Research Article

Port Environmental Quality or Economic Growth? Their Relevance and Government Preference in Developing Countries

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In the past few years, the marine ecosystem has been a cheap resource in developing countries in the process of pursuing short-term vested interests. Therefore, high economic development of the developing countries is at a huge environmental cost. Nowadays, environmental protection is becoming a global concern. In this background, the government of the developing countries begins to formulate reasonable marine economic and environmental policies to find a balance between rapid economic development and marine environmental protection. In this contribution, a dynamic stochastic general equilibrium model (DSGE) is constructed with the environmental constraints, and Bayesian estimation is used to calibrate the main parameters. Next, the model is employed to analyze the effects of government and consumer environmental preferences on macroeconomic variables, environmental quality, and consumer and government utility. Results show that the government’s preference for environmental quality is positively related to port environmental quality and negatively related to output, capital stock, and consumption. An enhancement of the environmental quality preference of the target audience can realize balanced development of economic growth and port environmental quality. The findings are conducive to coordinating the relationship between economic development and environmental protection and achieving sustainable development of the port.

1. Introduction

Over the past thirty years, China focuses on economic development, and environmental issues were far less important than economic issues. Nowadays, the level of environmental awareness is keeping rising; for instance, large industrial institutions need to consider environmental protection. Ports as the key part of the marine ecosystem are facing the same issue. Environmental cost, corporate social responsibility programs, and environmental effects are taken into account by customers of ports increasingly. As the important roles in macroeconomic activities, the basic function of the government is to provide public services and correct externalities. While formulating economic policies, the government should consider adopting corresponding environmental policies to improve the impact of economic development on the environment. Policymakers and legislative frameworks must also take enforcement measures to meet the growing environmental needs of ports. Therefore, port environmental protection is an important part of marine ecological protection. Pollution from ship garbage is a problem to be solved in marine environmental protection in China and abroad. Nowadays, environmental quality has become an important index to evaluate port quality [1]. To deal with the problem of sustainable development caused by environmental deterioration, the concept of “green port” construction was put forward by the port industry in the last century [2]. Green port is a sustainable port with both environmental and economic benefits. However, due to resource constraints, low production efficiency, trade slowdown, and homogenization competition among others, China is encountering difficulties in pushing forward the development of green ports.
How to maintain a good ecological environment and, at the same time, promote rapid economic growth? This has become a difficult problem to be solved by countries all over the world, especially developing countries. China is the world’s largest developing country; it has become the world’s largest trade importer and exporter for 20 consecutive years, with plenty of ports. The huge trade volume brings a large quantity of ships, which increases the pressure on the port environment. The traditional view holds that there is an opposition between economic growth and environmental protection. Economic growth is built at a certain environmental cost, and on the contrary, environmental protection represses economic growth to some extent. Under the influence of this view, consumers generally have low awareness of environmental protection in order to pursue relatively high profits. There have been several pollution cases, such as random dumping of ship garbage, split oil-water, and residual goods.

The hypothesis of the Environmental Kuznets Curve (EKC) puts forward a new relationship between the environment and economic growth. Barbier et al. [3] believed that, in the early stage of economic development, economic growth will increase environmental pollution, but once the total economic volume reaches a certain level, economic growth will help to improve environmental quality. EKC promotes research on the dynamic relationship between environment and economy and macro industrial policy regulation in China at the present stage.

Under the framework of the DSGE model, this study analyzes the government’s attention to environmental quality, the change of environmental quality preference of port enterprises and ships, and the impact of their random shocks on macroeconomic variables and environmental quality. Figure 1 shows the health status of a typical marine ecosystem in 2020. It summarizes the recent situation of China’s port development, which can provide a reference for policymakers, help to change the current situation of the relationship between economic growth and marine environment protection, and speed up the construction of sustainable ports.

This section is followed by a literature review. In the third part, we establish the DSGE model with government preference and horizon, and the fourth section is parameter calibration and equilibrium solution of the model. The conclusions are drawn in the last section.

