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Study on Emission Permits Trading Model under the Differentiated Supervision Cost

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Abstract: Emission trading mechanism as an important factor to measure the efficiency of regional emission trading market, it related to the rational use of environmental capacity, the rationality of regional industrial development, as well as regional environmental control objectives and so on, the reasonable design of trading mechanism directly determines the regional emission trading practice effect. In this study, on the basis of a reasonable definition of environmental capacity, builds regional emissions trading model and establishes a emission rights trading supervision mechanism led by the government considering the regional economic structure and benefit of each participant body, through the analysis of the emission trading efficiency under different regulatory cost , the paper concludes that the relevant government departments should be play a role in macro-control and market management, encourage enterprises to actively participate in the transaction, to continuously reduce transaction costs and constantly improve the level of emission monitoring and improve the trading punishment system, in order to prevent enterprises in the transaction market fraud and the emergence of monopoly power due to the emission trading.

Key words: Emission permits trading, model, supervision cost

INTRODUCTION

According to the research on the mechanism of emission trading market, domestic and foreign scholars' researches focus mainly on the foundation of the emission trading price formation mechanism. But according to emission trading practice in Europe and the United States, the emission trading usually chooses two forms: Namely the sealed auction mechanism and the multilateral trading system. Some research results are considered that the superiority of sealed auction mechanism can not be replaced by other methods in the study: (1) Determine the price of emission trading and for emission trading by using auction, to ensure that all enterprises can participate in the market, to prevent a handful of large enterprises' monopoly behavior of emission rights (Grether *et al*., 1989; OECD, 2001). (2) Auction can be a real reflection of the price of emission rights and to ensure its stability, in order to facilitate the enterprises control pollution. Ledyard and Szakaly-Moore (1994) pointed out that emission trading by auction model is optimal in the study, for it can solve the political feasibility problems in the process of emission trading policy implementation.

Hahn and Stavins (2000) have studied the revenue-neutral auction; they pointed out that aggregate demand curve and the inelastic supply curve intersection is the market clearing price, clear market prices and competitive pricing method can guarantee market fairness, but this method is easily lead to market monopoly power. Plott (1991) analyzed the multi-item double auction mechanism which can satisfy both parties for continuous bids of more emission trading, with the characteristics of one-off transition and transaction at the same price, its trading system is highly organized. Ledyard and Szakaly-Moore (1994) further study has shown that double auction mechanism has the market continuity, each stage transaction can make a bargain at different prices, two sides can make price corrections. Cramton and Kerr (2002) pointed out the simple auction is most close to Vickery auction, the operation is easy, it can motivate disadvantaged bidders participate in the auction which is the most appropriate auction way of emission trading. Because the market is not perfectly competitive market and the existence of market power, so the Viceroy auction is difficult to emerge in reality, can not achieve allocation of resources Pareto optimal.

From the emission trading practice all over the world, government cost and transaction supervision cost is obviously an important factor affecting the emission trading. In the different cost constraints, enterprise behavior reaction with different, its fundamental purpose is to seek the enterprise profit maximization in a given space.

MODEL AND BASIC ASSUMPTIONS

Assumptions: Those involved in emissions trading are heavy pollution enterprises, enterprises pollution control cost function is based on a quadratic function of emission

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amount, so with the increase in emission amount, the marginal cost of enterprises pollution control is increasing first and decreasing after, with the growth of sewage cost, enterprises will weaken the willing of pollutant emissions, so as to continually reduce the enterprises emission amount. In some region, there are n manufacturers producing homogeneous goods, the production is: x_1, x_2,⋯, x_i,⋯, x_{n-1}, x_n. When n = 1, illustrate that the sewage industry is monopolized production industry; when $n\to+\infty$, illustrate that it is perfectly competitive industry. The inverse demand function of the enterprise i in the product market is x = t-yQ, t represents the size of the market, y means the price elasticity of demand, the industry total production volume is:

