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# Assessment of the effects of integrated coastal zone management based on synthetic control method

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As a policy tool to promote sustainable development of coastal zone cities, Integrated Coastal Zone Management (ICZM) was introduced to China for experimentation in the 1990s. Among them, the Xiamen government took ICZM as an opportunity to conduct a large number of policy pilots, making the evaluation of the policy effects worth studying. This paper takes Xiamen city as the research object based on 180,000 samples from 188 Chinese municipalities from 1980-2017. Based on the theoretical framework of the Social-Economic-Natural Complex Ecosystem (SENCE), we use the synthetic control method (SCM) to conduct its two rounds of policy pilots. The study found that the first round of experiments focused on environmental pollution prevention and control, and the economic development gap between Xiamen and similar coastal zone cities was narrowed despite the economic lag effect. Finally, based on robustness tests, policy recommendations are made for coastal zone cities.

KEYWORDS

**synthetic control method, integrated coastal zone management, assessment, xiamen, China**

## 1 Introduction

As the combination and transition zone between sea and land, the coastal zone is the most active area for human socio-economic production activities, concentrating about two-thirds of the world's population and human wealth, yet facing the dilemma of economic governance of the area under the premise of environmental protection and promotion. On the one hand, the coastal zone possesses unique land and sea characteristics and superior

natural conditions, enabling the concentration of 90% of the world's fisheries resources (Ray, 1991). On the basis of this, the large population is attracted to the coastal zone cities due to export and import convenience, thus enabling the coastal zone areas to achieve a huge economic return of 58,000 USD per hectare per year (Costanza et al., 1998). This economic development has put enormous pressure on the management of coastal zone cities (Lotze, 2005). On the other hand, the fragile and complex ecological environment of the coastal zone and the scarcity of reserve land resources, combined with the development of coastal resources and rapid socio-economic development, making an increasing degree of disturbance and destruction of the coastal zone ecosystem by human activities (Lau, 2005) and the coastal environment vulnerable to threats such as habitat loss, pollution, eutrophication and species loss (Dolan and Walker, 2006). Fortunately, the international community has recognized that most coastal zones face serious environmental and socioeconomic conflicts.

ICZM has been the subject of many international conferences since Agenda 21 of 1992, which proposed "the conservation and rational development and use of marine and coastal resources". Scholars agree that ICZM is the most appropriate way to deal with the complex problems of environmental pollution and ecosystem degradation in coastal cities. It refers to a policy tool to achieve sustainable development through a series of institutional reforms (Christie, 2005), policy and regulatory development in order to realize the economic development of coastal cities, maintain the health of ecosystems, and reconcile human and environmental conflicts. ICZM is a continuous and dynamic process to control the impact of human activities on the coastal zone environment (Biliana and Cicin-Sain, 1993), and has been proven to have stable and long-lasting benefits in many developed countries (Gu and Wong, 2008). As one of the most important policy tools for solving a range of political, ecological, and economic problems in coastal zones (Biliana and Cicin-Sain, 1993), ICZM has been widely active in coastal zone management around the world, with typical examples being the 100% integrated management of coastal zones in the United States, Canada, and Mexico.

However, Le Gentil and Mongruel (2015) pointed out that most of the current research on ICZM pilots had focused on high-income countries rather than middle-income countries, mainly developing countries. In fact, developing countries are currently facing more common coastal zone management problems due to population growth and urbanization than developed countries. This is because of "their (developing countries') low physical and financial capacity to withstand economic shocks, their disproportionate dependence on climate-sensitive sectors, and the inherently low capacity of developing country governments to provide social safety nets or invest in basic infrastructure aimed at disaster preparedness and relief" (Ward and Shively, 2012, p. 916). Meanwhile, Lau (2005) points out that developing countries are more inclined to economic development than environmental protection, causing a huge volume of wasteful resources and environmental pollution problems. However, these are precisely the issues can be initially addressed with ICZM practices and finally "promotes linkages and harmonization between sectoral coastal and ocean activities" (Cicin-Sain and Knecht, 1995, p. 41). Therefore, it is reasonable to focus on the world's largest developing country, China.

China, with 18,000km of mainland coastline and nearly over 60% of its urban population in the coastal zone (Gu and Wong, 2008), has a total marine economy that accounts for over 10% of total GDP. In the pursuit of combining economic and environmental benefits, China introduced pilot ICZM policies in the 1990s, which were launched in Yangjiang City, Guangdong Province, Fangchenggang City, Guangxi District, Xiamen City, Fujian Province, Wenchang City, Hainan Province, and some cities in Bohai Bay, respectively, as an attempt to manage the coastline belonging to China. Therefore, China is used as a research sample to further study the practical effects of its ICZM pilot projects, so as to provide good experiences for many other countries of the same type.

