

Study on the balance mechanism of interests in marine ecological compensation

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Abstract. From the point of view of game theory and through establishing the game model of the subject and object of marine ecological compensation, this paper makes a research on the balance mechanism the interests of marine ecological compensation. The results show that the optimal amount of capital investment of environmental protection enterprises for ecological compensation depends not only on energy conservation and emission reduction of itself as well as competition enterprises, but also on the policy support for ecological compensation. At the same time, it is limited by the public's understanding and acceptance for ecological compensation.

1. Introduction

The establishment of marine ecological compensation mechanism must take into account the interests of stakeholders and balance the interests of all parties. From the point of view of game theory, analyzing stakeholders of marine ecological compensation, and through establishing the game model of the subject and object of marine ecological compensation, this paper gives the optimal decision-making of stakeholders and puts forward the proposal which can balance the interests of all parties.

2. Model hypothesis of game analysis of ecological compensation

It is assumed that enterprises in each region can be divided into two categories: one is traditional polluting enterprises and the other is energy saving and environmental protection enterprises. Taking into account the high input and high pollution characteristics of current enterprise production in China, this paper takes into account Stackelberg game in the games between two types of enterprises. Further assumes of the model include:

Hypothesis 1: Polluting enterprise 1 which is a leader in the market competition organizes the daily production with constant marginal cost c_1 and sells the final product q_1 with the unit price P_1 in the market. The waste formation rate of the unit production is η_1 in the process of manufacture. Environmental protection enterprise 2 which is a follower in the market competition organizes the daily production with constant marginal cost c_2 , pays f for energy-saving emission reduction innovation and sells the final product q_2 with the unit price P_2 in the market. The waste formation rate of the unit production is η_2 in the process of manufacture. The energy-saving emission reduction



of environmental protection enterprises is manifested as $0 < \eta_2 < \eta_1$. The two types of enterprises do not consider fixed costs.

Hypothesis 2: Government intervention on ecological compensation is realized through environmental tax, which shows concretely two types of enterprises are levied the unit penalty t_1 according to the amount of waste emissions. Environmental protection enterprise 2 is given unit tax subsidy t_2 because of the waste reduction according to output of environmental protection products.

The amount of subsidy satisfies the condition: $t_2 = (\eta_1 - \eta_2)t_1$.

Hypothesis 3: The consumer public which is a continuous system with the same utility function has a linear demand form for products. The impact of consumer public on ecological protection is reacted in product selection through the environmental neglect degree γ .

3. Association analysis between subject optimal decision and ecological compensation

3.1 the optimal decision of consumer

According to the utility function established by Singh and Vives through analyzing the competition equilibrium of heterogeneous products (Singh&Vives,1984), this paper establishes a utility function including pollution products, environmental protection products and environmental utility.

$$U(q_1, q_2) = \alpha q_1 + \alpha q_2 - \frac{1}{2}(q_1^2 + q_2^2 + 2\gamma q_1 q_2) \quad (1)$$

The $\alpha > 0$ represents the quality of the product, and the $\gamma > 0$ means that the two products are substitutes for each other. In this section, we only consider the influence of product differentiation on the environment and do not consider the alternative function. Then γ represents the degree which consumers ignore the environment. The number of γ degree represents product differentiation. The closer γ is to 1, the lower the environmental preferences of the consumer. Therefore, the higher consumption consumers ignore the environmental protection function of environmental protection products, the smaller the difference between environmental protection products and pollution products.

The maximum consumer surplus:

$$\max U(q_1, q_2) - \sum_{i=1}^2 p_i q_i \quad (2)$$

3.2 the optimal decision of producer

Based on the two formulas of (1)、(2) and the first-order optimal condition of the maximization of consumer utility, we can obtain linear inverse demand function of two types of products:

$$\begin{aligned} p_1 &= \alpha - q_1 - \gamma q_2 \\ p_2 &= \alpha - \gamma q_1 - q_2 \end{aligned} \quad (3)$$

According to the backward induction, the maximize profit of environmental protection enterprise 2 in the second phase is:

$$\begin{aligned} \Pi_2 &= [p_2 - (1 + \eta_2)c_2 - f - \eta_2 t_1 + t_2] q_2 \\ &= [\alpha - \gamma q_1 - q_2 - (1 + \eta_2)c_2 - f + \eta_1 t_1] q_2 \end{aligned} \quad (4)$$

