Does environmental regulation slow down marine environmental pollution?--Empirical study based on panel threshold model

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Abstract. In order to identify the real impact of environmental regulation on the marine environment pollution in China, the paper constructs a panel threshold model of environmental regulation on the marine environment pollution, by adopting data from year 2006-2016 of 11 coastal provinces and cities in China, perform a linear regression analysis and a threshold regression analysis, taking environmental regulation as a threshold and explanatory variable, population at the end of the year, the GOP and total population, GDP as control variables, the annual amount of wastewater discharged directly into the sea as dependent variable. The results show that environmental regulation cannot slow down marine environmental pollution, China's environmental regulation has a significant threshold effect on marine environmental pollution, GOP and GDP have significant positive impacts on marine environmental pollution, and impact of GOP is higher than that of GDP, and population has insignificant negative impacts on marine environmental pollution. Therefore, regulations should be improved to protect the marine environment.

1. Introduction
Due to the industrialization and urbanization, marine environmental pollution has become an urgent problem to be solved worldwide, and environmental regulation has become a governmental means to interfere with the resources and environment of enterprises. With the diversification of environmental problems, environmental regulation is changing from a single executive order mode to a diversified mode such as executive order mode, market encouragement and moral persuasion, such as emission charge, information publicity, ideological education, etc. The report of the 19th National Congress has clearly emphasized the government should improve the comprehensive governance of watershed environment and coastal waters, but in 2019 there were still 38 red tides, and ending time of green tides was the latest during the past five years. The above problems are still seriously restricting the sustainable development of marine economy. Therefore, academics proposed a problem what environmental regulation impacts on marine environmental pollution.

2. Literature review
The domestic and foreign governments and academic researchers have done extensive research on the issue of environmental regulation. The major controversial focus is whether environmental regulation can relieve marine pollution.

Most of the foreign academics focus on qualitatively researching the effect of environmental regulation on the environment. The Australian government has invested US$3 billion in the...
The construction of the “Yanbu” Industrial City, where pollutant emissions are restricted by the laws, manage criteria and guidelines [1]. Brian Garrod [2] argues that corporate environmentalism can never be a perfect substitute for the government intervention in marine environment management, while the government’s environmental regulation remains the main way to govern the marine environment. Borsatto Jaluza Maria Lima Silva [3] reviewed the 2011-2019 literature, concluding that environmental regulation is one of the main factors the promote enterprises to make green innovations. Danny Marks [4] discovered in 19 interviews with the actors from the public, private and non-profit sectors that main factor restricting the reduction of ocean plastics is the lack of the government’s environmental regulation. Agovino Massimiliano [5] has proven by the generalized method of moments (GMM) that environmental regulation is beneficial to the sorted collection of waste.

The Chinese academic researchers focus on quantitatively researching the effect of environmental regulation on the environment. Fan Qingquan [6] has drawn a conclusion based on the panel threshold model that environmental regulation is a necessary condition for corporate pollution treatment and able to reduce energy consumption. Du Wencui [7] has drawn a conclusion based on the Stackelberg model that strengthened environmental regulation can increase industrial concentration, thereby reducing the intensity of air pollution emissions, but the intensity of water pollution emissions is enhanced. Zhang Zhibin [8] performed regression with the 2011-2017 panel data of 35 key Chinese cities, concluding that the government’s environmental regulation helps to reduce local pollutant emissions. Liang Rui [9] has drawn a conclusion based on the threshold regression model that environmental regulation is only beneficial to the reduction of air pollution in a specific economic growth range. Kuang Chang’e [10] conducted a threshold regression analysis with the 2006-2017 data of 14 prefecture-level cities in Hunan Province, concluding that environmental regulation has a significant inhibitory effect on industrial pollution below the threshold level and has an opposite effect above the threshold level.

In summary, there are already abundant studies, and there is a difference in the conclusions caused by factors such as regionalism, climate, and economy. At present, most academic researchers mainly study the effect of environmental regulation on the terrestrial environment, while there are few studies on marine pollution. As the sea-land ties are strengthened, the environmental regulation on land has also exerted a certain effect on marine pollution and on the sustainable development of the marine economy.

Based on that, this paper intends to build a threshold model between environmental regulation and marine pollution by panel threshold regression, and use the statistical data of 11 coastal provinces and cities to empirically test the effect of environmental regulation on marine pollution in the hope of paving the way for the solving of the problem.