For a long time, scholars have achieved a consensus that ICZM can promote sustainable economic and ecological development of coastal zone cities and have strongly recognized the enhancement effect of ICZM on Xiamen City, China (Lau, 2005). In addition, international studies on the assessment of the effects of ICZM have mainly focused on the field of socio-economic assessments (Le Gentil and Mongruel, 2015). However, the quantitative aspects are relatively under-researched, and there are two main obstacles. First, the interference of multiple policies makes it difficult to obtain scientific and rigorous conclusions when other policies are mixed with ICZM policies (Tian et al., 2018). Second, the lack of evaluation methods can quantify the effects of policies (Le Gentil and Mongruel, 2015).

What role will the introduction of ICZM pilots in developing countries have on coastal zone cities? To specifically measure this issue, this paper used SCM to deal with panel data of 188 Chinese cities from 1980-2017, which is an attempt to use policy evaluation models in the study of China's coastline management. On the one hand, it helps to quantitatively compare the different effects of the two rounds of policy reforms in Xiamen city, analyzes the real utility of ICZM on it, and breaks the previous literature's obsession with using the cost-benefit approach or DPSI. On the other hand, it helps Xiamen and similar cities to absorb the experience of policy reform, pursue sustainable development, and improve the ICZM optimization mechanism.

The rest of the paper is structured as follows. Section 2 clarifies previous studies. Section 3 reports on the research design including research background, theory basis, sample and variables, model construction. Section 4 presents empirical results. Section 5 is the discussion and policy recommendation section. Section 6 reports the main conclusions.

## 2 Literature review

As an important research area in ICZM (Bowen and Riley, 2003; Ban et al., 2009), Socio-economic assessments have a relatively small number of publications but a relatively focused research approach, as shown in Table 1. As stated by Le Gentil and Mongruel (2015), socio-economic assessments can play an important role in the practical implementation of ICZM by assessing the management process and being able to take into account ICZM stakeholders.

In the literature using surveys, the topics assessed include vulnerability studies (Milena Marília Nogueira Lloret et al., 2008; de Andrade et al., 2010), decision support tools (Sardá et al., 2005), rather than providing an evaluation of the effects of ICZM.

In terms of economic evaluation, monetary valuation is an important direction. For example, Samonte-Tan et al. (2007) obtained annual revenues attributed to ecosystems: coral reefs, US$1.26 million; beach/intertidal area, US$1.5 million. Another important direction is the use of cost-benefit analysis (CBA) or cost-effectiveness analysis (CEA) for valuation. Unlike monetary valuation, these scholars focus more on the costs and benefits of ICZM projects to predict project feasibility. For example, Turner et al. (2007) and Peng et al. (2006) used cost-benefit analysis and thus evaluated the economic benefits of multiple scenarios. While CBA and CEA are effective in providing an ex-ante reference for decision-makers, they do not include any empirical measurement of the overall benefits of ICZM projects or allow for a definitive calculation of the contribution of ICZM projects to the city.

Both spatial data analysis and trends analysis rely on a large amount of data to support their research. The former focuses on the spatio-temporal dimension to understand the spatio-temporal dynamics of coastal activities, the coastal environment, and the impact (or potential impact) of management decisions, while the latter revolves more around temporal trends. Typical examples include Brenner et al. (2010) who calculated the value of ecosystem services in the coastal zone of Catalonia, Spain is $3,195 million USD/yr. However, both types of studies and scenario analysis (Ledoux et al., 2005; Tompkins et al., 2008; Mongruel et al., 2011), and indicator analysis (Smith et al., 2007; Mangi et al., 2007; Roca et al., 2008; Yoo et al., 2011), are unable to conclusively point out that assessing effects is not related to policies other than ICZM policies, making it difficult to strip the actual effects of ICZM (Tian et al., 2018).

In summary, although scholars have recognized that one indicator for assessing the success of ICM programs is their socioeconomic benefits. However, most of the literature, similar to Peng et al. (2006), treats it as a short-term governance project and thus measures its costs and benefits. Therefore, the long-term sustainability requirements of ICZM have been neglected. Therefore, it can be argued that if the long-term effects of ICZM are further considered, the effects of other factors need to be further stripped away.

## 3 Research design

### 3.1 Research background

At the end of the 1990s, China started the practice of ICZM in the form of joining the GEF (Global Environmental Fund)/UNPD (United Nations Population Division)/IMO (International Maritime Organization) (GEF et al., 1996). Then Chinese marine governance began with the implementation of the ICZM East Asian Regional Programme for Marine Pollution Prevention and Control (Kong et al., 2015).

In terms of practical action, China introduced the ICZM experiment in 1994 (Lau, 2005). China first established the ICZM in Xiamen and participated in the "Xiamen Program for the Prevention and Management of Marine Pollution in East Asian Seas" from 1994 to 1998 with the support of the Global Environment Facility, the United Nations Development Program, and the International Maritime Organization (Office USGA, 2011). Based on this, the second round of Xiamen ICZM (Zhou and Yi, 2006) was launched from July 2001 to 2006, with the aim of marine ecological conservation.

