Research on the configuration paths of Sustainable Marine Eco-Efficiency: Based on fuzzy-set qualitative comparative analysis of 11 coastal areas in China

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Research Article

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Abstract

Studying the sustainable configuration path of marine ecological efficiency (MEE) is significant for China's efforts to build a marine power and achieve high-quality development of the marine economy. The existing studies have deficiencies in explaining the complex interaction among multiple land-based influence factors on MEE. Based on the Technology-Organization-Environment (TOE) framework and combined with the characteristics of government behavior under the background of the Chinese system, this study puts forward an integrated analysis framework to understand the differences in MEE among different coastal areas. Taking 11 coastal areas in China as cases, the fuzzy-set qualitative comparative analysis (fsQCA) method is used for configuration analysis, and the findings are as follows: (1) Conditions derived from technology, organization, and environment cannot, on their own, constitute the necessary conditions for high or low MEE, indicating that a single condition has limited explanatory power on MEE.(2) There are three configuration paths for high MEE: a path of development based on innovation, a path of ecological industry based on unique geographical location, and a path of development based on political pressure. Among them, the path of development based on innovation plays a more important role in improving MEE and has more value in making effective policy. (3) There are two ways to have a low MEE: one with a lot of innovation elements and another with a lot of environmental regulation and political pressure on the technology. These two paths imply that the lack of green technology capability is an important conditional variable for low MEE. The findings of this study will help people understand MEE's long-term development path in a more rational way and give them useful practical advice.

1. Introduction

Maritime power has become China's national strategy. China needs to promote the high-quality development of marine economy to provide economic support for the realization of this strategy [1]. However, in order to achieve sustainable marine economic development, China must protect the marine ecological environment, which makes the construction of marine ecological civilization an important part of China's marine power strategy [2]. Therefore, balancing the relationship between marine economic development and marine ecological protection by studying the sustainable configuration path of marine ecological efficiency (MEE) has important theoretical and practical significance for China.

The existing literature has carried out empirical research on the basic theory and accounting methods for land ecological efficiency in different scales and fields such as enterprises and regions [3–5]. Compared with the abundant research on land ecological efficiency, the current research on MEE has not received enough attention, and the study characteristics and deficiencies are specifically reflected in the following two aspects:

(1) Index system construction and accounting of MEE. In the research of marine economic efficiency, environmental benefits are often ignored, and the construction and measurement of relevant index system mainly focus on economic benefits [6]. Based on the study of marine economic efficiency, the

index system of MEE includes not only expected outputs (such as seawater quality) other than economic benefits, but also includes various types of unexpected outputs (such as the discharge of industrial waste gas, wastewater and solid waste), and Super efficiency DEA model, super efficiency SBM-DEA model and Network RAM model are adopted to calculate MEE [7–10]. Among these calculation models, the super efficiency SBM-DEA model has been more widely used.

(2) Correlation between MEE and certain factor. Based on the accounting of MEE, an important research trend is that taking MEE as the dependent variable and use econometric models (such as panel regression model, Tobit regression model, spatial correlation analysis and VAR model) to analyze the impact of specific factors (such as green technology, industrial structure, scientific and technological resource allocation and urbanization) on MEE [11][12]. However, marine ecosystem is a special composite system of ecosystem, economic system and social system [13]. Only considering the correlation between specific single factors and MEE may be difficult to explain the causal complexity behind MEE.

The configuration perspective is widely used to understand the causal complexity behind the outcomes [14]. According to the configuration perspective, multiple influencing conditions are interdependent, and the common purpose of influencing the outcomes can be achieved through differential arrangement and combination. Marine environmental pollution mainly comes from land-based pollution [15]. Thus, this study will empirically analyze the complex causal relationship between the MEE and multiple influencing interdependent conditions of land from the configuration perspective. We try to answer the following research questions: what are the sustainable configuration paths of marine ecological efficiency? What conditions play a more important role? What is the matching relationship among these conditions?

The main contributions of this study are as follows: (1) Based on Technology-Organization-Environment (TOE) framework, an integrated analysis framework for understanding sustainable marine ecological efficiency is proposed. Taking 11 coastal areas in China as cases, this study attempts to reveal the configuration paths and driving mechanism leading to different MEE outcomes through fuzzy-set qualitative comparative analysis (fsQCA). (2) Through the analysis of multiple conditional synergy in TOE framework, this study explains the complex interactive nature of multiple land-based influencing conditions behind MEE, which makes up for the deficiency of existing studies in explaining such problems. This study will help to deepen the rational understanding of the sustainable development path and driving mechanism of MEE, as well as provide new evidence and analytical ideas for Chinese local governments to achieve sustainable marine economy.

2. Methodology And Materials

2.1 fuzzy-set Qualitative Comparative Analysis

This study tries to analyze the land-based influencing conditions of MEE from the configuration perspective, which makes the fsQCA a suitable method for carrying out our empirical test. QCA was proposed by Ragin in the 1980s. By using QCA, researchers can find out the logical relationship (for instance: what kind of configuration formed by certain condition variables may lead to the emergence or disappearance of certain outcome?) between the matching patterns of different conditions and the outcomes through cross cases comparison, so as to further identify the synergistic effects of multiple condition variables on the premise of recognizing the causal complexity [14].

Comparing with quantitative research based on traditional regression analysis, the advantages of QCA are as follow [16]: (1) Through cross cases comparison, researchers can ensure the external promotion of empirical results to a certain extent on the basis of identifying the mechanism of condition variables. (2) Researchers can identify configurations with equivalent outcomes, which can help to understand the differential driving mechanism of outcomes in different case scenarios, and further discuss the matching relationship among condition variables. (3) Researchers can further compare the configurations that lead to the emergence or disappearance of outcomes, and broaden their theoretical interpretation dimension of specific research problems. Because under the logical premise of causal asymmetry, the condition variables that lead to the emergence of the outcome variables may be different from the condition variables that lead to the emergence of the "non-set" of the outcome variables.

QCA includes three basic categories: clear set qualitative comparative analysis (csQCA), fuzzy set qualitative comparative analysis (fsQCA) and multivalued set qualitative comparative analysis (mvQCA). csQCA and mvQCA are only suitable for dealing with category problems, while fsQCA can further deal with problems related to continuous changes and partial subordination [14][16]. Therefore, fsQCA has been widely used in empirical research in recent years.

2.2 TOE framework

TOE framework is mainly applied to the analysis of new technology adoption and its influencing factors, and a variety of analysis frameworks have been developed. Among existed analysis frameworks, the TOE framework proposed by Tornatzky and Fleischer in 1990 has the most extensive impact, which puts forward three factors affecting the adoption of organizational innovative technology [17–19]: Technology refers to the characteristics of various technical means and their relationship with the organization; Organization mainly includes organizational structure, organizational scale, system regulations, organizational resources, etc; Environment mainly refers to the industry structure, external pressure, institutional environment, etc. Recently, TOE framework is widely used in QCA analysis because it can help QCA users refine condition variables and construct configuration models from technology, organization and environment.

This study takes MEE as the outcome variable in the context of green technology application in coastal areas. The condition variables selected in this study include: (1) green technology innovation and green technology capability in the technology condition, (2) urbanization and environmental regulation intensity in the organization condition, and (3) peer competition pressure and openness in the environment condition. With the outcome variable and condition variables, we build a configuration model as shown in Fig. 1. The names and abbreviations the variables involved in the model are shown in Table 1.