The innovations of this paper are as follows: First, the non-linear relationship of environmental regulation to marine pollution is taken into consideration, and a threshold regression model is used for conjecture verification. The second is the research object. Owing to the sea-land connection, GOP, year-end population and GDP, and year-end population are taken as control variables to study the effect of marine and terrestrial activities on marine pollution.

3. Research design

3.1. Threshold regression model
In order to comprehensively explore the effect of environmental regulation on marine pollution, nonlinear regression is used in this paper for a comparative study of the empirical results. On the basis of Hansen’s threshold regression model, a panel threshold regression model is built by reference to Qi Shaozhuo’s model [11]:

\[
MP_{it} = \mu_i + \beta_1 TRI(TR \leq \gamma) + \beta_2 TRI(TR > \gamma) + \beta_3 x + \alpha_{it}
\]

(1)

\[
MP_{it} = \mu_i + \beta_1 TRI(TR \leq \gamma_1) + \beta_2 TRI(\gamma_1 < TR \leq \gamma_2) + \beta_3 TRI(TR > \gamma_2) + \beta_4 x + \alpha_{it}
\]

(2)

Equation (1) is for a single-threshold situation, while equation (2) is for a double-threshold situation, where \(MP_{it}\) represents the degree of marine pollution in i Province in year t; \(TR\) represents
the environmental regulation, adopted as an explanatory variable and threshold variable here; x represents control variable, including \(GP, GDP\), and population; \(I\) is an indicative function, divided into different parts according to the threshold value; \(\beta_i (i = 1, 2, 3, 4)\), \(\mu_i\) represents the regression coefficient; \(\gamma_1, \gamma_2\) represents the threshold value; \(\epsilon_{it}\) represents the stochastic disturbance term.

3.2. Data and indicator system description

Marine pollution (MP) is taken as an explanatory variable, and the annual amount of wastewater discharged directly into the sea is used to represent the degree of MP. Environmental regulation (TR) is taken as an explanatory variable and threshold variable. By reference to Gai Mei’s method [12], the ratio of 11 coastal provinces and cities’ total investment in environment pollution treatment to their fixed investments is used to represent TR. The control variables include: (1) Marine economic status, represented by annual per-capita gross ocean product (GOP). (2) Terrestrial economic status, represented by annual per-capita gross domestic product (GDP). (3) Population (PD): The increase in population leads to an increase in the use of resources, with more and more waste thus generated from consumption, exerting a certain impact on the marine environment. Therefore, the total year-end population of the 11 coastal provinces and cities is used to represent the population size.

11 coastal provinces and cities of China are taken as research objects, including Liaoning Province, Tianjin city, Hebei Province, Shandong Province, Jiangsu Province, Shanghai City, Zhejiang Province, Fujian Province, Guangdong Province, Guangxi Province and Hainan Province. The data come from the 2006-2016 China Marine Statistical Yearbook, China Statistical Yearbook on Environment and Bulletin of China Marine Ecological Environment Status. Logarithm of some variables is taken and is expressed by lnMP, lnGOP, lnGDP, lnPD. The descriptive statistics of the data are shown in Table 1.

Table 1. Descriptive statistics of indicators.

| Variable | Observation | Mean   | Std.Dev. | Min   | Max   |
|----------|-------------|--------|----------|-------|-------|
| lnMP     | 121         | 10.1056| 1.277    | 7.080 | 12.190|
| lnGOP    | 121         | 8.831  | 0.913    | 6.457 | 10.409|
| lnGDP    | 121         | 10.697 | 0.532    | 9.233 | 11.666|
| TR       | 121         | 2.125  | 0.940    | 0.419 | 9.064 |
| lnPD     | 121         | 8.328  | 0.769    | 6.729 | 9.306 |

4. Empirical analysis

4.1. Related variable test

The correlation coefficients of the marine pollution status and its effect variables are analysed in order to test the correlation among the variables. As can be seen from Table 2, there is the greatest correlation between GOP and GDP, 0.8153. Therefore, it is necessary to separate GOP from GDP for threshold regression analysis.