Xiamen, located in the south of Fujian Province, China, on the west side of the Taiwan Strait, is an important foreign trade port in China. Besides, Xiamen has a sea area of 390 square

TABLE 1 Literature on Socio-economic Assessments.

| Frequency Ranking | Type | Examples |
|---|---|---|
| 1 | Survey | Morgan (1999), Sardá et al. (2005); Lloret et al. (2008); Milena Marília Nogueira de Andrade et al. (2010) |
| 2 | Monetary valuation | Samonte-Tan et al. (2007) |
| 3 | Spatial data analysis | Brenner et al. (2010) |
| 4 | Trends analysis | Carneiro (2011) |
| 5 | Scenario, prospective | Ledoux et al. (2005); Tompkins et al. (2008); Mongruel et al. (2011) |
| 6 | Indicators system | Smith et al. (2007); Mangi et al. (2007); Yoo et al. (2011) |
| 7 | CBA or CEA | Turner et al. (2007) |
| 8 | Multi-criteria analysis | Roca et al. (2008) |

kilometers, a sea area of 390 square kilometers, a total coastline of 234 kilometers, and 31 islands of various sizes. According to statistics, the fishery output value of Xiamen has grown rapidly from 24.99 million yuan in 1980 to 804 million yuan in 2018.

Lau (2005) has generally held a positive attitude toward the process of ICZM in Xiamen, arguing that its two rounds of policy focus differed. ICZM mainly acts on various aspects of coastal zone protection and economic development through policies, so we compiled the laws, regulations, and policy provisions during the two rounds of experiments in Xiamen (Table 2).

In the first round of experiments, Xiamen focused its remediation and management on environmental remediation, such as refining the sewage system, lake management system, and animal protection system. One of the main drawbacks is the failure to recognize the function of the sea area and the weak concept of economic benefits and marine awareness, which is reflected in the failure to regulate the taking of sea resources. With the continuous promotion of the ICZM, Xiamen has gradually paid attention to the paid use of resources, introduced the paid use system and the right to use system, and promoted the economization of resources. In addition, the city also included ports and islands in the jurisdiction of ICZM, which realized the integrated development of sea and land while creating a dual management model of regional and ecosystem. Therefore, Xiamen's first round of ICZM is mainly focused on the prevention and control of pollution in the waters. Although there is the drawback of neglecting the economic awareness of the sea, the initial completion of the institutional basis on ecological protection.

Differently, the second round of the ICZM has gradually developed toward the ecological conservation function of the ocean. It incorporates the paid-use system and guarantees the integrated development of sea and land.

In this policy context, considering that the ultimate goal of ICZM is to achieve sustainable urban development, this paper introduces the existing theoretical model, with GDP as the central variable, to test whether this policy pilot project promotes green economic development in Xiamen while reversing the environmental improvement of the city's coastal zone.

## 3.2 Theoretical basis

Ma and Wang (1984) proposed the theory of Social-Economic-Natural Complex Ecosystem (SENCE). Wang et al. (2011), and Deng et al. (2011) applied the theory. The theory considers that the world consists of three systems of different nature: social, economic, and natural. Among them, the economic subsystem includes production, supply, consumption, etc … The natural subsystem includes organisms, resources, media, etc … The social subsystem includes policy and decree, science and technology education, ideology and culture, and organization and management. The three are connected with each other and constrained by the other systems, together forming a whole ecosystem. Besides, Ma and Wang (1984) believe that the most active factor in SENCE is humans. Human beings and their activities have the main influence in making up this system (Ma and Wang, 1984).

In this theoretical framework, the interaction mechanism of the coastal zone complex ecosystem is shown in Figure 1.

For coastal zone cities, the proactive policy response (ICZM): first, can optimize the circulation in the economic system and reduce environmental stress by reversing the disorder in the social and economic drivers, e.g., by introducing a property rights system to order the exploitation of resources. Secondly, ICZM can improve social conditions and

TABLE 2 Laws and regulations on ICZM in Xiamen.

| No. | Year | Policy document | Policy effect |
|---|---|---|---|
| 1 | 1996 | Xiamen City Marine Environment Protection Regulations | Refining discharge regulations |
| 2 | 1996 | Xiamen Yundang Lake Management Measures | Ensuring the flood storage and prevention function of Yuandang Lake, and giving comprehensive benefits |
| 3 | 1996 | Xiamen City shallow beach aquaculture management regulations | Refining the regulations on large-scale aquaculture to protect the ecological environment of fisheries |
| 4 | 1997 | Xiamen City Egret Nature Reserve Management Measures", "Xiamen City Chinese White Dolphin Management Regulations", "Xiamen City Amphioxus Nature Reserve Management Measures | Protecting species diversity, achieving harmonious development of human and nature, and protecting tourism resources |
| 5 | 2000 | Xiamen Port Management Regulations | Implementing the development strategy of "establishing the city by the port |
| 6 | 2003 | Xiamen City Sea Use Management Regulations | Providing for the right to use the sea and the system of paid use |
| 7 | 2004 | Measures for the Protection and Utilization of Uninhabited Islands in Xiamen | Comprehensively protecting and strictly limiting the use of island resources, and reduce the disorderly management of islands |
| 8 | 2005 | Xiamen City Maritime Joint Law Enforcement Work System | Strengthening the comprehensive management of sea area, protecting marine resources and environment, and implementing the strategy of bay-type city |