Table 1
Outcome and Conditions

Measure	Name	Abbreviation
Outcome	Marine Eco-Efficiency	MEE
Conditions	Green Technology Innovation	GTI
	Green Technology Capability	GTC
	Urbanization	URB
	Environmental Regulation Intensity	ERI
	Peer Competitive Pressure	PCP
	Openness	OPEN

Marine Eco-Efficiency. There is no unified definition of MEE in the present. Schaltegger and Sturm (1990) put forward the concept of ecological efficiency and defined it as the ratio of added value to increased environmental impact [20]. World Business Council for Sustainable Development (1995) defined ecological efficiency as meeting human needs and improving the quality of life by creating products and services with price competitive advantages, while controlling its environmental impact and resource utilization intensity within the earth's carrying capacity level [21]. The organization for economic cooperation and development (1998) extended this concept to governments, industrial enterprises and other organizations, and held that ecological efficiency refers to the efficiency of using ecological resources to meet human needs [22]. Although different institutions and scholars have made different definitions of ecological efficiency, they have reached a consensus on the basic connotation, that is, ecological efficiency is "creating more value with less impact" or "obtaining more benefits from less resources" [23–24]. Following this connotation, this study considers that MEE refers to the maximization of economic output and the minimization of environmental pollution with the least consumption of marine resources.

Technology Condition. Green Technology Innovation (GTI) and Green Technology Capability (GTC) are taken as two secondary conditions in the technology condition. (1) The sustainable configuration path of MEE is a concept related to the high-quality development of marine economy, and the driving force of high-quality economic development lies in technological innovation. Thus, from the perspective of sustainable development, to effectively improve MEE needs to rely on GTI [25–26]. (2) It is worth noting that possessing green technologies is different from the effective application of green technology. Technical capability is the ability to use technical knowledge effectively [27]. If technology innovation or technology progress is to have an effect on economic development, it must take the form of products

[28]. From this point of view, if we want to make GTI work effectively on MEE, the GTC to transform GTI into products will be needed.

Organization Condition. Urbanization (URB) and Environmental Regulation Intensity (ERI) are taken as two secondary conditions in the organization condition. Most technology innovations occur and gather in cities [29]. (1) The advantages of cities in specialization and diversity, accumulation of human capital, formation of information exchange network and improvement of transaction efficiency are conducive to technological innovation [30]. Thus, cities have technological advantages and scale effects in improving resource utilization and pollution control. In this case, the higher the URB of coastal areas, the more likely it is to carry out green technology innovation and have higher green technology capacity. (2) Unexpected output is an important part of MEE accounting, which refers to marine environmental pollution. Due to the externality of marine environmental pollution, it is difficult to effectively solve this problem by relying solely on market mechanism, so that environment regulation has become an important means to make up for market failure and solve environmental problems [31]. Environment regulation not only increases the production cost of enterprises, but also forces enterprises to carry out green technology innovation [32–33]. Therefore, the ERI not only reflects the attention of governments in coastal area to the marine environment, but also is closely related to the innovation and application of green technology, which has an important impact on MEE.

Environment Condition. Peer Competition Pressure (PCP) and Openness (OPEN) are taken as two secondary conditions in the environment condition. (1) From the perspective of intergovernmental relations, the competitive pressure between governments at the same level constitutes an important environment condition [34]. Under the institutional background of China, the central government personnel appointment system based on the relative performance appraisal of officials profoundly shapes the behavioral logic of local governments [35]. When facing the pressure brought by superior task (such as the construction of marine ecological civilization), there will be competition between governments at the same level, and the winner will receive additional incentives. Thus, PCP drives the local government to improve the performance on the corresponding task [36]. (2) The openness of a region affects its MEE. Openness may bring technology diffusion effect, promote the flow and matching of green innovation elements, and promote product and technology innovation [37]. However, Openness may also lead to pollution transfer and the emergence of a "pollution paradise" [38].

2.3 Variables and Data Source

2.3.1 Research Area

In this study, 11 coastal areas were selected as research units, including Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi and Hainan. According to the geographical location of each area, Tianjin, Hebei, Liaoning and Shandong are located around the Bohai Sea; Shanghai, Jiangsu and Zhejiang are located in the Yangtze River Delta; Fujian, Guangdong, Guangxi and Hainan are located in the Pan Pearl River Delta. The seas adjacent to the 11 areas are the Bohai Sea, the Yellow Sea, the East China sea and the South China Sea. The correlation between the marine system and the land system is increasing, which makes land-based pollution the main source of marine environmental pollution [39]. Since it is difficult to directly quantify the exhaust gas, non-aqueous and solid waste discharged from land, the existing literature often selects the municipal or provincial administrative region when selecting the research regional unit, because the statistical yearbook of relevant data generally takes the municipal or provincial regional unit as the statistical object [6–12]. Considering that the distinction between different sea areas may not be significant when taking municipal administrative regions as the research unit, 11 coastal provincial administrative regions are selected as the research regional units.

2.3.2 Outcome Variable

The outcome variable of this study is MEE. Our data source for measuring PCP is the annual evaluation of ecological civilization construction jointly initiated by National Bureau of Statistics, the National Development and Reform Commission, the Ministry of Ecology and Environment and the Organization Department of the Central Committee. The evaluation is conducted once every five years, and the most recent data is the "*Bulletin of Results of 2016 Annual Evaluation of Ecological Civilization Construction*". Considering the lag of the impact of land-based conditions on MEE, this study selects the data of the year 2017 to calculate MEE, while the six condition variables are measured with the data of the year 2016.

Referring to the existing research literature [8–9], considering the availability, comparability and operability of data, this study constructs the MEE evaluation index system as shown in Table 2.

Table 2
Measurement indices and Data Source of Marine Eco-Efficiency

Outcome for fsQCA	Indicator Type	First-Level Indicators	Secondary Indicators	Data Source
MEE	Input	Capital	Marine Economic Capital	Statistical Yearbook of China's Marine Economy
		Labor	Marine-related Employment	Statistical Yearbook of China's Marine Economy
		Energy	Electricity Consumption	China Statistical Yearbook
		Environment Protection	Completed investment in industrial pollution control	China Statistical Yearbook
	expected output	Economic Benefit	Gross Ocean Product (GOP)	Statistical Yearbook of China's Marine Economy
		Ecological Benefit	Proportion of class I and class II seawater quality	Bulletin on Environmental Quality of China's Coastal Waters
	unexpected output	Environment Pollution	Waste Gas Emission	China Statistical Yearbook
			Wastewater Discharge	China Statistical Yearbook
			Solid waste Discharge	China Statistical Yearbook

Input indicators include capital, labor, energy and environmental protection inputs. Marine economic capital is selected as the quantitative index of capital investment, marine-related employment as the quantitative index of labor investment, electricity consumption as the quantitative index of energy investment, and industrial pollution control investment as the quantitative index of environmental protection investment.

Expected output indicators include economic benefit and ecological benefit. The GOP is selected as the quantitative index of economic benefit, and the proportion of class I and class II seawater quality is selected as the quantitative index of ecological benefit.

The unexpected output indicator is environment pollution. Waste gas emission, waste water discharge and solid waste discharge are selected as the quantitative indicators of environment pollution.

Except for the data of GOP and seawater quality that are directly related to the ocean and its ecological environment, other data do not clearly distinguish whether they are derived from land or sea. Based on the practice of Ding et al. [9], these data are corrected by using the ratio of GOP / GDP:

marine economic capital = fixed asset investment in coastal areas * GOP / GDP

marine-related employment = employment in coastal areas * GOP / GDP

electricity consumption = electricity consumption in coastal areas * GOP / GDP

completed investment in industrial pollution control = completed investment in industrial pollution control in coastal areas * GOP / GDP

waste gas (wastewater and solid waste) emission = Waste gas (wastewater and solid waste) emission in coastal areas * GOP / GDP

Referring to the methods of dealing with unexpected output in the existing literature, this study uses super SBM-DEA model to calculate MEE, and uses MaxDEA Ultra 8 to process the data. The accounting results are shown in Table 3 and Fig. 2.

Table 3
Accounting results of MEE as Outcome Variable

DMU	Marine Eco-Efficiency
Tianjin	1.071
Hebei	0.454
Liaoning	1.191
Shanghai	1.098
Jiangsu	0.683
Zhejiang	0.397
Fujian	0.611
Shandong	0.331
Guangdong	1.046
Guangxi	1.186
Hainan	1.211

2.3.3 Condition Variables

The quantitative methods and data sources of conditional variables are shown in Table 4.