According to the first-order optimal condition, the optimal response function of environmental protection enterprise 2 is:

$$q_2 = \frac{\alpha - \gamma q_1 - (1 + \eta_2)c_2 - f + \eta_1 t_1}{2} \quad (5)$$

When polluting enterprise 1 foresaw the response of environmental protection enterprise 2, the maximize profit of polluting enterprise 1 in the first stage:

$$\begin{aligned} \Pi_1 &= [p_1 - (1 + \eta_1)c_1 - \eta_1 t_1] q_1 \\ &= \left[\alpha - q_1 - \gamma \frac{\alpha - \gamma q_1 - (1 + \eta_2)c_2 - f + \eta_1 t_1}{2} - (1 + \eta_1)c_1 - \eta_1 t_1 \right] q_1 \end{aligned} \quad (6)$$

So, the equilibrium output is:

$$q_1^c = \frac{2[\alpha - (1 + \eta_1)c_1 - \eta_1 t_1] - \gamma[\alpha - (1 + \eta_2)c_2 - f + \eta_1 t_1]}{2(2 - \gamma^2)} \quad (7)$$

There are $\Delta_1 = \alpha - (1 + \eta_1)c_1 - \eta_1 t_1$ and $\Delta_2 = \alpha - (1 + \eta_2)c_2 - f + \eta_1 t_1$, then according to the formulas of (3)、(4)、(5)、(6), we can obtain:

$$q_2^c = \frac{(4 - \gamma^2)\Delta_2 - 2\gamma\Delta_1}{4(2 - \gamma^2)} \quad (8)$$

$$p_1^c = \alpha - \frac{1}{2}\Delta_1 - \frac{\gamma}{4}\Delta_2 \quad (9)$$

$$p_2^c = \alpha - \frac{2\gamma}{4(2 - \gamma^2)}\Delta_1 - \frac{4 - 3\gamma^2}{4(2 - \gamma^2)}\Delta_2 \quad (10)$$

$$\Pi_1^c = [p_1^c - (1 + \eta_1)c_1 - \eta_1 t_1] q_1^c = \frac{(2\Delta_1 - \gamma\Delta_2)^2}{8(2 - \gamma^2)} \quad (11)$$

$$\Pi_2^c = [p_2^c - (1 + \eta_2)c_2 - f + \eta_1 t_1] q_2^c = \left[\frac{(4 - \gamma^2)\Delta_2 - 2\gamma\Delta_1}{4(2 - \gamma^2)} \right]^2 \quad (12)$$

Proposition 1: In the early stage of ecological compensation development, the environmental tax policy scope of government supporting the environmental protection industry must satisfy:

$\frac{\gamma}{2} < \frac{\Delta_1}{\Delta_2} < \frac{4 - \gamma^2}{2\gamma}$; if and only if $\frac{\gamma}{2} < \frac{\Delta_1}{\Delta_2} < \frac{4 - \gamma^2 + \gamma\sqrt{4 - 2\gamma^2}}{2\gamma + 2\sqrt{4 - 2\gamma^2}}$, environmental protection enterprises have the first-mover advantage.

Proving: In the early stage of ecological compensation development, the environmental tax policy scope of government supporting the environmental protection industry must ensure that two types of enterprises coexist, that is: $q_1^c > 0$, $q_2^c > 0$. According to the formulas of (7)、(8), we can

obtain: $\frac{\gamma}{2} < \frac{\Delta_1}{\Delta_2} < \frac{4 - \gamma^2}{2\gamma}$;

The necessary and sufficient condition that the environmental protection enterprise 2 have the first-mover advantage is: $\Pi_1^c < \Pi_2^c$. According to the formulas of (11)、(12), $\Pi_1^c < \Pi_2^c$ is equivalent

to $\frac{\Delta_1}{\Delta_2} < \frac{4 - \gamma^2 + \gamma\sqrt{4 - 2\gamma^2}}{2\gamma + 2\sqrt{4 - 2\gamma^2}}$, and $\frac{4 - \gamma^2 + \gamma\sqrt{4 - 2\gamma^2}}{2\gamma + 2\sqrt{4 - 2\gamma^2}} \in \left(\frac{\gamma}{2}, \frac{4 - \gamma^2}{2\gamma} \right)$. So, when $\frac{\gamma}{2} < \frac{\Delta_1}{\Delta_2} < \frac{4 - \gamma^2}{2\gamma}$,

environmental protection enterprises have the first-mover advantage.