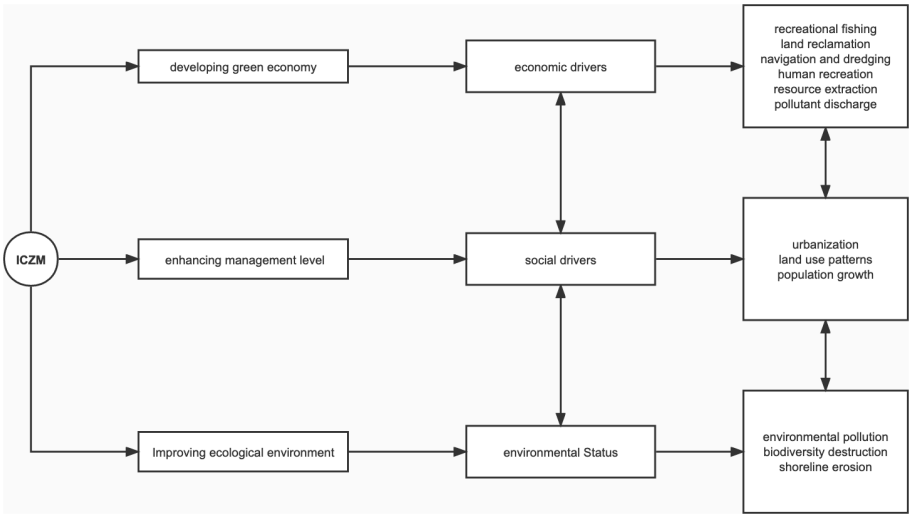


FIGURE 1
Interaction mechanisms of coastal zone complex ecosystems.

reduce environmental damage from the perspective of controlling rapid population growth and improving land use through certain policy instruments. Finally, ICZM can improve the functional impact of the ecosystem and optimize its cycle, and finally achieve sustainable development of ICZM.

Therefore, this paper argues that the impact of ICZM on cities is mainly focused on three main dimensions: economic, social, and environmental, with the ultimate goal of achieving green economic development in the coastal zone.

## 3.3 Sample and variables

In this paper, we collected preliminary data from sources such as the China City Statistical Yearbook and the China Urban Construction Statistical Yearbook for the corresponding years. Also, considering that ICZM experiments have also been conducted in several cities in China, we excluded these cities that have also implemented ICZM. Finally, panel data for 188 Chinese cities from 1980-2017 were collected. The detailed sample city map is shown in Figure 2.

The purpose of this paper is to evaluate the effect of ICZM on Xiamen city and consider that the ultimate goal of ICZM implementation is to promote sustainable growth of the national economy. Therefore, this paper firstly selects GDP as the outcome variable of the model in an attempt to explore the actual effect of ICZM policies on creating green GDP.

In addition, referring to Figure 1 and previous scholars' studies, this paper selected (1) population density, reflecting the scale of urban population; (2) added value of primary, secondary and tertiary industries, reflecting the level and structure of economic growth; (3) fixed asset investment amount, reflecting the degree of economic development; (4) international tourism foreign exchange income, reflecting the degree of opening to the outside world; (4) industrial wastewater discharge, reflecting the perimeter discharge pollution and (5) seafood and aquatic products output, reflecting the degree of dependence on the water. Thus, the assessment model shown in Figure 3 was developed. Besides, the distribution of the total sample data can be found in Table 3.

## 3.4 Model construction

In this paper, we refer to the SCM proposed by Abadie (2003; 2010) so as to simulate a synthetic group as much as possible by weighted averaging. This synthetic group needs to be similar to Xiamen before ICZM in terms of predictor variables. Naturally, we calculate the policy effect by calculating the difference between the outcome variables of the synthetic group and the policy implementation group (Xiamen City).

Therefore, this paper assumes that there is a total of $(1+J)$ regions, where the first region (i.e., Xiamen City) is subject to policy intervention while the remaining $J$ regions are not subject to shocks. Assume that $y_{it}$ is the actual observed outcome variable for region $i$ in period $t$, where $i = 1,2,3,\ldots, J+1$, and $t = 1,2,3,\ldots,T$. Suppose $y_{it}^{N}$ is the GDP of region $i$ in period $t$ if it were not subject to policy intervention ($N$ denotes not subject to intervention).