2. Literature Review

In the past 20 years since the EKC theory was accepted, China’s achievements in environmental protection can be attributed to the continuous improvement of the government management system and corresponding institutional arrangements [4–6]. After studying the problems in the development of the modern world, including ecology, environment, and resources, Leontief [7] pointed out that pursuing pure economic growth is not a development path leading to the future, and efforts should be made to reduce the growth that leads to environmental degradation. Mesarovic et al. [8] propose to change the mode of economic growth to achieve environmental and economic coordination. Zhang and Chi [9] analyzed coordination between regional economic development and the environment in some provinces of China. Many scholars study the coordinated development of the environment and economy [10–13], but there are a few studies on the coordinated economic development model of the carrying capacity of resources and environment and its structural characteristics in a specific region. In real society, there are often various conflicts between the economic and environmental objectives among different regions, and the study of targeted solutions is the basic condition to improve the efficiency of regional resource allocation and market competitiveness. It is the key to coordinate the contradiction between regional resources environment and economic social development and to improve the quality of regional economic operation and environment. It is also an important guarantee to prevent resource depletion, control environmental pollution, and ecological damage and realize regional sustainable development.

With the acceleration of the process of world economic integration, port cities are promoting the evolution and optimization of regional industrial structure with their unique basic resources through agglomeration effect, synergy effect, and city self-growth effect. This has made port cities a core part of global economic development [14]. The growth of transportation demand caused by the growth of resource demand is largely carried out by sea, which increases the development demand of the port. As the port of import and export of the logistics subsystem of the dependent city, the development of the port depends to a great extent on the transportation demand caused by the economic development of the city. It is the key point in the development of a city that cultivates the port, and once the port forms, it has become an important infrastructure, the city’s economic development has a strong role in promoting [15]. China has the largest port scope in the world; exchanging environmental costs for the rapid development of the economy in the past few decades has led to serious marine environmental pollution in China [16]. The diversified functions of the port in the upgrading period need to protect the marine ecological environment and establish an ecological port. Taking the northern South China Sea (NSCS) as an example, Cheung and Sumaila [17] discussed the trade-off between conservation objectives and socioeconomic objectives in fishery management of the tropical marine ecosystem. It is found that reducing fishing intensity can improve the marine ecological environment and reduce economic benefits. Similar trade-offs are common in marine ecosystems. In the early stage of port development, the ecosystem-based design method is an effective method to achieve more sustainable development. The challenge facing ports is how to improve their international competitiveness and environmental performance. Taking the port of Rotterdam as an example, Hollen et al. [18] analyzed how the port authorities promote ecosystem development in their port industry complex. Garcia-Onetti et al. [19] attempted to build a bridge between the environmental management systems and tools (EMT) of the economic sector and the ecosystem-based integrated management model (IEBM) and
proved that the traditional phenomenon of difficulties in private capital participation in these processes participations most obvious in the port sector, although they play an important role in the environmental and economic transformation of coastal and marine areas. How to seek a reasonable industrial structure and suitable speed of economic development in the process of port economic development, to ensure the protection and improvement of the environment, and to realize the sustainable development of the port is worth deep research of scholars.

3. Materials and Methods

3.1. Methodology. The DSGE model emphasizes the microbasis of the macroeconomy, which can carry out various numerical simulation experiments in the absence of historical data and comprehensively analyze the long-term equilibrium and short-term fluctuation of various economic variables. In this part, a closed DSGE economic model is established, which includes four sectors: representative ship, port enterprise, environment, and government. The interaction system of the four sectors determines the stable result and dynamic changing process of the economy. Production planning and environmental pollution mainly come from the manufacturer’s production behaviour. There are two main ways to discuss environmental problems in literature. The first way is to take pollution discharge as an input factor that directly affects economic production; the second approach is to regard environmental pollution as a negative externality in the production process. In producing ideal products, enterprises will inevitably produce waste gas, waste liquid, waste, and other undesirable products, which will worsen the environmental quality and have a negative impact on the whole society. In this paper, the second method is chosen to make environmental pollution a by-product of production. Next, the production behaviours of the manufacturer and the form of environmental pollution are described.
According to the Solow Growth Model, suppose that the production function of a representative enterprise looks like this:

\[ Y = A \cdot f(K, L) = K^a \cdot (AL)^{1-a}, \]  

(1)

where \( A \) is the production technology, \( K \) is the stock of the capital elements of the input, and \( Y \) is the total output.