Table 4
Measurement indices and Data Source of Conditions Variables

Conditions for fsQCA	Indicators	Data Source
GTI	(number of invention patents authorized + number of utility patents authorized) /10,000 persons	China Statistical Yearbook
GTC	Location Entropy	China Statistical Yearbook on High Technology Industry
URB	urban population / total population at the end of the year	China Statistical Yearbook
ERI	completed investment in industrial pollution control / 10,000 persons	China Statistical Yearbook
PCP	ranking of green development index	Bulletin of 2016 annual evaluation results of ecological civilization construction
OPEN	total foreign investment by region / 10,000 persons	China Statistical Yearbook

GTI. Based on the existing research [40], this study uses "(number of invention patents authorized + number of utility patents authorized) / 10,000 persons" to measure GTI. The larger the value is, the higher level of GTI will be.

GTC. The impact of GTI on MEE needs to have the GTC to transform GTI into products, and the degree of high-tech industry agglomeration is the direct embodiment of GTC. The core of high-tech industry is scientific and technological innovation [41]. High-tech industry can improve the utilization rate of resources and energy through technology innovation, thus, it has the characteristics of environment-friendly and resource-saving green industry [42]. As a strategic industry of economic development, high-tech industry has become an important driving force for the country to achieve green development. According to the classification in *China Statistical Yearbook on High Technology Industry*, high-tech industries mainly include six industries: (1) information chemical manufacturing, (2) medical instrument and equipment manufacturing, (3) computer and office equipment manufacturing, (4) electronic and communication equipment manufacturing, (5) aviation, spacecraft and equipment manufacturing, and (6) pharmaceutical manufacturing. The degree of high-tech industrial agglomeration can be calculated by using the method of Location Entropy [43]. If the location entropy is greater than 1, the high-tech industry agglomeration in this region has advantages in the whole country; Otherwise, the region is at a disadvantage. The calculation formula of location entropy is as follow:

$$GTC = HT_{ij} = (q_{ij} / \Sigma q_j) / (q_i / \Sigma q)$$

This study classifies the above six industries into high-tech industries i. HT_{ij} is the national location entropy of industry i in region j, q_{ij} is the output value of industry i in region j, and Q_j is the output value of all industries in region j. Q_i refers to the output value of industry i nationwide, and Q is the output value of all industries nationwide.

URB. This study uses the proportion of urban population in the total population at the end of the year to measure URB of each coastal area.

ERI. This study uses the completed investment of industrial pollution control / 10,000 persons to measure ERI.

PCP. In 2016, the annual evaluation of ecological civilization construction was carried out nationwide in accordance with the requirements of *The Evaluation And Assessment Measures For Ecological Civilization Construction Objectives* issued by the General Office of the CPC Central Committee and the General Office of the State Council, *The Green Development Index System* and *The Evaluation Objective System For Ecological Civilization Construction* issued by the National Development and Reform Commission, the National Bureau of Statistics, the National Development and Reform Commission, the Ministry of Ecology and Environment and the Organization Department of the Central Committee. At the end of 2017, the *Bulletin Of 2016 Annual Evaluation Results Of Ecological Civilization Construction* was issued. We use the ranking of green development index of coastal areas as the measurement index of PCP. The bigger the ranking number of the area is, the higher PCP the area is facing.

OPEN. This study uses the total foreign investment /10,000 persons in different regions to measure OPEN of each coastal area.

According to the measurement method adopted in this study, the data processing results of each conditional variable are shown in Table 5.

Table 5
Data Processing Results of Conditions Variables

Area	GTI	GTC	URB	ERI	PCP	OPEN
Tianjin	23.195	1.095	0.829	66.323	28	4.488
Hebei	3.214	0.292	0.533	33.262	20	0.669
Liaoning	5.081	0.499	0.674	44.279	27	1.839
Shanghai	22.391	1.54	0.879	214.664	4	7.454
Jiangsu	19.85	1.478	0.677	93.485	9	4.869
Zhejiang	26.891	0.6776	0.67	107.669	3	2.825
Fujian	12.721	0.791	0.636	58.407	2	2.984
Shandong	8.593	0.613	0.59	127.08	18	1.31
Guangdong	14.254	2.204	0.692	24.076	13	3.67
Guangxi	2.417	0.704	0.481	26.96	12	0.611
Hainan	1.695	0.734	0.568	17.599	6	0.785

2.4 Data Calibration

In fsQCA method, calibration refers to the process of assigning collective membership to cases [44]. Specifically, researchers need to calibrate variables into sets according to existing theoretical knowledge and case scenarios. The membership degree of the calibrated set will be 0 ~ 1, and the calibration points include “fully in”, “crossover” and “fully out”. Due to the lack of clear theoretical concepts and external standards as the calibration basis for MEE and land-based conditions and, this study calibrates based on case descriptive statistics [14]. Referring to the existing research [45], calibration points in this study are set as the upper quartile, the lower quartile and the mean value of sum of the upper and lower quartiles of the sample data respectively. The calibration points of each variable are shown in Table 6.

Table 6
Calibration for Outcome and Conditions

Outcome and Conditions	Calibration points		
	Fully in	Crossover	Fully out
MEE	1.142	0.837	0.533
GTI	21.121	12.634	4.418
GTC	1.287	0.966	0.645
URB	0.685	0.632	0.579
ERI	100.577	65.344	30.111
PCP	19	12	5
OPEN	0.906	0.601	0.297

This study uses fsQCA3.0 to analyze the data. Since the crossover value of PCP in Guangxi is exactly 0.5 after calibration, according to the "partial subordination" of this crossover value, we adjust 0.5 to 0.501 [45]. Table 7 is the truth table or each variable after calibration.

Table 7
Truth Table

Area	MEE	GTI	GTC	URB	ERI	PCP	OPEN
Tianjin	0.91	0.98	0.77	1	0.52	1	1
Hebei	0.02	0.03	0	0	0.06	0.97	0.01
Liaoning	0.97	0.06	0.01	0.92	0.14	1	0.25
Shanghai	0.93	0.97	1	1	1	0.03	1
Jiangsu	0.18	0.93	0.99	0.93	0.92	0.22	0.99
Zhejiang	0.01	0.99	0.06	0.9	0.97	0.02	0.43
Fujian	0.1	0.51	0.16	0.56	0.36	0.01	0.46
Shandong	0.01	0.19	0.04	0.08	0.99	0.93	0.03
Guangdong	0.89	0.64	1	0.97	0.03	0.61	0.75
Guangxi	0.97	0.03	0.08	0	0.04	0.501	0.01
Hainan	0.98	0.02	0.1	0.03	0.02	0.07	0.07

3. Results

3.1 Necessary Condition Analysis

Before analyzing the configuration, the necessity of each condition needs to be tested separately. Researchers need to analyze the sufficiency of each condition that cannot be used as a necessary condition alone, and identify the configuration with the greatest explanatory power to the target case through "Boolean algebra minimization". The results of necessary condition analysis are shown in Table 8.

Table 8
Results of Necessary Condition Analysis

Conditions	High MEE		Low MEE	
	Consistency	Coverage	Consistency	Coverage
GTI	0.487	0.544	0.575	0.540
~ GTI	0.588	0.621	0.515	0.458
GTC	0.516	0.732	0.280	0.335
~GTC	0.531	0.467	0.775	0.574
URB	0.667	0.623	0.533	0.419
~URB	0.379	0.490	0.523	0.568
ERI	0.335	0.396	0.690	0.687
~ERI	0.735	0.738	0.394	0.333
PCP	0.556	0.619	0.489	0.459
~PCP	0.514	0.544	0.594	0.530
OPEN	0.541	0.646	0.414	0.416
~OPEN	0.511	0.508	0.648	0.543

Note: “~” represents Low in this study. For example, ~ ERI indicates low environmental regulation intensity, while ~ PCP indicates low peer competition pressure.

