Game Analysis on the Government's Economic Subsidy in Regional Environmental Protection

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Abstract. From the perspective of game theory, this paper analyzed the promotion effect of government subsidy policy on environmental governance. Three main results were obtained as follows. 1. A positive effect is achieved when the government increases the amount of penalties imposed on companies and uses fines as a reward subsidy to environmental companies. Such policy can not only improve the probability of pollution control by enterprises, but also enable the government to reduce the regulatory costs in environmental issues. 2. When government departments choose small enterprises for environmental protection subsidies, they can not only greatly increase the probability of pollution control by enterprises, but also increase the complexity of government supervision. 3. The government needs to strengthen supervision to maintain the high probability of pollution control by enterprises.

1 Introduction

China achieved recognized astonishing success in economy in the past 40 years. But the other side of the coin is the escalating environmental problem including serious environmental pollution and ecological damage. This not only restricts the development of our country's economy, but also threatens the public's life, health and social stability and unity, and becomes a great obstacle to the development of a harmonious society.

There are many reasons for the current bad environmental situation, which have been expounded by many scholars. Huang and Wang [1] discussed the reasons by mathematics modeling. From their point of view, one of the economic reasons is that environmental resources are a kind of scarce public resources, which are non-competitive and non-exclusive in consumption. Moreover the motive of enterprise seeking profit, the reason of individual leads to the overuse of natural resources and the destruction of environment. Ren etc. [2] concluded that the source of environmental problems lies in the lack of environmental resources and the overuse of environmental resources. Zhang etc. [3] built a cost-benefit decision model to explore the fundamental causes of pollution.

Game theory, which originated with the pioneering work of von Neumann and Morgenstern [4] in 1944, is a mathematical tool for analyzing and resolving allocation problems related to conflicting interests. Game theory has been applied to a variety of areas, including economics and social sciences. For more details see [5] and [6]. It has also been used in environmental management. Many scholars use game models to analyze the relationship between environmental pollution and the

interests involved in the process of governance. Based on the mathematic modelling, Wang [7] made a game analysis of enterprises 'pollution control and government control, and put forward some suggestions to strengthen environmental protection. Sun and Zhi [8], through the analysis of the choices among the subjects, concluded the following solution. Firstly, the public needs to improve the enthusiasm of participation. Secondly, the enterprises need low cost environmental protection equipment and technology. Lastly, the government should increase the punishment. Wang and Li [9], by game modeling, explained the causes of environmental problems. They also used the dynamic game model of Stackelberg for further analysis. Zhang and Zhang [10] discussed energy saving and emission reduction especially as an example and established the government signal game model to analyze the equilibrium solution. This solution showed that the government should open the standards of emission reduction and subsidy and improve the transparency to guide the market actively. It also provided the basis and reference for the government to make relevant policies.

From the perspective of the long-term interests of the world, Heikkio.K. [11] stressed the importance of cooperation among countries, opposed the focus on short-term profits while ignoring the long-term benefits that lead to vicious competition, and called for the development of clean energy. By establishing a dynamic game model across time, Steffen [12] analyzed the environmental pollution situation from the perspective of economic management. Walls and Palmer [13] studied the modelling of enterprise, public and government. Their work also focus on the design, the principle and the evaluation standard of government environmental

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policy Kwerells [14] pointed out that under the tradable license policy, the cost of pollution control would be maliciously amplified by the enterprise, while the cost of pollution control would be misrepresented by the enterprise.

Environmental resource is a kind of scarce public resource, which has non-competitive and non-exclusive consumption. Most of the environmental problems are caused by the irregular economic behavior of people. As an important executor and leader of environmental protection work, regional governments play a crucial role in environmental protection. In addition to formulating necessary environmental protection policies and adjusting economic levers to regulate corporate behavior, regional governments can also use appropriate administrative interventions to exert some economic pressure through external coercion to better regulate and guide people's production behavior. The administrative intervention mainly includes the revocation of business licenses and the collection of a certain proportion of environmental protection taxes and sewage charges, severe sanctions for some enterprises that damage and pollute the environment.

Subsidies sometimes occur as negative taxes in problems of optimal taxation. This could be considered as a technicality when the focus is on taxation, not subsidies. Subsidies are offered as incentives for encouraging decision makers to take environmentally favorable actions. Zhang and Li [15] demonstrated the importance of establishing the government subsidy policy and optimizing the government guidance mechanism by comparing the pollution data of different provinces in China.