Let \((AL)^{1-a} = Q_t\):

\[ Y = Q \cdot K^a. \]  

(2)

The following conditions are met during period \( t \), and \( \varepsilon_{at} \) are met \( N \sim (0, \sigma^2_a)\):

\[ \log Q_t = \rho_a \log Q_{t-1} + \varepsilon_{at}. \]  

(3)

As a result, port companies set their production plans with profit maximization:

\[ \max \pi_t = (1-W_t)Y_t - K_{t-1} \cdot r_t. \]  

(4)

Here, products prices are standardized at 1, \( r_t \) is the capital rate, and \( W_t \cdot Y_t \) is the government’s pollution tax on port companies, representing the cost to the economy.

In a closed economy, the shipowner, as a producer, owns the ship and provides the capital for production, and as a consumer, it determines the consumption plan under the budget constraint. The lifetime utility of a representative consumer is assumed to be as follows:

\[ \max_{t, k_t} U = E_0 \sum_{t=0}^{\infty} \beta^t u_t, \]  

(5)

where \( U \) represents lifetime utility value, \( \beta \) represents subjective discount rate, \( 0 < \beta < 1 \), and \( u_t \) is the instantaneous utility of consumer \( t \) period. In order to explore environmental issues better, this paper assumes that consumers can derive not only satisfaction from consumer product \( C \) but also utility from consumer clean environment \( E \) and designs the instantaneous utility function in the following separable logarithmic form:

\[ u_t = (1-\theta) \log C_t + \eta^C_t \log E_t, \]  

(6)

where \( \theta \) indicates the consumer’s preference for environmental quality and takes \( \eta^C_t \) as the preference impact of environmental quality, assuming that it obeys the next order autocorrelation process, and \( \varepsilon_{at} \) are met \( N \sim (0, \sigma^2_a)\):

\[ \log Q_t = \rho_a \log Q_{t-1} + \varepsilon_{at}. \]  

(7)

The budgetary constraints faced by representative shipowners are

\[ k_t + c_t = (1-\delta)k_{t-1} \leq \pi_t + k_{t-1} \cdot r_t. \]  

(8)

The above formula shows that the owner uses the profit-sharing \( \pi_t \) and the investment income \( k_{t-1} \cdot r_t \) for consumption \( c_t \) and investment \( k_t - (1-\delta)k_{t-1} ; \delta \) is the depreciation rate.

According to Jouvet et al. [20] and Tahvonnen and J. Kuuluvainen [21], the dynamic equation of environmental quality is designed as

\[ Q_t = \rho_a Q_{t-1} - SY_t + \phi \varepsilon_t (T_t, y_t), \]  

(9)

where \( 0 < \rho_a < 1 \) is the sustainable parameter of the environment, \( SY_t \) is the new pollution quantity of the production department, \( \phi \) represents the improvement degree of the environment after the unit tax revenue is used to treat the pollution and represents the level of the environmental protection technology, and \( \varepsilon_t \) is the environmental protection technology impact; it obeys

\[ \log \varepsilon_t = \rho_a \log \varepsilon_{t-1} + \varepsilon_{at}. \]  

(10)

where \( \varepsilon_{at} \) are met \( N \sim (0, \sigma^2_a)\).