$$Q=\sum_{1}^{n}x_i$$

the total emission amount of all enterprises productions is $x = \theta Q$ $(0<\theta<1)$, means that the levels of pollutants products, x represents that enterprises production pollutant gross. Where μ_t means the enterprises emission total amount through free distribution and market trading. $(x-\mu_t)$ means that the amount of entering the pollutant treatment plant which meets the discharging standard after treatment. $X_{(m)}$ represents after government invest cost of pollution control m, the environment self-cleansing ability on pollutants, namely the maximum amount of environment endorsement on some pollutants, that is to say regional environmental capacity. That is the government is for protection and conservation of the environment by the investment management fees m, then when you discharge pollutants $x_{(m)}$ into the environment, the environmental conditions will not deteriorate.

We can get that $x_{(m)}$ is a decreasing function about m:

$$\frac{\partial x(m)}{\partial m}<0\frac{\partial^2 x(m)}{\partial m^2}<0$$

when m = 0, $x_{(m)}$ represents that the self-purification capacity of the environment itself when there is no government funding. Suppose that the pollutants from the enterprises into treatment plant parts $(x-\mu_t)$, pollutant control costs are met and can be expressed as $\beta(x-\mu_t)$ (β means the average pollution control cost in the industry regions).

MODEL BASED ON INDUSTRY COST-REVENUE EMISSION TRADIN MECHANISM

When there is no government supervision, the corporate emission behavior is not restricted, the emission cost is zero. When there is government supervision, the enterprise emission is divided into two parts: the first part is to enter the treatment plant for harmless disposal, discharge after treatment, the cost is per unit β; the other is the distribution and trading emission rights in the emission trading market which can discharge without any treatment.

Analysis from the perspective of the government, the government is in pursuit of minimum social cost, that is to say enterprise sewage and pollution control are minimum impact on social production.

With the following equation:

$$\min TC = \min (F_{(X)}+G_{(x)}-T_{(x)} \quad (1)$$

where, $F_{(x)}$ is the reduction of the total social output in the implementing emissions trading mechanism. The expression of $F_{(x)}$ is:

$$F_{(x)} = \Delta U \quad (2)$$

where, $G_{(x)}$ represents the management cost of enterprise discharge pollutants. The expression of $G_{(x)}$ is:

$$G_{(x)} = \beta(x-\mu_t)+m+g \quad (3)$$

where, $T_{(x)}$ represents the government net income by the trading center repurchase and transact emission rights, its expression is shown as follows:

$$T_{(x)} = p_S\sum_{i=1}^{n}w_i - p_i\sum_{i=1}^{n}\varepsilon_i\delta\overline{w}_{(T-1)} \quad (4)$$

Equation 1-4 are taking sulfur dioxide as an example. In Eq. 3, m represents that the amount of government investment funds for the environment protection, G_i represents the regulatory costs in order to ensure the effective implementation of emission rights trading, ε_i means the proportion of the remaining emission amount in low pollution enterprises accounted for its entire free allocation amount of emission rights.

From the viewpoint of enterprise, the pursuit of enterprise is to maximize their benefit; its expression is shown as follows:

$$\max U = \max\sum_{1}^{n}u_i \quad (5)$$

where, U means industry overall benefits, u_i is the benefit of enterprise c.

MODEL ANALYSIS UNDER DIFFERENT REGULATORY COSTS

- When the government doesn't regulate Enterprise sewage emission behavior.

Under these circumstances, the benefit of enterprise i is:

$$\frac{\partial u_i}{\partial q_i} = 0$$

it shows that the optimal production of enterprise:

$$q_i = \frac{t - y\bar{q}}{2y}$$

is i and $\bar{q} = Q - q_i$ when $q_1 = q_2 = \ldots = q_i = \ldots = q_n$ Revenue is equilibrium.