The necessary condition analysis results of high MEE show that the consistency of each condition is lower than the critical value of 0.9, which indicates that each condition alone cannot constitute the necessary condition to explain the result variable. The necessary condition analysis results of low MEE show that the consistency of each condition is lower than the critical value of 0.9, which indicates that each condition alone cannot constitute the necessary condition to explain their own result variables. The necessary condition analysis results show that the land-based impact on MEE is complex. The land-based technology, organization and environmental conditions need mutual linkage and matching to jointly affect MEE.

3.2 Configuration Analysis

Configuration analysis is the process of exploring whether the set composed of multiple conditions is a subset of the result set. During parameter setting, in order to distinguish whether the configuration passes the consistency of fuzzy set theory, the consistency threshold is set to 0.8 [14]. Considering that the setting of frequency threshold should include at least 75% of observed cases, the case frequency threshold is set to 1 for there are 11 cases in this study [16]. Proportional Reduction in Inconsistency (PRI) can effectively reflect the extent to which a particular truth table row is y rather than ~ y subset, which is suggested to be set to 0.75 [46]. Through the configuration analysis of high MEE and low MEE, their complex solution, parsimonious solution and intermediate solution are obtained respectively. Since the configuration analysis results of fsQCA mainly observe the parsimonious solution and intermediate solution, we use Table 9to show the results.

Table 9
Results of Configuration Analysis

Configurations		**raw coverage**	**unique coverage**	**consistency**
Configuration Solution for High MEE				
Parsimonious Solution	URB*PCP	0.454	0.367	0.928
	~URB*~PCP	0.280	0	0.769
	~GTI*~PCP	0.340	0	0.815
Intermediate Solution	GTI*GTC*URB*PCP*OPEN	0.276	0.265	0.959
	~GTI*~GTC*~URB*~ERI*~PCP*~OPEN	0.259	0.248	0.816
	~GTI*~GTC*URB*~ERI*PCP*~OPEN	0.173	0.124	1
solution coverage: 0.650 solution consistency: 0.902				
Configuration Solution for Low MEE				
Parsimonious Solution	GTI*~GTC	0.368	0.030	0.916
	~GTC*ERI	0.497	0.159	0.906
Intermediate Solution	GTI*~GTC*URB*~PCP*~OPEN	0.235	0.211	1
	~GTI*~GTC*~URB*ERI*PCP*~OPEN	0.195	0.171	0.942
solution coverage: 0.406 solution consistency: 0.971				

In order to better present the results, we adopt the presentation form of QCA analysis results proposed by Ragin and Fiss (2008) [47], which can clearly show the relative importance of various conditions in each configuration. The results are shown in Table 10, in which “●” indicates the present of the core condition, “•” indicates the present of the supplementary condition, “⊗” indicates the absent of the core condition, “⊗” indicates the absent of the supplementary condition, and “blank” indicates that the present or absent of the condition is insignificant for outcome. Since the parameters of each configuration are already shown in Table 9, they are not repeated in Table 10. Table 10. Configurations of High MEE and Low MEE

Table 10. Configurations of High MEE and Low MEE

Conditions	Configurations for High MEE			Configurations for Low MEE	
	H1	H2	H3	L1	L2
GTI	•	⨂	⨂	●	⊗
GIC	•	⊗	⊗	⨂	⨂
URB	●	⨂	●	•	⊗
ERI		⊗	⊗		•
PCP	●	⨂	●	⊗	•
OPEN	•	⊗	⊗	⊗	⊗

3.2.1 Configurations of High MEE

Table 10 presents three configuration paths to explain high MEE. As shown in Table 9, the solution coverage is 0.650, that is, three configuration paths can explain 65% of high MEE cases. The solution consistency is 0.902, that is, 90.2% of all cases meeting the three configuration paths are high MEE.

(1) Configuration H1: path of development based on innovation. Configuration H1 shows that when coastal areas have rich GTI elements and good GTC, under high OPEN environment, strengthening PCP and promoting URB will obtain high MEE. Among them, URB and PCP are core conditions, GTI, GTC and OPEN are supplementary conditions, while ERI is insignificant. As the technology, organization and environment conditions need to be synergized and matched to play a role, we named configuration H1 as “path of development based on innovation”. This path can explain about 27.6% of high MEE cases, of which about 26.5% can only be explained by this path. Typical cases within this path are Tianjin and Guangdong (as shown in Fig. 3).

(2) Configuration H2: path of ecological industry based on unique geographical location. Configuration H2 shows that when the coastal areas have low GTI and GTC in technology condition, low URB and ERI in organization condition, and low PCP and OPEN in environment condition, the region will obtain high MEE. Among them, low GTI, high URB and high PCP are core conditions, and low GTC, low ERI and low OPEN are supplementary conditions. It is worth noting that although the technology, organization and environment conditions are all at a low level, they also need to be synergized and matched to play a role, so that we name configuration H2 as “path of ecological industry based on unique geographical location”. This path can explain about 25.9% of high MEE cases, of which about 24.8% of high MEE cases can only be explained by this path. A typical case within this path is Hainan (as shown in Fig. 4).

(3) Configuration H3: path of development based on political pressure. Configuration H3 shows that when coastal areas lack GTI and GTC in technology, although the ERI and OPEN are at low level, high PCP and URB will help these areas obtain high MEE. Among them, low GTI, high URB and high PCP are core conditions, and low GTC, low ERI and low OPEN are supplementary conditions. Similarly, technology, organization and environment conditions can only work through synergy and matching, so that we name configuration H3 as “path of development based on political pressure”. This path can explain about 17.3% of high MEE cases, of which about 12.4% of high MEE cases can only be explained by this path. The typical case within this path is Liaoning (as shown in Fig. 5).

3.2.2 Configurations of Low MEE

Table 10 presents two configuration paths to explain low MEE. As shown in Table 9, the solution coverage is 0.406, that is, two configuration paths can explain 40.6% of low MEE cases. Solution consistency is 0.971, that is, 97.1% of the coastal areas show low MEE in all cases that meet the two configuration paths.

(1) Configuration L1: path of insufficient technology capability with abundant innovation elements. Configuration L1 shows that when coastal areas lack GTC, even if they have high GTI and URB, these areas obtain low MEE under the environment of low PCP and OPEN. Among them, high GTI and low GTC are core conditions, high URB, low PCP and low OPEN are supplementary conditions, while ERI is insignificant. As the technology, organization and environment conditions need to be synergized and matched to play a role, we name configuration L1 as “path of insufficient technology capability with abundant innovation elements”. This path can explain about 23.5% of low MEE cases, of which about 21.1% of low MEE cases can only be explained by this path. typical cases within this path is Zhejiang and Fujian.

(2) Configuration L2: path of insufficient technology capability with environmental regulation and political pressure. Configuration L2 shows that when coastal areas lack GTI and GTC, and the URB and OPEN are low, even if the ERI and PCP are high, these areas can only obtain low MEE. Among them, low GTC is the core condition, low GTI, URB and OPEN are supplementary conditions, and high ERI and PCP are also supplementary conditions. For configuration L2, low MEE is the result of the synergy and matching among technology, organization and environment conditions. We name Configuration L2 as “path of insufficient technology capability with environmental regulation and political pressure”. This path can explain about 19.5% of low MEE cases, of which about 17.1% of low MEE cases can only be explained by this path. A typical case within this path is Shandong.

3.3 Robustness Test

By increasing the PRI value from 0.75 to 0.8 [44], The robustness of the configuration model is tested (see Table 11). The single consistency and solution consistency of the new model are both higher than 0.9. The high MEE configuration is a perfect subset of the high MEE configuration of the original model (see Table 9). The low MEE configuration is consistent with the low MEE configuration of the original model (see Table 9). The results of new model meet the criteria for the robustness test of fsQCA [44].