Economic growth is the primary concern of the government. China’s rapid economic growth in previous decades has been accompanied by worsening environmental problems. Nowadays, not only the economic transition but also the government’s preference for the environment has deepened as follows:

\[ u_t^\lambda = (1-\lambda) \log (1-T_t) y_t + \eta^\lambda_t \lambda \log Q_t, \]  

(11)

where \( \lambda \) is the government’s environmental quality preference parameter, which reflects the social managers’ attention to environmental quality. \((1-T_t) y_t \) is the output except for \( T_t y_t \), which is used to control pollution. It is the effect function of the output entering the government. \( \eta^\lambda_t \) is the impact of the government’s preference for environmental quality. It can express the impact of sudden environmental events and the pressure of social public opinion on environmental improvement, or the impact of foreign governments’ environmental liability requirements on pollution, assuming they meet

\[ \log \eta^\lambda_t = \rho_a \log \eta^\lambda_{t-1} + \varepsilon^\lambda_{at}. \]  

(12)

The government’s decision-making has an intertemporal nature; see unified formulas (4), (9), and (11). On the one hand, immediate tax costs will be incurred while the total benefits of environmental improvement cannot be recovered immediately. The high-quality environment not only brings praise to the current government but also provides a better environment space for future development. It can be said that government pollution control has an intertemporal positive externality. On the other hand, the government’s taxation affects the investment decision-making of enterprises and the total output level of the economy. Tax incentives encourage enterprises to produce more help to improve the current government’s performance evaluation results, but production of environmental pollution needs to pay greater efforts in the future. The government’s economic performance preference has a negative intertemporal externality. The government’s optimal behaviour is

\[ \max_{T_t} E_0 \sum_{t=0}^{\infty} u_t^\beta. \]
Given the initial environmental quality $q$ and the capital stock $k$, the consumption Euler equation of a representative shipowner is

$$\frac{1 - \theta}{c_t} = E_t \left[ \beta (1 - \theta)(r_{t+1} + 1 - \delta) \frac{c_{t+1}}{c_{t+1}} + \beta \eta_1 \theta (1 - T_{t+1}) r_{t+1} \left( \phi T_{t+1} - S_{t+1} \right) Q_{t+1} \right].$$ (13)

The optimal pollution tax rate path is satisfied as in equation (14). The government considers that the environmental costs of reducing a unit of tax revenue would be greater and that an increase in unit tax revenue would have a greater effect on the government, thus leading to a more stringent tax on pollution:

$$\frac{1 - \lambda}{1 - T_t} = \frac{\lambda \phi y_t}{Q_t} + \frac{\beta \rho \lambda \phi y_t}{E_t Q_{t+1}}.$$

### 4. Results and Discussion

#### 4.1. Result

Table 3 shows the steady-state values of macrovariables such as output, consumption, capital stock, environmental quality, and environmental quality per unit of output when the environmental preference coefficients of government and households change, and the corresponding values of consumer utility and government utility.

#### 4.2. Discussion

The DSGE model is transformed into a data simulation system for measuring the implementation effect of port environmental policy. It is analyzed from three aspects: policy (government preference for the environment), investment (GDP, port investment, and environmental quality), and market demand (ship preference for the environment), which are close to the reality of China’s economy and port environment.

First, the influence of the government’s environmental preference coefficient is investigated, where $\theta$ remains unchanged and $\lambda$ changes. The enhancement of the government’s preference for environmental quality has negative effects on output, capital stock, and consumption but has positive effects on environmental quality. The reason for the negative effect is that the government needs to levy taxes to control pollution, which reduces the shipowners’ enthusiasm for investment and consumption [32]. However, because of the significant improvement in environmental quality, the environmental quality per unit of output has been improved, and the increase of port investment caused by the change of environmental quality remedies the loss of port investment caused by the decrease of other variables; therefore, the relative enhancement of the government’s environmental preference will improve the port investment to some extent. The policy implication of the model is that changing the single view of political achievement and bringing environmental protection into the assessment mechanism will help to build a more harmonious society [33].

Secondly, there is not a positive correlation between GDP, port investment, and environmental quality, where $Q$ remains unchanged when $Y$ and $K$ change, as shown in Figures 2 and 3. GDP is relatively stable and has little impact on port investment. Before 2016, port investment was negatively correlated with environmental quality, which became positively correlated after 2016. This shows that the investment in port environmental protection before 2016 is less, which lags the economic development. After that, the environment and economy develop together and enter a benign development stage.
Consider the change of ship environment preference coefficient and keep $\lambda$ unchanged and $\theta$ changed. As the shipowners’ preference for environmental quality becomes larger, they are more willing to reduce immediate consumption for the improvement of environmental quality; it will lead to environmental effects. Considering that the pollution efficiency parameter of the government unit tax $\phi$ is higher than the pollution coefficient $P$ of the enterprise unit output, more investment means more pollution control funds. The result of equilibrium is that the economic growth and environmental quality can realize a positive correlation when the residents’ environmental quality preference is strengthened.