At this point, the optimal production of the entire industry is:

$$Q = \sum_1^n q_i = \frac{nt}{(n+1)y} \tag{6}$$

The total pollutant emission for the industry is:

$$x = \frac{\theta nt}{(n+1)y} \tag{7}$$

In the industry, enterprises total profit is:

$$U_1 = \sum_1^n u_i = \frac{nt^2}{(n+1)^2 y} \tag{8}$$

Without supervision of the government of the state, emission trading mechanism fails, emission rights trading is zero, That is as follows: $T_{(x)} = 0$, $F_{(x)} = 0$.

At this time, the total social cost is:

$$\begin{aligned} TC_1 = G_{(x)} &= \beta(x - \delta\bar{w}_{T-1}) + m \\ &= \frac{\beta n\theta t}{(n+1)y} - \beta\delta\bar{w}_{T-1} + m \end{aligned} \tag{9}$$

and we can get the formula as follow:

$$\begin{aligned} \frac{\partial u_1}{\partial n} &= \frac{yt^2(n+1)^2 - 2yt^2 n(n+1)}{y^2(n+1)^4} \\ &= \frac{yt^2(1-n^2)}{y^2(n+1)^4} \end{aligned} \tag{10}$$

because $n \geq 1$, so:

$$\frac{\partial u_1}{\partial n} \leq 0$$

we can get the following equation:

$$\frac{\partial TC_1}{\partial n} = \frac{\beta\theta ty(n+1) - \beta\theta tyn}{y^2(n+1)^2} = \frac{\beta\theta ty}{y^2(n+1)^2} \tag{11}$$

Then we get:

$$\frac{\partial TC_1}{\partial n} \succ 0$$

So when the Government has taken no regulatory strategy, with the increase in the number of enterprises, the reduction of the industry total benefit, the total social costs will be increased.

How to understand the results of the practical significance? In fact, as the number of entering the industry increases, the emission trading in the absence of government regulation will lose its original resource regulation, because there is no regulation, no punishment, enterprise to avoid pollution discharge right exchange cost increases, the rational choice is to avoid the emission trading, direct discharge of pollutants, so the environment pollution increased significantly, increased social cost.

- When the presence of regulatory costs, emissions trading and corporate self-pollution exist at the same time

The analysis is based on the difference between the costs. Government's cost function is:

$$TC = \beta(x - \mu_t) + m + \Delta U + G_i - T_{(x)} \tag{12}$$

- When the costs of regulation tends to 0, the market is mature enough, Government regulatory policies and systems have been very sound, Punitive measures against the phenomenon of severe waste-water treatment is strong, Sewage enterprises consciously abide by guidelines. In this case, the optimal production of the entire industry is:

$$Q_0 = \frac{t + 2\theta\beta w}{2y + 2\theta^2\beta} \tag{13}$$

The expression of total pollutants generated by all businesses is:

$$x_0 = \frac{\theta t + 2\theta^2\beta w}{2y + 2\theta^2\beta} \tag{14}$$

At this point, assuming the pollution generated by pollution enterprises is SO_2, according to price mechanism under the emissions trading market, then the emission rights trading price of SO_2 is P_s, if we know, the amount of emission rights initially allocated of each enterprise is:

$$w_1 = \sum_1^n \delta\bar{w}_{T-1} \tag{15}$$

where, $\bar{w}_{T-1}$ is the average emission of enterprises in the previous year in industries h, δ is the free distribution coefficient for the initial allocation of emission rights. The full cost for the enterprises to purchase emission rights:

$$p_s(0.6\bar{w}_{T-1}-\delta\bar{w}_{T-1})+\frac{1}{\lambda_s}p_s(\delta\bar{w}_{T-1}+w-0.6\bar{w}_{T-1}) \tag{16}$$