Table 11
Results of Robustness Test

Configurations		raw coverage	unique coverage	consistency
Configuration Solution for High MEE				
Parsimonious Solution	URB*PCP	0.454	0.454	0.928
Intermediate Solution	GTI*GTC*URB*PCP*OPEN	0.276	0.265	0.959
	~GTI*~GTC*URB*~ERI*PCP*~OPEN	0.137	0.126	1
solution coverage: 0.402 solution consistency: 0.972				
Configuration Solution for Low MEE				
Parsimonious Solution	GTI*~GTC	0.368	0.030	0.916
	~GTC*ERI	0.497	0.159	0.906
Intermediate Solution	GTI*~GTC*URB*~PCP*~OPEN	0.235	0.211	1
	~GTI*~GTC*~URB*ERI*PCP*~OPEN	0.195	0.171	0.942
solution coverage: 0.406 solution consistency: 0.971				

4. Discussion

4.1 Equivalent Configuration and Asymmetry of Causality

When we use the QCA method to analyze the configuration, the assumption that conditions are inter-dependent and causal relationship between configuration and outcome is complex has been adopted, which is different from the traditional regression analysis method which assumes that variables (conditions) act independently [48]. The configuration analysis based on QCA in this study shows that three configuration paths can achieve high MEE, while two configuration paths will lead to low MEE. This not only shows the equivalent configuration caused by the interdependence among land condition variables, but also reveals the asymmetry of the causal relationship between these condition variables and MEE (as shown in Fig. 6).

In the research from the traditional regression perspective, it is generally to control other conditions unchanged and analyze the unified and symmetrical relationship between a specific variable (such as GTI or ERI) and MEE. For example, high GTI promotes MEE, while low GTI reduces MEE. However, the configuration analysis here shows that different configurations consisted of high GTI (low GTI) and other conditions may produce high or low MEE. For example, the outcomes of configuration H2 and configuration H3 that contain low GTI are both high MEE, while the outcome of configuration L1 that contains high GTI is low MEE. For another example, high GTC in each of the high MEE configuration is a supplementary condition, but low GTC is a core condition in each of the low MEE configuration. The asymmetry of equivalent configuration and causality suggests that we must pay attention to the specific practice of improving MEE, because a unique best path may not exist.

4.2 Green Technology Capability, Urbanization and Marine Ecological Efficiency

This study holds that coastal areas must have sufficient GTC to make GTI GTI have a positive impact on MEE. This point of view has been confirmed in this study. The configuration path in table 10 shows that although high MEE does not necessarily require high GTC (see H2 and H3 in table 10), low MEE is accompanied by low GTC (see L1 and L2 in table 10). This finding is consistent with existing studies, that is, high-tech industrial agglomeration promotes green economic efficiency in corresponding regions [42–43].

This finding has also been empirically verified, which is reflected in the corresponding typical cases explained by different configuration paths. For example, Guangdong is a typical case explained by configuration H1, while Fujian is a typical case explained by configuration L1. In 2016, the GTI of Guangdong and Fujian were 14.25 pieces per 10000 persons and 12.72 pieces per 10000 persons respectively, but the location entropy of high-tech industry in Guangdong and Fujian were 2.20 and 0.79 respectively. There is little difference between Guangdong and Fujian in GTI. As to GTC, however, Guangdong has higher national advantages, while Fujian is at a disadvantage.

In addition, the configuration analysis of this study reflects the asymmetric dependence between GTC and URB. High GTC matching high URB can obtain high MEE (such as configuration H1), but high URB does not have to match high GTC to obtain high MEE (such as configuration H2 and H3). A possible explanation is that high URB is conducive to technological innovation and high-tech industrial agglomeration [49], but the former does not necessarily lead to the latter. For example, the typical case Liaoning explained by configuration H3 is mainly characterized by resource-based cities, of which the location entropy of high-tech industry is just 0.499.

4.3 Peer Competition Pressure and Marine Ecological Efficiency

The results of this study show that PCP is an important conditional variable affecting MEE under the institutional background of China. The concept of Political Tournament was put forward by Chinese scholars based on the institutional analysis of China's political centralization and economic decentralization. It is proved that there is an action logic of local officials competing for promotion in China's political system. For example, Zhou (2005) verified the positive correlation between local officials' promotion and local economic performance through provincial data [50]. Political tournament is the realistic political ecology of China's current local officials' promotion game. In operation, it evaluates officials' political performance during their tenure through explicit indicators (such as the annual evaluation of ecological civilization construction adopted in this study), and the winner will get the opportunity for promotion [51]. Therefore, political tournament is believed to be an important mechanism for local governance in China.

It can be seen from Table 10 that the high PCP generated by the evaluation of ecological civilization construction is the core condition of configuration H1 and H3. In November 2012, the 18th CPC National Congress made the strategic decision of “vigorously promoting the construction of ecological civilization” from a new historical starting point, and comprehensively and deeply discussed all aspects of the construction of ecological civilization. In May 2015, *the opinions of the CPC Central Committee and the State Council on accelerating the construction of ecological civilization* was issued. In October 2015, with the convening of the Fifth Plenary Session of the 18th CPC Central Committee, enhancing the construction of ecological civilization was written into the national five-year plan for the first time.

Marine ecology is an important part of China's ecological civilization construction. As China attaches importance to the construction of ecological civilization at the national level, ecological civilization (including marine ecology) has become a common task faced by local governments at all levels in China. In particular, the release and implementation of the evaluation indicators of ecological civilization construction means that the central government has launched a political tournament around ecological civilization. The winners will be rewarded, and the losers will be punished by losing the opportunity for promotion in this round. Therefore, when local governments (such as Tianjin, Guangdong and Liaoning) rank low in the ecological civilization evaluation in 2016, the officials of these local governments will have the motivation and pressure to improve the ecological civilization evaluation in the coming year. For instance, more attention and political resources will be invested in fields related to ecological civilization (such as marine ecology), which may lead to a better outcome (such as high MEE).

4.4 Other Condition Variables and Marine Ecological Efficiency

Firstly, in received literature, the relationship between ERI and MEE (including green economy and green innovation) has always been controversial. For example, some studies believe that the excessive use of environmental regulation policy tools may have a negative impact on marine environmental pollution control [52]. Some studies believe that strengthening the intensity of marine environmental regulation in coastal areas is conducive to promoting the green total factor productivity of marine economy [53]. Other studies have pointed out that there is an inverted “U” relationship between environmental regulation and green total factor productivity [54]. The results of this study show that the ERI in high MEE configuration is insignificant or low, while the ERI in low MEE configuration is high, which means that whether ERI is valid or not needs to consider its matching with other conditions. If the interdependence between ERI and other conditions is brought into study, the controversy in received literature may continue.

Secondly, by comparing the five configurations, we put forward such a view that if the coastal areas expect to obtain GTC through OPEN, they need to have a certain GTC. The diffusion and transfer of technical knowledge is costly [55]. Only when various elements reflecting technical competence are combined into a purposeful technical activity system that can effectively use technical knowledge in some way, can an industrial organization have technology capability [56]. For the coastal areas in this study, high-tech industry is their green technology activity system. The higher the degree of high-tech industrial agglomeration is, the higher GTC of the areas will be, and more likely can these areas absorb external green technology to improve their MEE (such as configuration H1) through OPEN. Otherwise, OPEN may lead to pollution transfer and “pollution paradise” as a consequence. Therefore, when a costal area does not have high-tech industrial agglomeration, low OPEN could actually lead to high MEE (such as configuration H2 and H3).

Finally, configuration H2 is a special path. It can be seen from Table 10 that each condition variable of configuration H2 is at a low level, but its outcome is high MEE. Why? MEE is not a concept divorced from the development of human society, but an economic concept related to costs and benefits. Although each conditional variable of configuration H2 is at a low level, it does not mean that there is no costs and benefits. Note that the typical case explained by configuration H2 is Hainan. With a tropical monsoon climate and surrounded by the sea (as shown in Fig. 7), Hainan Province is the southernmost provincial administrative region in China.

