Restriction Mechanism Design for Realizing Governments' Target for the Energy Conservation and Emission Reduction Program

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Abstract—The final aim for the energy conservation and emission reduction program is to reduce energy waste and control pollutants emission. This paper studied a restriction mechanism for the realization of governments' target for the energy conservation and emission reduction program from the perspective of game theory. In view of information asymmetry between the two parties governments and enterprises, this paper built non-zero-sum game models, based on which strategies were presented and strategy mixes were analyzed, and methods for determining penalty coefficient enacted by governments and national average seized ratio for illegal pollutant emissions were formulated. This paper provided an operable theoretical basis for governments to formulate reasonable penalty coefficient which is used to punish those enterprises that conduct non-abatement actions.

Keywords-energy conservation and emission reduction; restriction mechanism; influencing factors; energy-saving target; government punishment

I. INTRODUCTION

Energy-saving and cost-reducing is an important strategic policy for long-term development of economy and society in China. National Development and Reform Commission (NDRC) pointed out in the *Comprehensive Work Program for Energy Conservation and Emission Reduction during the 12th Five Year Plan* that by 2015, energy consumption per GDP would dive to 0.869 ton standard coal per ten thousand Yuan, which declined dramatically by 16% than 2010; the total amount of discharge for national oxygen demand and sulfur dioxide would be controlled no more than 23,476,000 ton and 20,864,000 ton respectively, which drops by 8% than 2010; the total amount discharge for ammonia nitrogen and nitrogen oxide emission would be controlled no more than 2,380,000 ton, 20, 462, 000 ton, which falls off 10% than 2010. As early as in May 2006, the state of China signed a target liability statement with local governments on the guideposts for wastewater pollutants for the first time in the history. Responsibility system was disassembled and tasks are assigned from provinces, cities, counties, villages to enterprises which discharge pollutants. However, it is still an intensive and complex question that what kind of mechanism should be adopted to ensure governments at all levels to play their due responsibilities, in order to realize target for the energy conservation and emission reduction program.

Some western countries levied such taxes as "Pigovian tax" or "Pigovian fee" to restrain enterprises' environment pollution actions. Those taxes provide basic frameworks for the governments to take part in the ecological environmental management by enforcing relevant laws, regulations and institutions[1-4]. In China, scholars established principal-agent models and excitation functions for linear payment contracts, then solved the models on the basis of government utility original value maximization method, got the optimal government fixed subsidy and motivation intensity factors, and at last put forward a series of countermeasures so as to promote the development of enterprises' energy conservation and emission reduction program[5]. This paper studied a motivation mechanism for the energy conservation and emission reduction program in China from the game theory perspective[6-10], and proposed some constructive suggestions for governments and enterprises in order to motivate the enterprises to participate in the program immediately and provide references for the attainment of the target of the energy conservation and emission reduction program .

II. CONSTRUCTION OF NON-ZERO-SUM GAME MODEL FOR ENTERPRISES

Economic subjects participating in market economic activities in the market-oriented economy have equal market positions. Their economic relationships are filled with equal-value exchanges and relatively fair competition.

As the main market players, enterprises should make their economic strategies with discretion in light of their pursuits for economic benefits maximization, fierce competition situation and the natural law of "survival of the fittest". They try their best to improve their service or goods quality and reduce economic cost in order to occupy more market shares and make themselves have more competitive edge in the marketplace.

Suppose that there are two identical enterprises A and B in a market, and both of them are faced with the problem how to make choices for the energy conservation and emission reduction program. At this time, the information in the game is complete, and enterprises A and B are two game agents for a complete information game. Given benefits of two enterprises R, the cost for non-abatement of the energy conservation and emission reduction program C_1 which includes expenses used for bribing governments' inspectors and expenses for counterfeit, benefits gotten from non-abatement of the program is T, then there is $T > C_1$. If both enterprises conduct the energy conservation and emission reduction program, their benefits are R; if both enterprises refuse the implementation of the program, their net earning is $R+T-C_1$; if one of them choose the implementation of the program and the other does not, the latter will get the net earning $R+T-C_1$ plus the market share which is denoted as benefits S captured from the former because the latter can invest the saved cost into the market or occupy more market share in the manner of selling at a reduced price. Therefore, the enterprise avoiding the program can gain the net earning $R+T-C_1+S$, while the enterprise adopting the program can gain the net earning $R-S$. The specific payoffs for the two parties involved are shown below as the table 1.

TABLE I PAYOFF MATRIX BETWEEN THE TWO ENTERPRISES

		Enterprise B	
		avoiding the program	**adopting the program**
Enterprise A	**avoiding the program**	$R+T-C_1$, $R+T-C_1$	$R+T-C_1$, $R-S$
	adopting the program	$R-S$, $R+T-C_1+S$	R，R

From the table 1, we can draw the conclusion that the enterprise avoiding the implementation of the program will gain more payoffs than the one adopting the program. There is a pure strategy Nash equilibrium in the game model, that is, enterprise A avoiding implementing the pollutants emission program and company B avoiding the implementation of the program either. Thus it can be seen that if it is possible for an enterprise to avoid implementing the program, it will choose non-abatement policy as long as it is rational.