4.3. Impulse Response Function. The impulse response function is used to analyze the impact of different shocks on the changing trend of main macroeconomic variables such as environmental quality and economic benefits.

### Table 1: Parameters determined by empirical calibration.

| No. | Parameters       | Description                                               | Value | References |
|-----|------------------|-----------------------------------------------------------|-------|------------|
| 1   | $\Theta$         | Consumer’s preference for environmental quality           | 0.3   | [22]       |
| 2   | $\beta$          | Subjective discount rate                                  | 0.9   | [23]       |
| 3   | $\delta$         | Depreciation rate                                         | 0.2   | [24]       |
| 4   | $\lambda$        | Government’s environmental quality preference parameter   | 0.3   | [25]       |
| 5   | $\rho$           | Sustainable parameter of the environment                 | 0.1   | [26]       |
| 6   | $\eta$           | The impact of the government’s preference for environmental quality | 0.2   | [27]       |

**Figure 2: GDP and total sewage, chemical oxygen content, and ammonia nitrogen.**

Thirdly, consider the change of ship environment preference coefficient and keep $\lambda$ unchanged and $\theta$ changed. As the shipowners’ preference for environmental quality becomes larger, they are more willing to reduce immediate consumption for the improvement of environmental quality; it will lead to environmental effects. Considering that the pollution efficiency parameter of the government unit tax $\phi$ is higher than the pollution coefficient $P$ of the enterprise unit output, more investment means more pollution control funds. The result of equilibrium is that the economic growth and environmental quality can realize a positive correlation when the residents’ environmental quality preference is strengthened.

### 4.3.1. Shocks of Government Environmental Preference.

Figure 4 shows the change of 1% of the random impact on the government’s environmental preference in period $t$. The change range of port environmental quality is the most violent, which increases at first, then decreases slowly, and after that returns to a stable level after about 9 cycles. The impact of environmental shocks urges the government to raise the optimal pollution tax rate [34], increase the sewage cost of ships, reduce the capital investment, and reduce the production of polluting products. At the same time, the government will invest more money in environmental governance. Therefore, the
initial port environmental quality has been improved. Relatively, the fluctuation of consumption and output is relatively stable. After being affected, the first and second periods decreased slightly, and the third period recovered smoothly.

4.3.2. Shocks of Ship Environmental Preference. When the economy is in equilibrium, the sudden increase of consumers’ environmental preference will immediately induce consumers to adjust the optimal strategy, reduce product consumption, and increase capital investment, as shown in Figure 5. Since the environmental quality of the port is mainly determined by the pollution discharge level of the ship and the pollution control capacity of the government, because the pollution coefficient of the unit output of the ship is less than the pollution control effect of the tax of the government, the shipowner, as a consumer, will try to ensure that the government has enough funds for pollution control through more investment, to improve the environmental quality. In Figure 5, although consumption declined in the first three periods after the

| Parameters | Prior distribution       | Posterior mean | 95% confidence interval |
|------------|--------------------------|----------------|-------------------------|
| $A$        | Beta (0.5, 0.005)        | 0.5032         | [0.494, 0.5115]         |
| $\rho_Q$   | Beta (0.9795, 0.005)     | 0.9801         | [0.9766, 0.9837]        |
| $\rho_L$   | Beta (0.95, 0.0025)      | 0.9499         | [0.9461, 0.9549]        |
| $\rho_a$   | Beta (0.95, 0.0025)      | 0.9503         | [0.9464, 0.9561]        |
| $\rho_c$   | Beta (0.5, 0.0025)       | 0.4998         | [0.4959, 0.5045]        |
| $\rho_e$   | Beta (0.5, 0.0025)       | 0.0395         | [0.3948, 0.5039]        |
| $\Phi$     | —                        | 2.612          | [2.6039, 2.6211]        |
| $\sigma_a$ | Inv_gama (0.01, inf)     | 1.7806         | [0.494, 0.5115]         |
| $\sigma_b$ | Inv_gama (0.01, inf)     | 1.3899         | [0.494, 0.5115]         |
| $\sigma_c$ | Inv_gama (0.01, inf)     | 0.0152         | [0.494, 0.5115]         |
| $\sigma_e$ | Inv_gama (0.01, inf)     | 0.0395         | [0.494, 0.5115]         |