3.3 the optimal decision of government

Under the path dependence of traditional economic development model, the goal of government will still be the maximization of total revenue of the production and the utility of consumers. Under the dynamic equilibrium of the two types of enterprises, the total revenue of production is :

$$\Pi^c = \Pi_1^c + \Pi_2^c = \frac{2(2-\gamma^2)(2\Delta_1 - \gamma\Delta_2)^2 + [(4-\gamma^2)\Delta_2 - 2\gamma\Delta_1]^2}{16(2-\gamma^2)^2} \quad (13)$$

According to the first-order optimal condition, we can obtain:

$$\text{opt} \frac{\Delta_1}{\Delta_2} = \frac{16+16\gamma-4\gamma^2-6\gamma^3-\gamma^4}{2(8+8\gamma-2\gamma^2-3\gamma^3)} \quad (14)$$

Proposition 2: In the early stage of ecological compensation development, the environmental tax policy scope of government supporting the environmental protection industry reduces with the degree γ which consumers neglect environment increasing. For any degree which consumers neglect

environment, there is a government tax policy t_1^* , making $\frac{\Delta_1}{\Delta_2}(t_1^*) = \text{opt} \frac{\Delta_1}{\Delta_2}$. At this time, the technology input of environmental protection enterprises can guarantee its first-mover advantage.

Proving: Because of $\frac{\partial \gamma}{\partial \gamma} \frac{\gamma}{2} = \frac{1}{2} > 0$ and $\frac{\partial}{\partial \gamma} \frac{4-\gamma^2}{2\gamma} = -\frac{8+2\gamma^2}{4\gamma^2} < 0$, when the degree which

consumers neglect environment increases, the tax policy space $\left(\frac{\gamma}{2}, \frac{4-\gamma^2}{2\gamma}\right)$ reduces;

Because of $\frac{\gamma}{2} < \text{opt} \frac{\Delta_1}{\Delta_2} < \frac{4-\gamma^2}{2\gamma}$ and $(1 - \text{opt} \frac{\Delta_1}{\Delta_2})\alpha + \text{opt} \frac{\Delta_1}{\Delta_2} \times [(1 + \eta_2)c_2 + f] - (1 + \eta_1)c_1 > 0$,

the tax policy of government $t_1^* > 0$. For any $0 < \gamma < 1$, there always is $\frac{4-\gamma^2 + \gamma\sqrt{4-2\gamma^2}}{2\gamma + 2\sqrt{4-2\gamma^2}} >$

$\text{opt} \frac{\Delta_1}{\Delta_2}$. According to proposition 1, environmental protection enterprises have the first-mover advantage.

If $\delta_2 = \alpha - (1 + \eta_2)c_2 + \eta_1 t_1$ and $g(\gamma) = \frac{16+16\gamma-4\gamma^2-6\gamma^3-\gamma^4}{2(8+8\gamma-2\gamma^2-3\gamma^3)}$, under balanced circumstances, the input amount of ecological compensation funds of environmental protection enterprises is:

$$f^* = \left| \delta_2 - \frac{\Delta_1}{g(\gamma)} \right|_{t_1^*} \quad (15)$$

Conclusion 1: In the early stage of ecological compensation development, the optimal environmental tax policy t_1^* of government supporting the environmental protection industry can guarantee the first-mover advantage of environmental protection enterprises and the ecological compensation input of enterprises f^* is proportional to t_1^* .

Conclusion 2: The input amount of ecological compensation funds of environmental protection

enterprises is proportional to constant marginal cost of polluting enterprises c_1 and the waste formation rate of the unit production η_1 . And it is inversely proportional to constant marginal cost of an enterprise c_2 and the waste formation rate of the unit production η_2 .

Conclusion 3: The input amount of ecological compensation funds of environmental protection enterprises is proportional to the degree γ which consumers neglect environment.

As can be seen from the above conclusions, the optimal amount of capital investment of environmental protection enterprises for ecological compensation depends not only on energy conservation and emission reduction of itself as well as competition enterprises, but also on the policy support for ecological compensation. At the same time, it is limited by the public's understanding and acceptance for ecological compensation. Therefore, when providing financial support for the enterprise ecological compensation, financial institutions should consider the profitability stability of enterprise and the establishment of a comprehensive review system.

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