We can get all the sewage industry's total revenue for the enterprise:

$$\begin{aligned}U_0&=(t-yQ_0)Q_0-\beta(x-\mu_t)-p_s(0.6\bar{w}_{T-1}-\delta\bar{w}_{T-1})\\&+\frac{1}{\lambda_s}P_s(\delta\bar{w}_{T-1}+w-0.6\bar{w}_{T-1})\\&=\frac{t+2\beta\theta\mu_t}{2y+2\beta\theta^2}\left(t-\frac{yt+2y\beta\theta\mu_t}{2y+2\beta\theta^2}\right)\\&-\beta\left(\frac{\theta t+2\beta\theta^2\mu_t}{2y+2\beta\theta^2}-\mu_t\right)-p_s(0.6\bar{w}_{T-1}-\delta\bar{w}_{T-1})\\&+\frac{1}{\lambda_s}p_s(\delta\bar{w}_{T-1}+w-0.6\bar{w}_{T-1})\\&=\frac{(ty+2t\beta\theta^2-2y\beta\theta\mu_t)(t+2\beta\theta\mu_t)}{(2y+2\beta\theta^2)^2}\\&-\frac{\beta(t\theta-2y\mu_t)^2}{(2y+2\beta\theta^2)^2}-p_s(0.6\bar{w}_{T-1}-\delta\bar{w}_{T-1})\\&+\frac{1}{\lambda_s}p_s(\delta\bar{w}_{T-1}+w-0.6\bar{w}_{T-1})\end{aligned} \tag{17}$$

The total social costs are the total representation of available enterprise sewage treatment costs, the cost of purchasing emission rights, environmental protection investment, the reduction of production costs.

Assuming that the amount of emission rights of the firm received does not exceed $0.6\bar{w}_{T-1}$ then we get:

$$F_{(x)}=\Delta,\ G_{(x)}=m+\beta(x-\mu_t) \tag{18}$$

$$T_{(x)}=p_S\sum_{i=1}^{n}w_i-p_1\sum_{i=1}^{n}\varepsilon_i\delta\bar{w}_{(T-1)} \tag{19}$$

We may have environmental objective function:

$$\begin{aligned}TC_0&=F_{(x)}+G_{(x)}-T_{(x)}\\&=m+\frac{nt^2}{(n+1)^2y}+\frac{\beta(t\theta-2y\mu_t))^2}{(2y+2\beta\theta^2)^2}\\&+\frac{(ty+2t\beta\theta^2-2y\beta\theta\mu_t)(t+2\beta\theta\mu_t)}{(2y+2\beta\theta^2)^2}\\&+\Delta U-T_{(x)}\\&=m+\frac{nt^2}{(n+1)^2y}+\frac{\beta(t\theta-2y\mu_t))^2}{(2y+2\beta\theta^2)^2}\\&+\frac{(ty+2t\beta\theta^2-2y\beta\theta\mu_t)(t+2\beta\theta\mu_t)}{(2y+2\beta\theta^2)^2}\\&+\Delta U-p_S\sum_{i=1}^{n}w_i-p_1\sum_{i=1}^{n}\varepsilon_i\delta\bar{w}_{(T-1)}\end{aligned} \tag{20}$$

Compared with the total social cost:

$$\begin{aligned}TC_1=G_{(x)}&=\beta(x-\delta\bar{w}_{T-1})+m\\&=\frac{\beta n\theta t}{(n+1)y}-\beta\delta\bar{w}_{T-1}+m\end{aligned}$$

government of no regulation, can be the difference between them was:

$$\begin{aligned}\Delta TC&=TC_0-TC_1\\&=\frac{nt^2}{(n+1)^2y}+\frac{\beta(t\theta-2y\mu_t))^2}{(2y+2\beta\theta^2)^2}\\&+\frac{(ty+2t\beta\theta^2-2y\beta\theta\mu_t)(t+2\beta\theta\mu_t)}{(2y+2\beta\theta^2)^2}\\&+\Delta U-p_S\sum_{i=1}^{n}w_i-p_1\sum_{i=1}^{n}\varepsilon_i\delta\bar{w}_{(T-1)}\\&-\frac{\beta n\theta t}{(n+1)y}-\beta\delta\bar{w}_{T-1}\end{aligned} \tag{21}$$