Figure 3: Seaport investment and total sewage, chemical oxygen content, and ammonia nitrogen.
Table 3: The steady-state value and utility value of variables under different preferences.

\[
(\theta, \lambda) & \quad y & \quad c & \quad k & \quad Q & \quad Q/y & \quad \text{Consumer utility} & \quad \text{Government utility} \\
(0.2, 0.05) & 2.9229 & 1.7851 & 8.5998 & 7.2225 & 2.4633 & 0.8549 & 1.0199 \\
(0.2, 0.15) & 2.9178 & 1.7601 & 8.5843 & 23.8875 & 8.2079 & 1.0867 & 1.2955 \\
(0.2, 0.2) & 2.9105 & 1.7488 & 8.5356 & 33.7597 & 11.5999 & 1.1342 & 1.4701 \\
(0.2, 0.25) & 2.9011 & 1.7367 & 8.4599 & 44.7198 & 15.4091 & 1.2033 & 1.6629 \\
(0.2, 0.3) & 2.8996 & 1.7265 & 8.3782 & 65.2178 & 22.7812 & 1.2655 & 2.0101 \\
(0.05, 0.2) & 2.9079 & 1.7476 & 8.5223 & 33.7562 & 11.5988 & 0.7059 & 1.4682 \\
(0.15, 0.2) & 2.9101 & 1.7454 & 8.5329 & 33.7591 & 11.6001 & 1.0019 & 1.4683 \\
(0.25, 0.2) & 2.9102 & 1.7479 & 8.5411 & 33.7593 & 11.6005 & 1.2178 & 1.4690 \\
(0.3, 0.2) & 2.9115 & 1.7501 & 8.5501 & 33.7875 & 11.5986 & 1.5952 & 1.4699 \\
\]

Figure 4: Response diagram of some endogenous variables under the impact of government environmental preference.

Figure 5: Response diagram of some endogenous variables under the impact of ship environmental preference.
impact, it reversed after the fourth period and finally achieved a win-win situation of economic growth and environmental quality improvement.

5. Conclusion

In the past few years, the marine ecosystem has been a cheap resource in developing countries in the process of pursuing short-term vested interests. Therefore, the high economic development of the developing countries is at a huge environmental cost. Nowadays, environmental protection is obtaining a global concern. In this background, the governments of the developing countries begin to formulate reasonable marine economic and environmental policies to find the balance between rapid economic development and marine environmental protection. In this contribution, the macroeconomic effect of China’s port environment under the general equilibrium framework is measured through the construction of the DSGE model, and parameters calibrations of Bayesian are estimated based on the data from 2013 to 2020. Next, this contribution analyzes the effects of environmental preferences of government and consumers on macroeconomic variables (output, consumption, and port investment), environmental quality (total sewage, chemical oxygen content, and ammonia nitrogen), consumers (shipowners), and government utility.

Results show that the government’s preference for environmental quality has negative effects on output, capital stock, and consumption, but it has positive effects on environmental quality. The increase in port investment caused by the change of environmental quality can make up for losing port investment caused by the decrease of other variables. The enhancement of the environmental quality preference of port consumers such as shipowners can achieve the common good of economic growth and environmental quality.

As the managerial implication, we recommend that the government must take the protection of the environment, ecology, and resources as an important function and become the regulator of the optimal allocation of resources and the protector of the ecological and natural environment, to better solve the problems of the regional economy and environmental protection in the future and take the road of coordinated development.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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