Compared with other coastal areas in China, the high-tech industry of Hainan Province is poor developed. According to the statistical data of 2016 used in this study, the total industrial output value of Hainan Province is RMB 48.25 billion, which is ranked last in 11 coastal areas (the penultimate place is Tianjin, with a total industrial output value of RMB 680.513 billion). However, Hainan's ecological agriculture and marine ecotourism are well developed. Hainan can use relatively less investment to obtain relatively large expected output and relatively small unexpected output, which leads to the outcome of higher MEE. The pity may be that because the high MEE of Hainan is highly related to its geographical location, this configuration path has little reference significance for other regions.

5. Conclusions

Based on TOE framework and combined with the characteristics of government behavior under the background of Chinese system, this study puts forward an integrated analysis framework to understand the differences of MEE among different coastal areas. Taking 11 coastal areas in China as cases, we apply fsQCA method for configuration analysis, and the findings are as follow:

(1) Conditions derived from Technology, organization and environment cannot alone constitute the necessary conditions for high or low MEE, indicating that a single condition has weak explanatory power on MEE.

(2) There are three configuration paths for high MEE: path of development based on innovation, path of ecological industry based on unique geographical location and path of development based on political

pressure. Among them, path of development based on innovation plays a more important role in improving MEE and has more value on making effective policy.

(3) There are two configuration paths of low MEE: path of insufficient technology capability with abundant innovation elements and path of insufficient technology capability with environmental regulation and political pressure. These two paths imply that the lack of green technology capability is an important conditional variable for low MEE

The synergy of technology, organization and environment reveals the complexity of the relationship between MEE and costal areas, which make it impossible to put forward policy suggestions in detail. Based on their existing conditional endowments, coastal areas can focus on the matching among multiple conditions from an overall perspective, formulate policies according to local conditions, and form a differentiated path to improve MEE. Furthermore, the central government should continue to promote and optimize the evaluation of ecological civilization construction, and guide local governments to carry out orderly competition around the improvement of MEE. Coastal local governments need to improve their GTC and the coordination between GTC and URB.

There are still some limitations in this study, which need to be improved in the future. On the one hand, although the TOE framework used in this paper covers the influencing conditions of technology, organization and environment in the relationship between MEE and costal areas, there are still some omissions because the QCA method is constrained by the number of conditional variables. On the other hand, considering the availability of data, this study does not carry out cross year case data analysis, which limits the interpretation of the research conclusions in the temporal dimension.

Declarations

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Data Availability Statement: The data that support the findings of this study are available from the author upon justifiable request.

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

Informed Consent

We declare that All authors have informed Consent.