Assuming that $T_0$ is the number of periods before the start of the policy intervention (non-zero), then $1 \le T_0 < T$. Letting $y_{it}^{I}$ be the GDP situation of region $i$ in period $t$ ($I$ denotes subject to policy

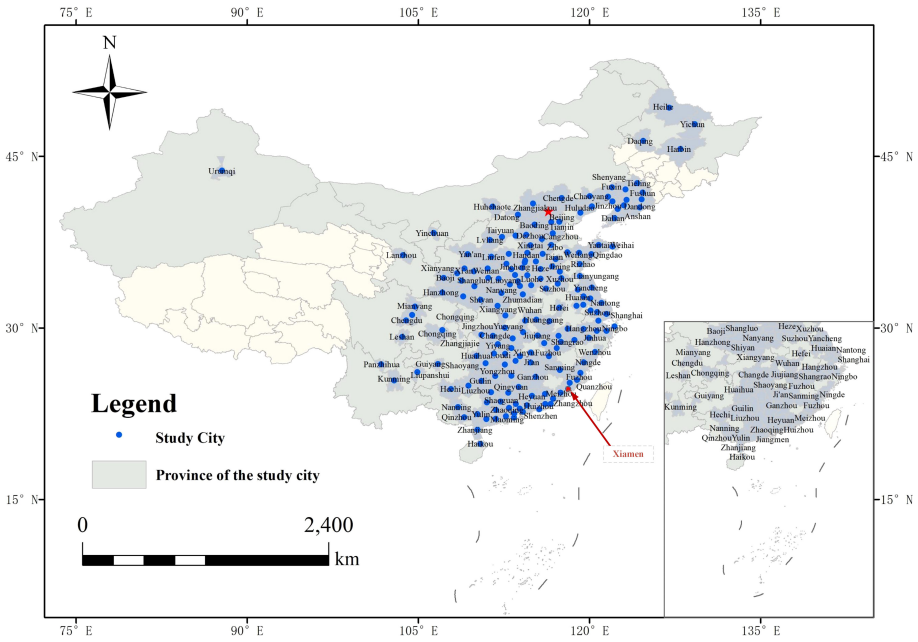


FIGURE 2
Sample city map.

intervention), we have region ***i*** subject to policy intervention continuously from period ($T_0$+1) to period ***T***. Assume that the policy has no effect on the outcome variable in the first $T_0$ periods, then $y_{it} = y_{it}^N = y_{it}^I$ holds for all ***i*** and $\mathbf{t} \leq T_0$, respectively.

Hypothesis goes like $y_{it} = y_{it}^N + D_{it}\,\partial_{it}$, representing the change in GDP of the city in the absence of ICZM, where $D_{it}$ is a dummy variable for whether area ***i*** is subject to policy intervention in period ***t***. Thus, the prediction focuses on $\partial_{it}$ .

From there, Abadie and Gardeazabal (2003) introduces a factor model to construct the following counterfactual framework: $y_{it}^N = \alpha_t + \beta_t Z_i + \lambda_t \mu_i + \epsilon_{it}$, where $\alpha_t$ is the time fixed effect, $Z_i$ is the control variable, $\lambda_t$ denotes the common

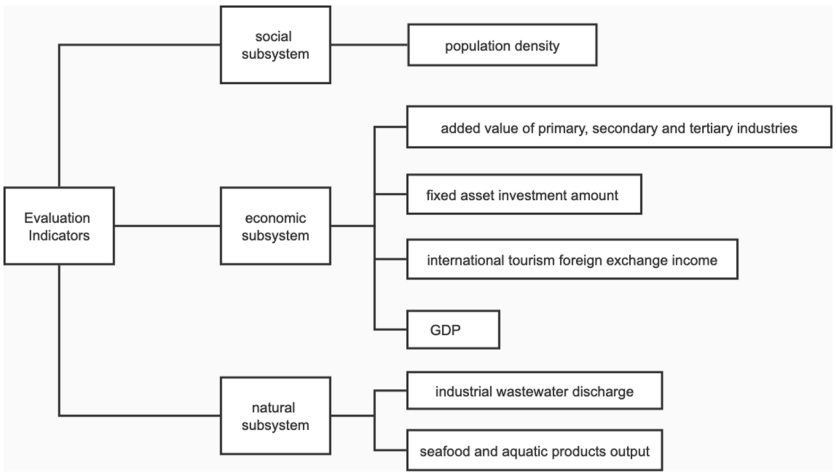


FIGURE 3
Model indicators for assessing the effects of ICZM.

TABLE 3 Distribution of the total sample data.

| | GDP (Billion RMB) | Primary industry added value (Billion RMB) | Value added of secondary industry (Billion RMB) | Value added of tertiary industry (Billion RMB) | Population density (million people/ Square kilometres) | Fish production (million RMB) | Investment in fixed assets (million RMB) | Industrial wastewater discharge (million tons) | Foreign exchange earnings from international tourism (million dollars) |
|---|---|---|---|---|---|---|---|---|---|
| Average | 1206.99283 | 252.95715 | 605.407197 | 576.476446 | 68959.5656 | 790549.4612 | 180967.838 | 229228.015 | 19274.5638 |
| Maximum | 413239 | 394111 | 368273 | 418594 | 3300000 | 1700000000 | 46000000 | 260000000 | 726139 |
| Minimum | 2.0498 | 0.1143 | 0.4089 | 0.0156 | 8.65465 | 1 | 0.3 | 0.23897 | 0.38 |
| Standard Deviation | 7143.79699 | 6215.13926 | 5767.60263 | 5995.86092 | 185125.956 | 24472616.04 | 678773.255 | 5257626.95 | 63624.5728 |

factor, $\mu_i$ is the fixed effect error and $\epsilon_{it}$ is the unobserved temporary shock.

