations of the fsQCA approach on the number of condition variables. Future improvements can be achieved by incorporating more condition variables into the model by using dimensionally reduction techniques (such as factor analysis, principal component analysis, independent component analysis, etc.).
(2) Our findings reflect the notable differences between QCA and mainstream statistical analysis methods. However, this does not mean that the two are mutually exclusive. Researchers are increasingly trying to integrate QCA methods with mainstream statistical analysis methods. In subsequent research, researchers can use mainstream statistical analysis methods (such as multiple regression analysis.) to quantify the innovation capability configuration [40], so as to quantify configurations, improve existing measurement methods, or enhance the descriptive power of the theory.

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Data Availability Statement: The [Excel Form File] data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest: The author declares no conflict of interest.

Appendix A

Table A1. Initial data.

Province	NP	RP	RE	FA	PA	TM
Beijing	52,201,988	52,719	2,690,851	8370.4	19,653	44,868,872
Tianjin	38,466,201	57,881	2,411,418	11,288.9	15,770	5,514,411
Hebei	64,847,324	79,135	3,509,684	33,406.8	13,855	889,245
Shanxi	19,892,632	31,757	1,122,323	6040.5	4398	941,471
Neimenggu	11,274,431	23,243	1,082,640	14,013.2	3796	196,087
Liaoning	42,835,981	49,463	2,749,477	6,676.7	11,206	3,858,317
Jilin	26,275,923	21,056	749,958	13,283.9	2894	2,199,199
Heilongjiang	7,336,240	24,046	825,854	11,292	3786	1,467,121
Shanghai	101,409,491	889,67	5,399,953	7246.6	27,581	8,106,177
Jiangsu	301,019,390	455,468	18,338,832	53,277	124,980	7,784,223
Zhejiang	260,993,704	333,646	10,301,447	31,696	85,639	3,247,310
Anhui	96,985,530	103,598	4,361,175	29,275.1	52,916	2,495,697
Fujian	57,893,119	105,533	4,487,934	26,416.3	31,433	754,634
Jiangxi	63,281,504	45,082	2,216,865	22,085.3	19,383	962,096
Shandong	134,800,845	239,170	15,636,785	55,202.7	55,881	5,116,448
Henan	67,883,527	123,619	4,722,542	44,496.9	22,367	768,528
Hubei	97,076,662	94,241	4,689,377	32,282.4	22,244	10,330,773
Hunan	81,053,560	94,228	4,617,716	31,959.2	21,319	2,031,915
Guangdong	429,700,648	457,342	18,650,313	37,761.7	199,293	9,370,755
Guangxi	18,382,401	16,163	935,996	20,499.1	5428	394,228
Hainan	935,498	1971	74,815	4244.4	443	41,079
Chongqing	43,654,109	56,416	2,799,986	17,537	17,269	513,581
Sichuan	42,118,322	71,968	3,010,846	31,902.1	26,687	4,058,307
Guizhou	8,188,302	18,786	648,576	15,503.9	5344	807,409
Yunnan	9,395,451	21,393	885,588	18,936	5389	847,625
Xizang	230,104	202	3186	1975.6	20	440
Shaanxi	25,660,429	44,672	1,963,697	23,819.4	9232	9,209,395
Gansu	5,527,138	10,096	466,912	5827.8	3102	1,629,587
Qinghai	1,233,887	1799	83,276	3883.6	729	677,186
Ningxia	4,476,886	6392	291,101	3,728.4	1978	66,679
Xinjiang	5,571,410	6191	400,468	12,089.1	3022	57,554

Appendix B

Table A2. Fuzzy-set data.

Province	NP	RP	RE	PA	FA	TM
Beijing	0.52	0.51	0.51	0.53	0.13	1
Tianjin	0.43	0.52	0.501	0.51	0.22	0.63
Hebei	0.55	0.55	0.55	0.501	0.79	0.23
Shanxi	0.17	0.25	0.16	0.11	0.08	0.25
Neimenggu	0.1	0.16	0.16	0.1	0.33	0.07
Liaoning	0.501	0.501	0.52	0.36	0.1	0.58
Jilin	0.24	0.15	0.11	0.08	0.29	0.52
Heilongjiang	0.07	0.17	0.12	0.1	0.22	0.501
Shanghai	0.64	0.57	0.64	0.57	0.11	0.71
Jiangsu	0.92	0.95	0.95	0.91	0.95	0.7
Zhejiang	0.89	0.89	0.81	0.82	0.76	0.56
Anhui	0.63	0.6	0.59	0.7	0.72	0.53
Fujian	0.54	0.6	0.6	0.59	0.67	0.19
Jiangxi	0.55	0.43	0.44	0.53	0.59	0.26
Shandong	0.71	0.8	0.92	0.71	0.96	0.62

Table A2. *Cont.*

Province	NP	RP	RE	PA	FA	TM
Henan	0.56	0.63	0.61	0.55	0.9	0.19
Hubei	0.63	0.58	0.6	0.54	0.77	0.76
Hunan	0.59	0.58	0.6	0.54	0.77	0.52
Guangdong	0.98	0.95	0.95	0.98	0.84	0.74
Guangxi	0.15	0.11	0.13	0.13	0.56	0.1
Hainan	0.05	0.05	0.05	0.05	0.06	0.05
Chongqing	0.501	0.51	0.52	0.52	0.501	0.12
Sichuan	0.501	0.54	0.53	0.57	0.77	0.58
Guizhou	0.08	0.13	0.1	0.13	0.4	0.2
Yunnan	0.09	0.15	0.13	0.13	0.53	0.22
Xizang	0.05	0.04	0.05	0.04	0.04	0.05
Shaanxi	0.23	0.43	0.36	0.26	0.63	0.74
Gansu	0.07	0.08	0.08	0.09	0.08	0.51
Qinghai	0.05	0.05	0.05	0.05	0.06	0.16
Ningxia	0.06	0.06	0.06	0.07	0.05	0.05
Xinjiang	0.07	0.06	0.07	0.08	0.24	0.05

Appendix C

Table A3. Complete results of the sufficiency analysis.

Configurations		Raw Coverage	Unique Coverage	Consistency
Configuration solution for the high innovation capability of the RIS				
Complex solution	RP * RE * PA* FA	0.795	0.187	0.979
	RP * RE * PA* TM	0.719	0.111	0.974
	solution coverage: 0.905			
	solution consistency: 0.975			
Parsimonious Solution	RP * PA	0.921	0.002	0.971
	RE * PA	0.922	0.003	0.974
	solution coverage: 0.924			
	solution consistency: 0.970			
Intermediate Solution	RP * RE * PA * FA	0.795	0.187	0.979
	RP * RE * PA * TM	0.719	0.111	0.974
	solution coverage: 0.905			
	solution consistency: 0.975			
Configuration solution for the low innovation capability of the RIS				
Complex solution	~RP *~RE *~PA	0.934	0.934	0.991
	solution coverage: 0.934			
	solution consistency: 0.991			
Parsimonious Solution	~RE *~PA	0.947	0.013	0.985
	~RP *~PA	0.942	0.008	0.985
	solution coverage: 0.955			
	solution consistency: 0.979			
Intermediate Solution	~RP *~RE *~PA	0.934	0.934	0.991
	solution coverage: 0.934			
	solution consistency: 0.991			

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