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Figures

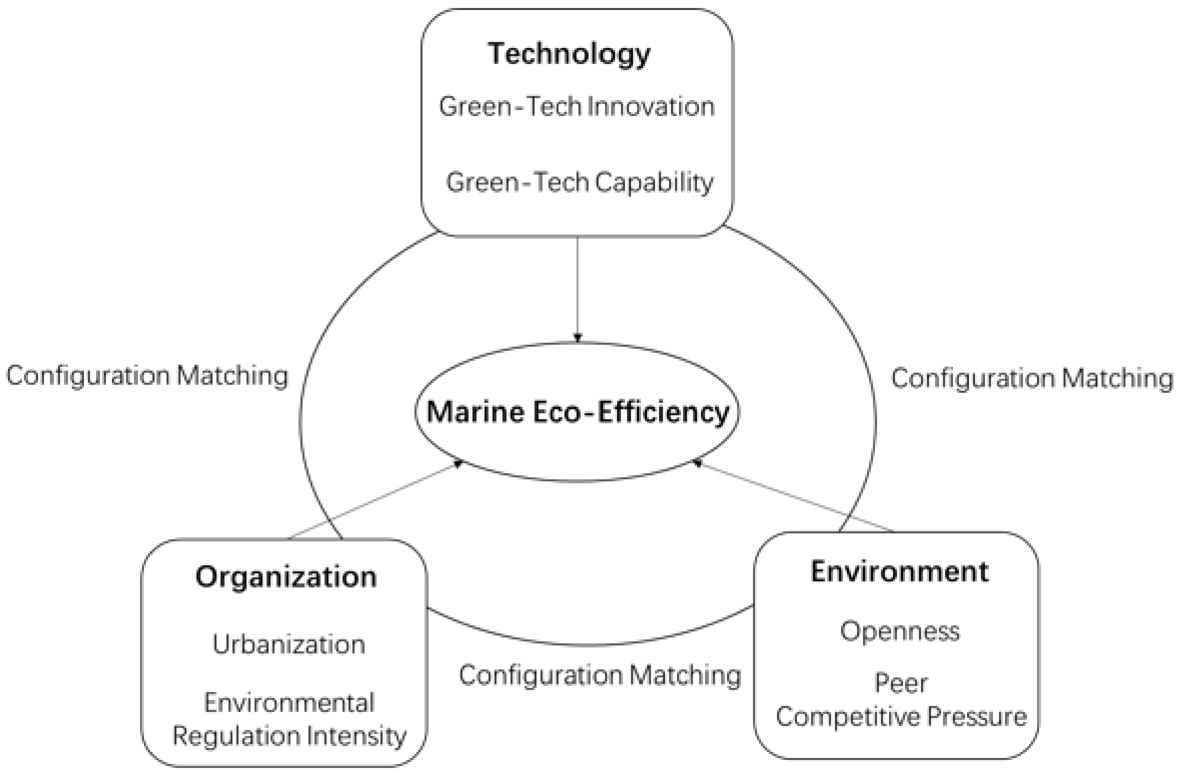

Figure 1

Confidence Model based on TOE

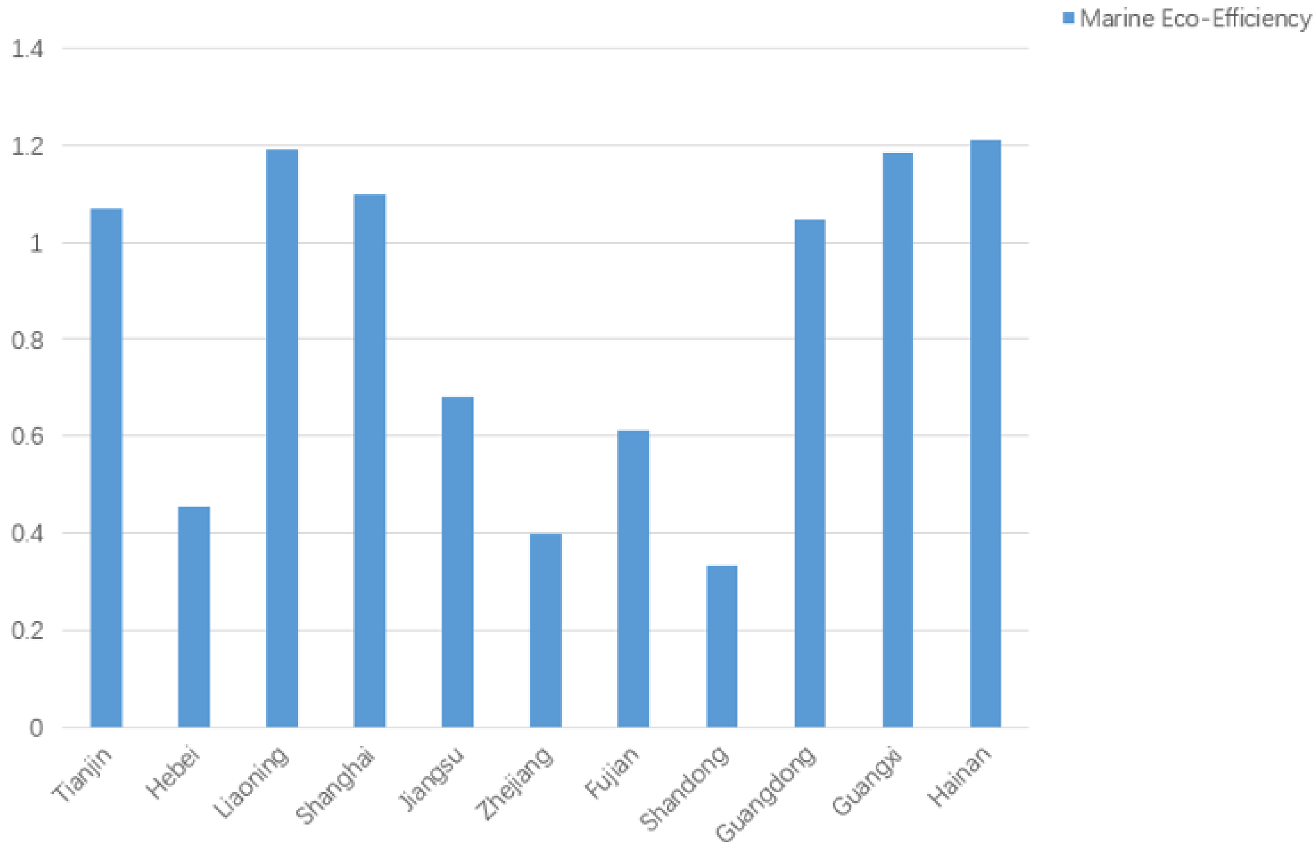

Figure 2

Marine Eco-Efficiency of 11 coastal areas of China

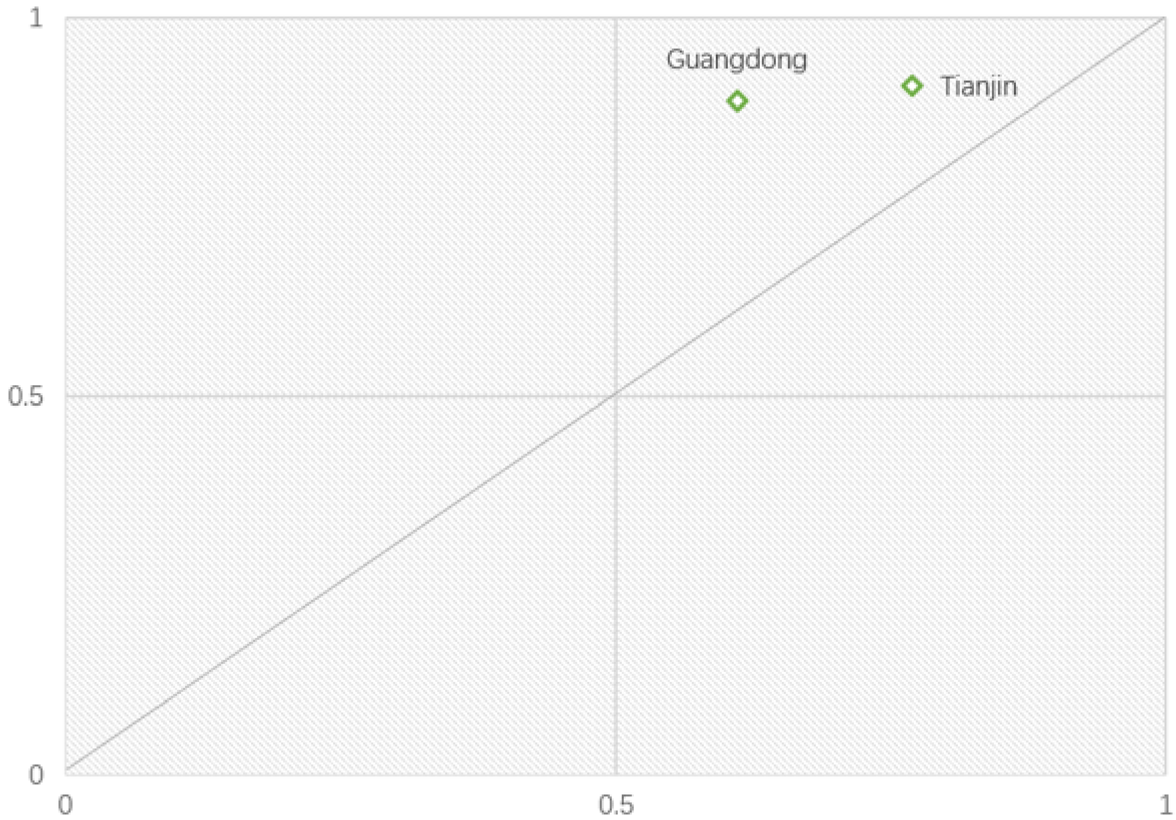

Figure 3

Typical cases within configuration H1