We note that in the game literature, only a few papers are concerned with subsidies as the primary environmental policy instrument [16-18]. Krawczyk and Zaccour [16] analyzed the environmental impact and budget implications in a context where the local government (Stackelberg leader) implemented constant subsidy and tax rates. Krawczyk and Zaccour [17] allowed for time-varying tax and subsidy rates and introduced a third instrument for the government. The model did not allow for a closed-form characterization of Stackelberg equilibrium strategies The authors of [18] also designed a decision-support system for the local government. This system is helpful in the assessment of the impacts on agents' payoffs of politically "acceptable" subsidy and cleaning effort policies. Chen and Hong [19] studied the optimal subsidy problem in Green Building Market from the perspective of policy benefit, in which the government and the end-user were the principals and the developer was their agent. They established optimal subsidy principal-agent models under conditions of asymmetric information and complete information. Their results showed that, from the perspective of policy benefits, subsidy policy is influenced by construction costs, transfer paid by the end-user and developer's preference toward green buildings.

This paper analyzeas this point of view through noncooperative game models.

2 The game of economic subsidy between government and enterprise in regional environmental protection

As rational economists, the business goal of enterprises is to pursue the maximization of their own interests. Therefore, a series of violations may occur in the course of business operations, such as excessive emissions. Moreover, under the conditions of market mechanism, enterprises will not consciously solve external environmental problems. In the production process, enterprises will receive far more benefits than the cost of pollution control, so they will choose to increase production and reduce governance.

Because of the inextricable links between the performance of local government and the income of local enterprises in the regional economy, such as the increase in the production of enterprises can increase the local government's tax revenue, which makes the government have the incentive to take the neglect in the face of the illegal pollution of enterprises. So that the implementation of environmental protection measures is blocked and the purpose of sustainable development is not reached. In order to maximize their own interests, various stakeholders will conspire and restrict, which has a major impact on environmental pollution and environmental governance. In terms of investment in improving environmental issues, it is impossible to expect investment returns in the short term. Because of the reasons for saving costs and obtaining short-term benefits, enterprises have no incentive to protect the ecological environment. At this time, the government must give certain environmental protection subsidies to enterprises to guide companies to protect the environment.

2.1 The game between government and enterprise without subsidy

Assumptions:

(1) The probability of the government conducting market supervision is γ , and the cost of supervision is K

⁽²⁾The probability of pollution control by enterprises is θ , and the cost is C_1 .

⁽³⁾The probability that the government can find the enterprise pollution is $p(0 \le p \le 1)$, the penalty amount is f, the cost of the enterprise shirking the responsibility of pollution control is $C_2 = pf$.

(1) Modelling:

Participant: the government department that carries out environmental supervision, the sewage enterprise that undertakes pollution control.

Strategy: Government strategy $S_1 =$ (regulation, no regulation).

Enterprise strategy $S_2 =$ (governance, no governance). The corresponding payment matrix is shown in table 1.

	governance ($\boldsymbol{\theta}$)	no governance $(1 - \theta)$
regulation	$-K, -C_1$	pf - K, - pf
no regulation $(1 - \gamma)$	0, - <i>C</i> ₁	0, 0

The government's payment function is

$$\pi_{g}(\gamma,\theta) = \gamma \left[-\theta K + (1-\theta)(pf-K)\right]$$
(1)

The enterprise's payment function is

$$\pi_{p}(\gamma,\theta) = \theta\left[-\gamma C_{1} - (1-\gamma)C_{1}\right] + (1-\theta)(-\gamma pf)$$
⁽²⁾

(2) Model solution

In the above payment Matrix, if K > pf, namely, the government regulatory costs are too high, there is a unique Nash equilibrium solution (no regulation, no governance). When pf > K. At this point, the model is a strategic game model. There is no pure strategic Nash equilibrium, and the Mixed strategic Nash equilibrium solution can be solved.

The optimal first order conditions of government and enterprise are:

$$\partial \pi_g / \partial \gamma = -\theta K + (1 - \theta) (pf - K) = 0$$
$$\partial \pi_g / \partial \theta = -C_1 + \gamma pf = 0$$

The Mixed strategic Nash equilibrium solution is:

$$\gamma^* = C_1 / pf, \theta^* = 1 - K / pf \tag{3}$$

(3) Analysis of results

The above equilibrium solution shows that when the variable value is certain, the higher the cost of pollution control, the more the government needs to strengthen supervision. The higher the cost of government regulation, the more companies tend to opt out.

2.2 Game model between government and enterprises with environmental subsidy

1). Government subsidies to all enterprises

(1) Modelling

On the basis of the above basic game model, we proceed with the assumption that:

In order to guide enterprises to clean up environmental pollution, the regulatory government will strengthen the punishment of polluting enterprises, the amount of the penalty will be increased to the maximum $f_1(f_1 > f)$, and the fines of polluting enterprises will be used to set up a subsidy fund. For all market-related enterprises, the environmental governance subsidy is given. The amount of the subsidy is *S*, then the game payment matrix is table 2:

Table 2. The payment matrix of the government-enterprise
game.