After Abadie's (2003) projection, if we can find $\boldsymbol{w}$ such that

$$z_1 \approx \sum_{j=2}^{j+1} w_j z_j, ||y_{1t} \approx \sum_{j=2}^{j+1} w_j y_{jt} (1 \le t \le T_0) \quad \text{is valid,}$$

then the effect of policy implementation in the Xiamen area is $\partial_{1t} = y_{it} - \sum_{j=2}^{j+1} w_j \star y_{jt}$.

# 4 Empirical results

## 4.1 Impact assessment

Two groups of city combinations constituting the synthetic Xiamen city were obtained separately by the synthetic control method (Table 4). It can be found that although the synthetic groups and their weights are different in the two rounds of experiments, the synthetic cities are all cities that have not implemented ICZM, including ten cities namely Beijing, Shenzhen, Shaoguan, Zhangjiajie, Zhuhai, Tongchuan, Guangzhou, Urumqi, Shanghai, Daqing.

Among them, it is worth adding that Zhuhai is the city with the largest weight in the synthetic group in both rounds with the explaination of about 48% when fitting Xiamen, indicating a high similarity between the two cities. This is because both Xiamen and Zhuhai are coastal zone cities and thus have similar economic characteristics, such as rich tourism resources, reasonable economic structure, and high foreign investment attractiveness, thus allowing Zhuhai to better fit Xiamen and account for a larger weight, and subsequent robustness tests will be conducted accordingly.

Table 5 shows the fitting of control variables for the synthetic Xiamen city before each round of experiments. It can be seen the absolute value of the difference rate between the two on each variable is less than 20% except for population density. Besides, the indicators and variables are well simulated between the factual and synthetic groups, indicating the gap between the synthetic Xiamen and Xiamen city is small when controlling for economic structure, fixed investment, tourism foreign exchange income, and environmental indicators.

Figures 4A, B show the GDP development and gap between Xiamen city and synthetic Xiamen after the first and second rounds of experiments. In Figure 3, before the implementation of the first round of ICZM, the GDP profiles of the synthetic group and Xiamen city were almost exactly overlapping, again verifying that the synthetic group fits the factual group better. Subsequently, during the first round of experiments, i.e., between 1994 and 1997, the two slowly began to diverge and the difference was not large. After the completion of the first round of experiments, the gap between the two began to gradually expand but was always kept within 100 billion yuan.

In Figure 4B, a gap has existed between the synthetic Xiamen and Xiamen city before the implementation of the second round of ICZM before the year of 2000. We think it is reasonable because of the gap between Xiamen and the synthetic group due to the implementation of the first round. Subsequently, it can be observed that, as in the image trend of Figure 4, a gap gradually appears. Besides, the GDP trend of Xiamen city always stays above the control group because it has implemented two rounds of ICZM.

Figure 4C further reports the development gap between the synthetic Xiamen city and Xiamen city. Before the implementation

TABLE 4 City weights of synthetic Xiamen.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **First Round** | **City** | Beijing | Shenzhen | Shaoguan | Zhangjiajie | Zhuhai | Tongchuan | Guangzhou | Urumqi |
| | **Weights** | 0.009 | 0.116 | 0.001 | 0.298 | 0.485 | 0.015 | 0.006 | 0.067 |
| **Second Round** | **City** | Beijing | Shenzhen | Shaoguan | Zhangjiajie | Zhuhai | Shanghai | Daqing | |
| | **Weights** | 0.011 | 0.109 | 0.001 | 0.371 | 0.487 | 0.006 | 0.015 | |

TABLE 5 The fitting of control variables.

| Variables | First Round | | | Second Round | | |
|---|---|---|---|---|---|---|
| Group | Treated (Xiamen) | Synthetic Control Group | Difference Rate | Treated (Xiamen) | Synthetic Control Group | Difference Rate |
| Primary industry added value | 4.2 | 4.1 | -2.38% | 9.2 | 7.6 | -17.39% |
| Value added of secondary industry | 18.1 | 17.9 | -1.10% | 69.7 | 68.5 | -1.72% |
| Value added of tertiary industry | 17.2 | 17.1 | -0.58% | 63.7 | 62.7 | -1.57% |
| Fish production | 100376.2 | 100156.3 | -0.22% | 100376.2 | 100681.9 | 0.30% |
| Population density | 963.6 | 1406.2 | 45.93% | 963.6 | 1627.4 | 68.89% |
| Industrial wastewater discharge | 12794.3 | 11048.7 | -13.64% | 12794.3 | 10971.5 | -14.25% |
| Investment in fixed assets | 651.1 | 650.1 | -0.15% | 651.1 | 651.5 | 0.06% |
| Foreign exchange earnings from international tourism | 77641.5 | 77683.1+N1:P10 | 0.05% | 77641.5 | 77706.8 | 0.08% |

of ICZM, the development between the two groups of cities remained almost gapless for a long time. Secondly, after 1994, i.e., since the beginning of the implementation of ICZM, the gap between the synthetic group and the Xiamen group gradually expanded to a positive level of about 20 billion yuan, and the gap between the two stabilized by about 2000. After that, the gap between the two began to widen again after the second round of experiments on ICZM began to be implemented in 2001, and gradually approached 100 billion yuan with the discovery of time, showing an increasing trend year by year.