III. CONSTRUCTION OF NON-ZERO-SUM GAME MODEL BETWEEN ENTERPRISES AND GOVERNMENTS

Suppose player A in the game is governments, and player B is enterprises, then the strategy set for the player A is { A_1 = inspection， A_2 = non-inspection}, and the strategy set for the player B is { B_1 = abatement， B_2 = non-abatement}. The implication for relevant parameters are as follows.

x : the probability for governments inspection ($0 \le x \le 1$);

y : the probability for enterprises abatement ($0 \le y \le 1$).

m : the administrative expense paid by enterprises;

∂ : the punishment coefficient when governments find out enterprises' non-abatement activities.

c_t : the cost for governments' inspection to taxpayers $c_t = c_t(x)$. The cost for inspection rises with the increasing inspection probability, but at a low increasing speed, that is, $c_t'(x) > 0, c_t''(x) < 0$.

k : the discovery rate for enterprises' non-abatement ($0 < k \le 1$).

c_s : the non-abatement cost for enterprises. The non-abatement cost includes expenses used for bribing governments' inspectors and counterfeit cost.

The non-abatement cost increases with the rising of the administrative expenses, and the more the administrative expenses are, the more expenses used to briber the inspectors. The non-abatement expense increase rapidly with the high-speed increasing administrative expense, that is, $c_s'(m) > 0, c_s''(m) < 0$.

δ : the proportion of governments' inspection cost to the enterprises' administrative cost which satisfies the equation $c_t = \delta km$.

β : the proportion of enterprises' non-abatement cost and administrative cost.

From the payment of player A and player B in table 1, it draws a conclusion that the payment of player A is the sum of inspection cost and tax loss, and the payment of player B is its illegal payoff.

- when government A chooses the option of inspection and enterprise B chooses the pollution abatement policy, the tax loss for the government A can be denoted as c_t, and the illegal payoff for the enterprise B is zero.

- When the player A does not choose the inspection option and B chooses to carry out the pollution abatement, the tax loss for the player A is zero, and the illegal payoff for the player B is zero as well.
- When the player A inspects the player B, and B does not implement the energy conservation and emission reduction program, if A by chance finds out the illegal activity of B, B will be punished by government A for the total sum of $c_t = \alpha km$ and the inspection cost paid by A, so the tax loss for A is $-\alpha km + (1-k)m + c_t$. In this case, the party B has to carry out the pollution abatement program immediately which costs km, and also pays for the punishment $c_t = \alpha km$, and tax evasion cost c_s. Therefore, the illegal payoff for the party B can be denoted as $-\alpha km + (1-k)m - c_s$.
- When the party A does not inspect at all and the party B adopts non-abatement policy, the illegal payoff of B becomes $m - c_s$.

TABLE II PAYMENT MATRIX FOR NON-ZERO-SUM GAME MODEL BETWEEN ENTERPRISES AND GOVERNMENTS

		Government A	
		inspection	**Non-inspection**
Enterprise B	**abatement**	（0，c_t）	（0，0）
	Non-abatement	（$-\alpha km + (1-k)m + c_t$， $-\alpha km + (1-k)m - c_s$）	（$m - c_s$， m）

IV. SOLVING NON-ZERO-SUM GAME

Given $X = (x, 1-x), Y = (y, 1-y)$ are the mixed strategies for player A and player B, then

$$\begin{cases} Q = c_t - [-\alpha km + (1-k)m + c_t] - 0 + m = (1+\alpha)km > 0 \\ q = m - [-\alpha km + (1-k)m + c_t] = (1+\alpha)km - c_t \end{cases}$$

and

$$\begin{cases} R = 0 - [-\alpha km + (1-k)m - c_s] - 0 + m - c_s = (1+\alpha)km > 0 \\ r = m - c_s \end{cases}.$$

In view of $Q > 0, R > 0$, three balance points of the game model are

$(x, y) = (0, 0)$,

$(x, y) = (\frac{1-\beta}{(1+\alpha)k}, 1 - \frac{\delta}{1+\alpha})$,

and $(x, y) = (1, 1)$.

The mixed strategies for solving the game is $[(0,1),(0,1)];[(\frac{1-\beta}{(1+\alpha)k}, 1-\frac{1-\beta}{(1+\alpha)k}),(1-\frac{\delta}{1+\alpha}, \frac{\delta}{1+\alpha})];[(1,0),(1,0)]$.

The optimal result for the game is that $(E_1, E_2) = (m, m - c_s); (\frac{c_t}{(1+\alpha)k}, 0); (c_t, 0)$.