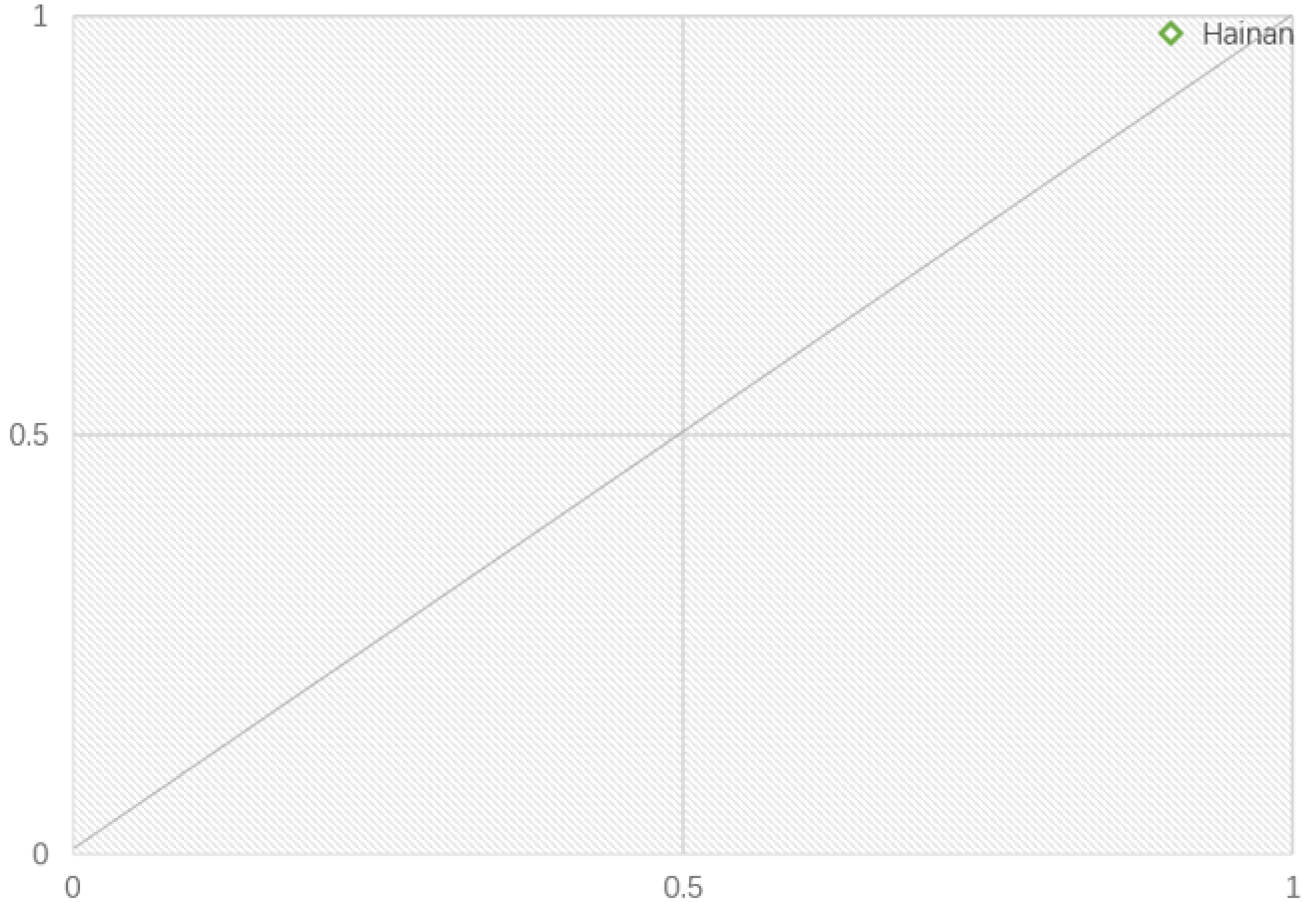

Figure 4

Typical case within configuration H2

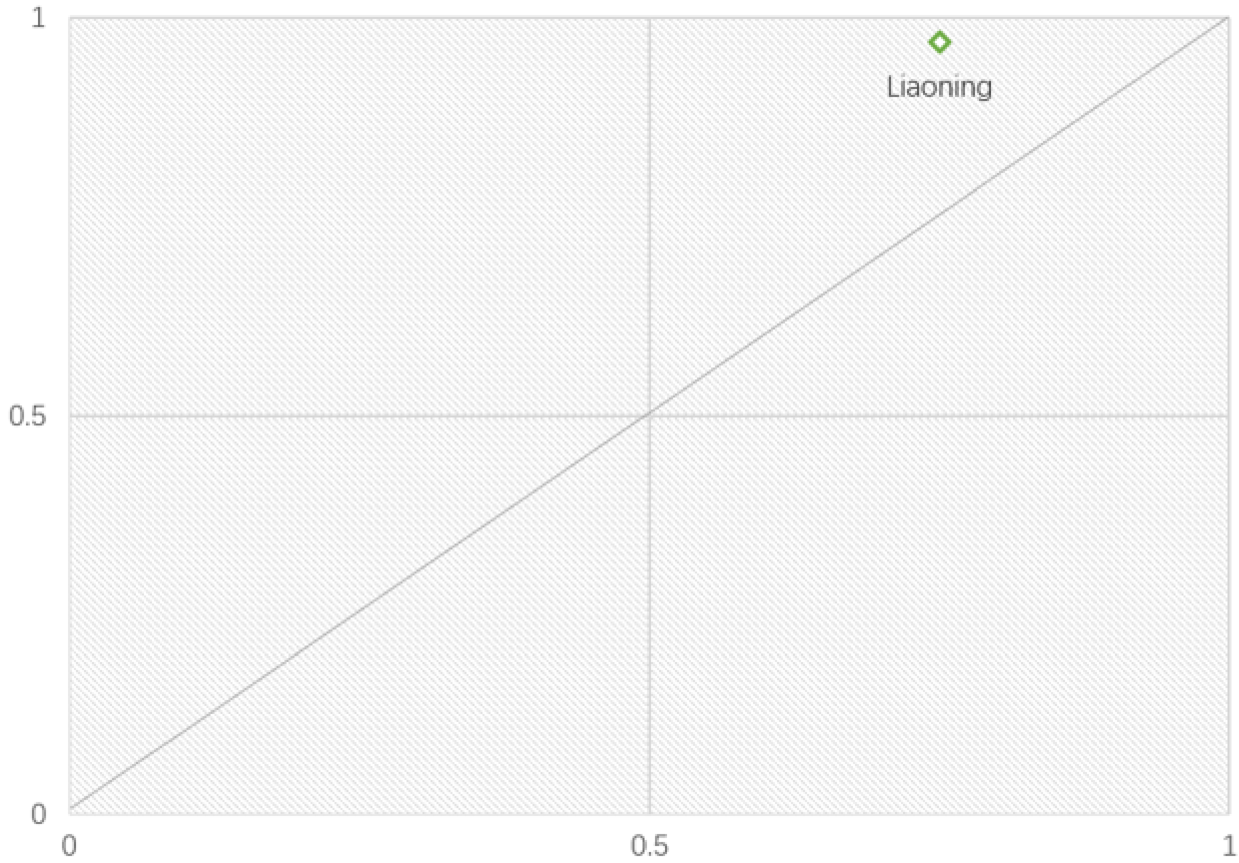

Figure 5

Typical case within configuration H3

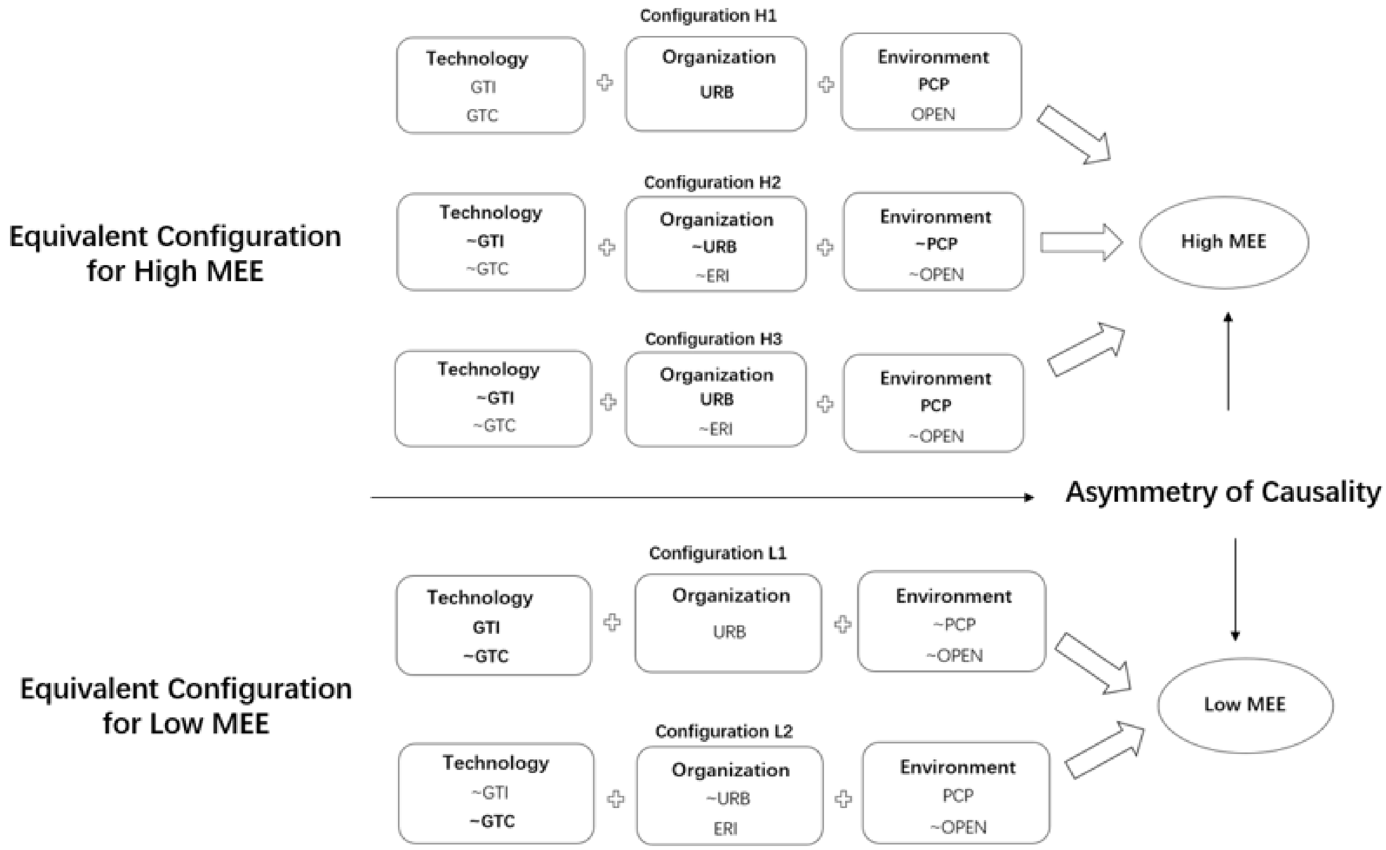

Figure 6

Equivalent Configuration and Asymmetry of Causality

Figure 7

Hainan (pointed by an arrow) and other coastal areas in China