Table 2. Correlation coefficient matrix.

| Variable | MP       | lnGOP    | lnGDP    | TR       | lnPD    |
|----------|----------|----------|----------|----------|---------|
| MP       | 1.0000   | 0.2345   | 0.0464   | 0.1648   | -0.0904 |
| lnGOP    | 0.2345   | 1.0000   | 0.8465   | -0.3841  | 0.1700  |
| lnGDP    | 0.0464   | 0.8465   | 1.0000   | 0.0179   | 0.2574  |
| TR       | 0.1648   | -0.3841  | 0.0179   | 1.0000   | -0.0788 |
| lnPD     | -0.0904  | 0.1700   | 0.2574   | -0.0788  | 1.0000  |

4.2. Basic regression analysis

To observe whether there is a linear or nonlinear relationship between environmental regulation and marine pollution, first, on the premise of not considering the nonlinear relationship, the static panel model is used to observe the marginal effect of environmental regulation on marine pollution, and
select fixed effects for testing. An estimation is made with GOP, population and GDP, and population as control variables and with control variables excluded. Table 3 shows the fixed effect estimation results. The regression coefficient of environmental regulation is positive, and significant at the level of 10% without control variables, indicating that at the present stage, environmental regulation remains unable to reduce marine pollution. The regression coefficient of population is negative but not significant, while the regression coefficients of GOP and GDP are positive, suggesting that economic development contributes to marine pollution.

Table 3. Basic regression analysis results.

| Variable | FE1     | FE2     | FE3     |
|----------|---------|---------|---------|
| TR       | 0.066*  | 0.040   | 0.044   |
| lnPD     | /       | -0.859  | /       |
| lnGOP    | /       | 0.458***| /       |
| lnGDP    | /       | /       | 0.427***|
| Conf     | 9.966***| 13.131**| 12.395***|

Note: ***, ** and * indicate high significance at the 1%, 5%, and 10% levels. FE means fixed effect.

4.3. Threshold regression analysis

Stata16 software was used for threshold regression analysis. Environmental regulation is taken as a threshold variable to verify the threshold effect of environmental regulation on marine pollution. The F-statistics and Bootstrap method are adopted for verification. The test results show that the single threshold is significant at the 10% level, while the double threshold is not significant (Table 4). Therefore, the single threshold model is selected, and the threshold value is 1.939.

Table 4. Threshold test results.

| variable       | environmental regulation |
|----------------|--------------------------|
| threshold      | Single threshold         | Double threshold       |
| Bootstrap      | 300                      | 300                     |
| Trim           | 0.01                     | 0.01                    |
| The threshold value | 1.939*               | 1.874;1.939            |
| 95% confidence interval | [1.840,1.942]     | [1.848,1.942]           |

Note: ***, ** and * indicate high significance at the 1%, 5%, and 10% levels.

After the threshold value is determined, the parameters of the threshold model are estimated and analyzed. Table 5 shows the threshold regression results. When it is lower than the threshold value (TR≤1.939), environmental regulation has an obvious deteriorating effect on the marine environment. When it is greater than the threshold value (TR>1.939), environmental regulation’s deteriorating effect on the marine environment is significantly reduced, but it still has a positive promoting effect on marine pollution. This is contrary to the conclusions reached by most scholars, because most scholars think environmental regulation is conducive to slow down environmental pollution [6-10]. According to the some academics’ ideas [13-14], the reason is that when China’s ER level was still low, local enterprises and governments didn’t pay attention to the environmental quality, and enterprises improved their economic income by reducing machinery and equipment and increasing product output. However, the amount of waste increased in this mode of production, which is characterized by emphasis on quantity rather than quality. The government treated environmental pollution by an ineffective means, i.e., “treatment after pollution”, causing continuous deterioration of the terrestrial environment. As a result, the waste generated during terrestrial activities was discharged into the ocean through rivers, acid rain, etc., posing a huge threat to the marine environment. With the continuous improvement of the environmental regulation level, the local enterprises and governments have started paying attention to the domestic environmental quality. Most enterprises have discarded
obsolete, aged and environmentally harmful machines and equipment and produced high-quality products. The government has also increased investment in environmental governance by getting rubbish out of water and strengthening human supervision, partly improving the quality of the terrestrial and marine environments, but overall, environmental regulation still has a deteriorating effect on China’s marine environment.