	Governance (θ)	no governance $(1 - \theta)$
$\begin{array}{c} \text{Regulation} \\ (\gamma) \end{array}$	$-K-s, -C_1+s$	$pf_1 - K - s ,$ - $pf_1 + s$
no regulation $(1 - \gamma)$	0,- <i>C</i> ₁	0,0

(2) Model solution

The government's payment function is

$$\pi_{g}(\gamma,\theta) = \gamma \left[-\theta(K+s) + (1-\theta)(pf_{1}-K-s)\right]$$
(4)

The enterprise's payment function is

$$\pi_{p}(\gamma,\theta) = r[\theta(-C_{1}+s) + (1-\theta)(-pf_{1}+s)] - \theta(1-r)C_{1} \quad (5)$$

The optimal first order conditions of government and enterprise are:

$$\partial \pi_g / \partial \gamma = (1 - \theta) p f_1 - K - s$$

 $\partial \pi_p / \partial \theta = -C_1 + \gamma p f_1$

The Nash equilibrium solution is:

$$\gamma^{**} = C_1 / pf_1, \theta^{**} = 1 - (K + s) / pf_1$$
(6)

(3) Analysis of results

Comparing formula (3) and (6), we can obtain that

$$\gamma^{**} < \gamma^*, \theta^{**} > \theta^*$$

Thus, when the government increases the amount of punishment to enterprises, and the fine as an incentive subsidy to environmental enterprises, will bring a positive effect: first, it can improve the probability of pollution control enterprises ($\theta^{**} > \theta^{*}$); Secondly, the decrease in the probability of government regulation shows that the government can properly reduce the cost of supervision on environmental issues.

2). Government subsidies to small businesses

(1) Modelling

In the market not all enterprises have the ability to control pollution, only those powerful large enterprises have the capital to apply it. So the government supports small enterprises and gives environmental subsidies, and these small enterprises are the ones that choose not to govern in the game model, at this time the average governance probability for all enterprises in the market.

Then the government's payment function is

$$\pi_{g}(\gamma,\theta) = -r\theta K + r(1-\theta)(pf - K - s)$$
(7)

The enterprise's payment function is

$$\pi_{p}(\gamma,\theta) = -r\theta C_{1} + r(1-\theta)(-pf+s) - (1-r)\theta C_{1} \qquad (8)$$

(2) Model solution

The optimal first order conditions of government and enterprise are:

$$\partial \pi_g / \partial \gamma = (1 - \theta)(pf - s) - K$$

 $\partial \pi_p / \partial \theta = -C_1 + r(s - pf)$

The Nash equilibrium solution is:

$$\gamma' = C_1 / (pf - s), \theta' = 1 - K / (pf - s)$$
 (9)

(3) Analysis of results

Comparing formula(3), (6) and (9), we can obtain that $\gamma^{**} < \gamma^* < \gamma', \theta^{**} > \theta^* > \theta$. Thus, when government departments choose small enterprises to carry out environmental subsidies, it can not only produce positive effects, but also increase the complexity of government regulatory work. This is reflected in two aspects: First, the enterprise can greatly improve the probability of pollution control($\theta^{**} > \theta^* > \theta'$); Second, the government needs to strengthen supervision to maintain the high probability of pollution control.

3 Conclusion

Environmental protection subsidies are mainly used to subsidize the treatment of pollution sources that cause environmental pollution. The Government provides environmental subsidies to enterprises that are inevitably contaminated, reduces the cost of pollution control, and enables the enterprises concerned to have the capability and motivation to control pollution and protect the environment.

We should also recognize that protecting the environment is a systematic project and that it needs to be carried out with the strength of the whole society. We have noticed that some enterprises and residents are not aware of environmental protection and do not have enough motivation to control pollution or protect the environment. They are the main body of the market, and their behavior directly affects the environment we live in. Therefore, it is necessary to study the game relationship between government, enterprises and residents in environmental protection; In the process of regional economic development, the cost of governance of environmental problems is too high. Local governments and the central government have a game of "wisdom pigs", which leads to the policy of the central government can not be carried out well. Therefore, it is necessary to study the game relationship between the central government and local governments in environmental protection; The implementation of environmental policy will inevitably be accompanied by corruption, which causes the failure of the environmental governance function and the worsening environment. Therefore, it is necessary to study the relationship between relevant stakeholders in environmental governance. The next step is to analyze and discuss these issues using game theory.

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