V. ANALYSIS ON STRATEGY CHOICES

At the second balancing point $(\frac{1-\beta}{(1+\alpha)k}, 1 - \frac{\delta}{1+\alpha})$, the expected loss for the government is $\frac{c_t}{(1+\alpha)k}$. The probability for enterprise's non-abatement of the program policy is denoted as $\frac{\delta}{1+\alpha} \in [0,1]$, thus there is $\frac{c_t}{(1+\alpha)k} = \frac{\delta km}{(1+\alpha)k} = \frac{\delta m}{(1+\alpha)} \le m$. The inspection probability for the government $\frac{1-\beta}{(1+\alpha)k} < \frac{1}{(1+\alpha)k} (0 \le \beta < 1)$, namely, the up limit for inspection probability is $\frac{1}{(1+\alpha)k} \le 1$, so there is $\frac{c_t}{(1+\alpha)k} = \frac{1}{(1+\alpha)k} c_t \le c_t$, and then $\begin{cases} \frac{c_t}{(1+\alpha)k} \le m \\ \frac{c_t}{(1+\alpha)k} \le c_t \end{cases}$.

Therefore, the government had better choose the second strategy $x = \frac{1-\beta}{(1+\alpha)k}$. The information asymmetry of $c_s(m)$ results in the uncertainty of β, but the up limit for inspection probability is $\frac{1}{(1+\alpha)k} \le 1$, so the government inspects the enterprise with the probability of $x \le \frac{1}{(1+\alpha)k}$. The economic significance for government's strategy choice is that if the government conducts sample inspection to taxpayers with the probability $x \le \frac{1}{(1+\alpha)k}$, and the expected loss reaches maximum. Meanwhile, enterprises choose non-abatement strategy with the probability of $y = \frac{\delta}{1+\alpha}$.

In fact, the first strategy (A pollution abatement, B non-inspection) is impossible, and it is unnecessary for governments to inspect all the enterprises in the third strategy (A non-abatement, B inspection) for the reasons that the inspection cost is too large and sample inspection and overall inspection have the same economic effects.

The expected payoff for enterprises if they choose non-abatement strategy with the probability $y = \frac{\delta}{1+\alpha}$ is denoted as below.

$$\Pi = [-\alpha km + (1-k)m - c_s(m)]x + [m - c_s(m)](1-x)$$
$$= m - (1+\alpha)kmx - c_s(m)$$

Enterprises choose game strategies in accordance with profit maximization, so the maximum first-order and second-order conditions for expected payoffs are

$$\begin{cases} \Pi' = 0 \\ \Pi'' < 0 \end{cases},$$

that is, $\begin{cases} c_s'(m) = 1-(1+\alpha)kx \\ -c_s''(m) < 0 \end{cases}$.

If $\begin{cases} -c_s'(m) \ge 0 \\ c_s'(m) = 1-(1+\alpha)kx \end{cases}$,

then $x \le \frac{1}{(1+\alpha)k}$.

The above formula shows that if $x \le \frac{1}{(1+\alpha)k}$, enterprises choose the second mixed strategy, namely, non-abatement of the policy with the probability of $y = \frac{\delta}{1+\alpha}$.

If $x > \frac{1}{(1+\alpha)k}$, enterprises have two choices, the first mixed strategy (A pollution abatement, B non-inspection) and the third mixed strategy (A non-abatement, B inspection). It is known that governments refrain enterprises from choosing the first mixed strategy. Therefore, enterprises have no choices but choose the third mixed strategy pollution abatement policy.

When governments make sample inspections for enterprises with the probability $x = \frac{1}{(1+\alpha)k}$, the expected loss for enterprises is maximized. In this case, enterprises had better choose pollution abatement strategy.

In conclusion, the punishment coefficient formula under the circumstance of non-zero-sum game between governments and enterprises is $\alpha = \frac{1}{kx} - 1$.

VI MAIN SUGGESTIONS FOR RESTRICTION MECHANISM CONSTRUCTION

It is concluded from the restriction mechanism game for the energy conservation and emission reduction policy as below.

This paper took asymmetric information between governments and enterprises into consideration, constructed non-zero-sum game models, analyzed the results, and pointed out the determining methods for punishment coefficient and discovery rate. A solid foundation is made for governments to make reasonable punishment coefficient.

Firstly, without government participation, the optimal strategy for enterprises is to choose non-abatement policy. For the enterprise A and enterprise B in a market, no matter which strategies they choose, their optimal game strategy is non-abatement policy. In this way, the net earning for the enterprise is as much as $R+T-C_1$. In addition, the enterprise may gain more profits on the condition of the other enterprise's pollution abatement choice by reducing cost, expanding brand advertisement, and occupying more market share S. Therefore, enterprises can increase their economic payoffs without implementing the energy conservation and emission reduction program.

Secondly, after governments formulate the generalized punishment coefficient for tax evasion, the audit departments at all levels can publish the inspection probability for their inferior inspection institutions according to the tax evasion discovery rate k and national generalized punishment coefficient A, in order that the inferior inspection institutions integrate inspection human resources and improve structure.

Thirdly, the national generalized punishment coefficient in accordance with the punishment coefficient formula, the audit departments in governments should conduct the punishment in the mode of penalty when finding out illegality activities, which will be helpful to prevent enterprises from the non-abatement policy and improve the implementation of the Energy Conservation and Emission Reduction Program.

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