The regression coefficient of GOP is positive, indicating that GOP has a positive effect on marine pollution. The main reason is that the increase in GOP also cause the generation of certain waste, which is directly discharged into the ocean, and this is not conducive to the control of marine pollution. The regression coefficient of GDP is positive and smaller than that of GOP, indicating that the development of the terrestrial economy also aggravates marine pollution, but the effect is smaller than GOP. This is consistent with most scholars' belief that economic development has a negative correlation with the marine environment within a certain interval [12, 15-16]. The regression coefficient of population is negative, indicating that population increase is conducive to large-scale governance of the marine environment and mitigation of marine pollution.

| variable | TR is the threshold variable |
|----------|-----------------------------|
|          | ≤ 1.939  | > 1.939  | ≤ 1.939  | > 1.939 |
| lnGOP    | 0.480*** | /        |          |         |
| lnGDP    | /        | 0.471*** | /        |         |
| lnPD     | -0.655   | -0.706   | /        |         |
| TR1(≤1.939) | 0.184*** | 0.204*** | 0.071**  | 0.078** |
| TR2(>1.939)| 0.071**  | 0.078**  | 11.12**  | 10.703* |

Note: ***, ** and * indicate high significance at the 1%, 5%, and 10% levels.

5. Conclusions and policy suggestions

5.1. Conclusions

The nonlinear relationship between the environmental regulation of coastal provinces and cities and marine pollution is taken into consideration in this paper. The 2006-2016 data of 11 coastal provinces and cities are used to a threshold model for marine pollution. GOP, population and GDP, and population are taken as control variables for threshold value grouping according to environmental regulation. The following conclusions are drawn:

1) Environmental regulation has an obvious marine and terrestrial economic threshold effect on marine pollution. That is, at different levels of environmental regulation, environmental regulation has a single threshold effect on marine pollution. On the left side of the threshold, because the enterprises prefer quantity to quality and the government harnesses environmental pollution based on the principle of “treatment after pollution”, environmental regulation’s improving effect on the environment falls far short of the deterioration of environmental pollution. Terrestrial pollution is discharged into the ocean through rivers and acid rain, so environmental regulation aggravates marine pollution. On the right side of the threshold, the enterprises carry out advanced production while the government prevents environmental pollution at the early stage and strengthens environmental governance at the later stage. Therefore, environmental regulation has some improving effect on the quality of the terrestrial and marine environments, but on the whole, environmental regulation still has a deteriorating effect on China’s marine environment.

2) The terrestrial economy and marine economy are significantly positively correlated with marine pollution. Economic development exacerbates marine pollution, and the effect of the marine economy on marine pollution is greater than that of the terrestrial economy. There is an insignificantly negative correlation between population increase and marine pollution. The increase in population improves manpower, making it possible to carry out marine environmental governance on a large scale.
5.2. Policy suggestions
Based on the research results, the following policy suggestions are put forward:

1. The government should strengthen environmental management and earnestly implement the environmental impact assessment system to prevent planning, development and construction from exerting an adverse effect on the environment at the source; strictly implement the “three simultaneous” system to ensure that environmental protection facilities and the main project are designed, constructed and put into production at the same time; fulfill the environmental protection targets set at all levels, and take environmental protection as important content of performance assessment for the Party and government leaders and cadres at all levels. The leaders and cadres who have made a decision mistake, causing a severe pollution accident, seriously disturbing environmental law enforcement, shall be held accountable in accordance with the law.

2. The government should advocate a circular economy and accelerate high-quality economic development; implement a policy on energy and resource saving in accordance with the principle of “resource conservation, secondary utilization and recycling use” to strengthen the comprehensive utilization of resources and improve the resource recycling system to comprehensively promote clean production, and increase the resource utilization efficiency to reduce the generation and discharge of pollutants. The concept of circular economy development must be practiced in key links such as planning, policy formulation, system design, project decision-making, law enforcement and regulation implementation.

3. The government should also coordinate the relationship between the economy and the environment. During economic development, environmental pollution shall not exceed its maximum carrying capacity. The government should formulate and implement correct industrial policies, and adjust the industrial structure to reduce environmental pollution and destruction. It is necessary to strictly limit the development of enterprises characterized by high energy consumption, large waste of resources and serious pollution, and implement industrial policies to support enterprises in improving the treatment and comprehensive utilization of the wastewater, exhaust gases and waste residues generated during their production.

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