We believe this is because, after the first round of ICZM, Xiamen basically completed the initial construction of the concept and institutions, and made initial progress in legislation and law enforcement, thus promoting the horizontal development of GDP and widening the gap between them and similar cities. Then, the second round of experiments continued to raise issues related to regional and ecosystem management, environmental remediation, and regional planning on the basis of the completion of the first round of experiments, overcoming the bottleneck period of development after the first round of experiments, sustainably widening the gap of economic development between the city and similar coastal zone cities, and achieving accelerated surpassing.

It is worth pointing out that, in line with the essential purpose of ICZM, the GDP development gap in Xiamen after the implementation of two rounds of experiments is a sustainable development curve, indicating that the experiments on ICZM in Xiamen not only did not fall into the trap of economic development premised on environmental destruction but also improved the sustainable economic development of coastal zone cities while protecting the regional environment.

## 4.2 Robustness tests

In total, we conducted three types of robustness checks to validate our results. First, we considered the similar coastal zone city of Zhuhai, referring to Roesel (2017), and assumed that Zhuhai was also affected by the ICZM as Xiamen and observed whether the curve separation also occurred in Zhuhai.

Figure 5A shows the difference between the GDP of Zhuhai and synthetic Zhuhai. It can be found that the curves of synthetic

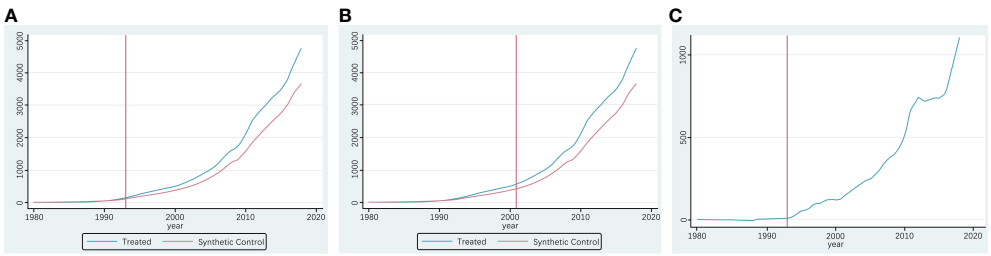


FIGURE 4
Difference in GDP between Xiamen and synthetic Xiamen after two rounds of experiments. **(A)** GDP of Xiamen city and synthetic Xiamen city after the first round of experiment. **(B)** GDP of Xiamen city and synthetic Xiamen city after the second experiment. **(C)**: GDP of Xiamen city and synthetic Xiamen city after the second experiment.

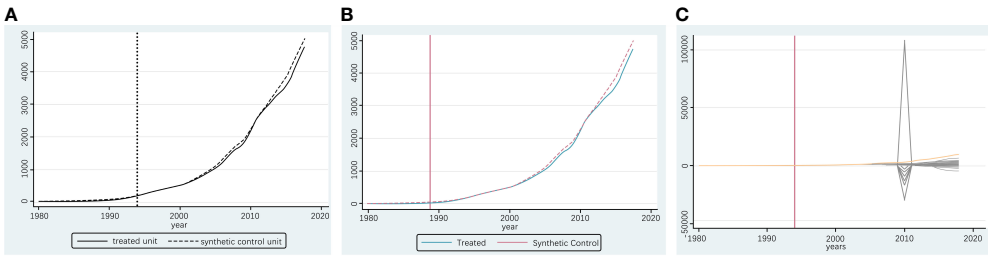


FIGURE 5
Ranking test results. **(A)** Difference in GDP between Zhuhai City and Synthetic Zhuhai City. **(B)** Difference in GDP between Xiamen and synthetic Xiamen. **(C)** Ranking test results.

Zhuhai and Zhuhai itself overlap well before the policy implementation, indicating that the situation of Zhuhai before the policy shock can be simulated better by synthetic Zhuhai. However, differing from Xiamen, there is no separation of curves between Zhuhai city and synthetic Zhuhai city. This indicates Zhuhai and synthetic Zhuhai have always maintained consistent economic growth, independent of the effect of receiving policy shocks. Thereby, Zhuhai, which is the most similar to Xiamen city, passes the placebo test. So it cannot be denied that there is some relationship between GDP growth and ICZM in Xiamen city.

Second, following Abadie (2021) and Opatrny (2020), we conducted a diagnostic check to assess the credibility of synthetic controls. In this work, we brought forward the intervention period to start in 1989. This is the "in-time placebo test" (Abadie et al., 2015), similar to the "pre-schedule test" (Heckman and Hotz, 1989). Thus, a plausible synthetic control result would show a lack of policy effects before the actual intervention begins, even though we do not use the information on the actual timing of the intervention.

Figure 5B shows the GDP trends of the synthetic group and Xiamen City are all largely overlapping, indicating there is sufficient evidence to find a synthetic group that does not differ from Xiamen City when the synthetic control method is performed in all years when the non-integrated coastal zone management policy is implemented. Further, it suggests the ICZM causes the difference between Xiamen City and the synthetic group. A second placebo test was passed.

In the final test, to assess the robustness of our results to unit selection for synthetic controls, we performed the leave-one-out test suggested in Abadie (2021) and Thomas et al. (2021). In this work, we re-estimate our main model and perform a city-by-city simulation for the other cities in the sample. We assumed that all cities in the sample underwent ICZM at the same two specific time periods as Xiamen. Then we calculated the policy effect separately for them, thus exploring the overall probability of the event of a change in the policy effect in Xiamen, which can then be judged based on the statistical significance level. This leads to the robust result that the exclusion of donor units from the SCM plot does not have a visually significant impact on the results.

Figure 5C returns the final result. Several of the solid gray lines in the figure represent the policy effects of the other cities in the sample in the "counterfactual framework," while the top solid orange line represents the policy effects of Xiamen. In line with the results in Figure 4C, the policy effect in Xiamen gradually increases and reaches about 100 billion RMB. The probability of this event is 0.0053, which is in line with the significance level of 1%. This means that the following conclusion can be drawn from the ranking test: there is 99% certainty that Xiamen's ICZM is the reason why it stands out among other cities.

# 5 Discussion and policy implication

## 5.1 Strengths and limitations

By introducing SCM to assess the policy effects of ICZM in Xiamen, this paper, like Lau (2005), quantitatively concludes that ICZM contributes to the all-around development of Xiamen. In addition, compared with other qualitative studies (Cicin-Sain and Knecht, 1995; Le Gentil and Mongruel, 2015), the strength of this paper is focusing on the real effectiveness of ICZM policies by using real data. Besides, the paper has the advantage of comparing the effects of the same policy on different coastal zone cities using certain mathematical paradigms and measured the long-term economic benefits of ICZM. Meanwhile, compared with Smith et al. (2007); Mangi et al. (2007); Roca et al. (2008); Yoo et al. (2011), and others, this paper effectively excludes a series of underestimation or overestimation problems due to the lack of data.

The first shortcoming of this paper is failing to consider the overall framework of sustainable development like other scholars (Tian et al., 2018). In the future, we can consider expanding the indicator system (e.g., resident happiness, ecological score, etc.) to include more variables in order to model the synthetic and factual groups as non-differentiated as possible. The second shortcoming is the limited data. There is a need to apologize that although we would have liked to fit more indicators adequately, the basic set-up of the model resulted in the need for a longer fitting interval

upfront in the policy. As a result, long and multi-city multi-indicator panel data was needed. This need, however, cannot be met with the existing database, mainly because monitoring data covering indicators of environmental quality and social well-being are scarce until 2000, so we are unable to obtain additional measures. Therefore we believe this is a limitation that cannot be solved by our ability.

### 5.2 Policy implication

1. Insist on the integration of sea and land construction, and actively prevent and control environmental pollution problems in the coastal zone.

Strictly control the discharge of sea and land pollution sources, including wastewater, solid waste, exhaust gas, and other forms of pollutants. Meanwhile, strengthen the comprehensive improvement of the coastal zone environment, actively carry out environmental relief, environmental assessment, and other aspects, and effectively protect the natural environmental resources from damage. On the basis of optimal regional planning, strengthen the monitoring and law enforcement of the coastal zone environment to ensure that the protection of the environment and economic development are coordinated. Thus, finally, realize the integrated development of sea and land.

2. Seize the opportunity of ICZM and summarize the experience to promote the integrated economic development of the coastal zone.

First, continue to optimize the overall layout of the development of the marine economy, continue to build the leading marine enterprises, and build a local or even national economic card with potential and fame. Second, continue to accelerate the structural transformation and upgrading of the marine industry. It is suggested to improve the added value of products, extend the industrial chain, focus on cultivating new industries with environmental protection concepts, and reverse the unreasonable economic structure of the past, thus promoting the development of the economy in the direction of higher quality.

## 6 Conclusion

In this paper, the policy effects of ICZM in Xiamen are evaluated by introducing the SCM, and the results are as follows.

(1) The first round of ICZM in Xiamen had a certain economic stimulating effect, as reflected in the horizontal growth of the city's economy of nearly 20 billion yuan, but there was a certain policy lag effect and unsustainability, as reflected in the zero-growth rate around 2000.

(2) The second round of ICZM in Xiamen has not only opened up the gap between Xiamen and similar cities but also turned this economic development gap into sustainable development in terms of environmental protection, which is in line with the ultimate goal of ICZM.

(3) Through robustness tests, the study found that the main reason why Xiamen City was able to widen the gap with similar cities (e.g., Zhuhai City) was the implementation of the ICZM, which is worth learning from the experience of similar coastal zone cities in developing countries.

## Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://data.cnki.net/.

## Author contributions

YQ led the whole design of the manuscript and Writing. XN, HW, ZW, HP: revision. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

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