And then:

$$\Delta TC\prec 0,\ \frac{\partial TC_0}{\partial n}\prec 0,\ \frac{\partial U_0}{\partial t}\succ 0,\ \frac{\partial TC_0}{\partial t}\prec 0,\ \frac{\partial U_0}{\partial y}\prec 0,\ \frac{\partial TC_0}{\partial y}\succ 0,\ \frac{\partial U_0}{\partial\theta}\prec 0,\ \frac{\partial TC_0}{\partial P_s}=0,\ \frac{\partial U_0}{\partial n}=0$$

thus, $\Delta TC\prec 0$, sewage market with government regulation and emissions permits trading mechanism, the total costs of the industry is significantly lower than the total social costs of unregulated state:

$$\frac{\partial U_0}{\partial t}\succ 0,\ \frac{\partial U_0}{\partial y}\prec 0,\ \frac{\partial U_0}{\partial\theta}\prec 0$$

in the market with the implementation of emissions trading mechanism, the total revenue function of sewage companies is an increasing function on the size of the market, a decreasing function about discharge coefficient of the unit product and product price elasticity of demand:

$$\frac{\partial TC_0}{\partial P_S}=0$$

it shows, enterprises through the purchase of emission rights does not the total social costs from the price of emission rights:

$$\frac{\partial U_0}{\partial n}=0$$

in the market with the implementation of environmental regulation and emissions trading , the sewage industry and sewage companies total revenue is independent of the number.

This result suggests that the government should play an important role in the emission trading market, in the absence of constraint in the market, a large number of enterprise profit increase profits in the short term and long term has increased social cost at. In emissions trading, the government for necessary system construction is favorable, a large number of enterprises must follow the

rules and the laws of the market competition, common in other words, the emissions trading market and also can only be effective government regulation under the sustained and healthy development.

CONCLUSION

- When the market trading costs and regulatory fees are very low, government through a comprehensive monitoring system to monitor sewage companies

When emissions trading market business a certain amount of emissions rights, it can reduce the total social costs and reduce pollutant emissions, can effectively improve the efficiency of pollution control industry, does not affect the total revenue of the society and will not format monopoly power to the emission rights and the industry is in an open state, new businesses join and leave unaffected. So, at this time, emissions trading market maturity is higher, mechanisms are efficient.

- When the cost of sewage market regulation is too large, in the follow formula:

$$\min TC = \min(F_{(x)}+G_{(x)}-T_{(x)}) = \beta(x-\phi_t)+\Delta U+G_i-T_{(x)} \quad (22)$$

the higher G_i is, it shows that the emissions permits trading market is in the pilot phase, the regulatory system is not perfect, in order to ensure the effective operation of emissions trading market, it is necessary to eliminate sewage companies candid behavior, we must increase investment in the construction of the regulatory system, Coupled with the regulatory techniques and tools also need to continue to improve which have increased regulatory fees of the emissions trading pilot phase.

- When $G_i>>|\Delta TC|$, It proves that Emission Trading increase the social costs and this process is inevitable, as the emissions trading mechanisms and regulatory systems continue to mature, emission rights will continue to reduce transaction costs, regulatory costs will decrease with technologies continue to make a progress. When G_i, = $|\Delta TC|$ the cost is the same whether Government regulation or not, emissions trading system is in the development phase, transaction costs and regulatory costs continue to reduce as the system and technology improve

When $G_i<|\Delta TC|$, at this point, emissions trading mechanism and operation mode of supervision have been developed, various social costs and companies emissions reduce, the level of social pollution raises, emissions trading to show fairness and efficiency, this is a maturity stage of the emissions trading mechanism.

In this study, from the point of the regional unit efficiency in an pollution emissions trading market, it analyzes the initial allocation of emissions trading in the way of the government distributed for free and government pricing transactions, combining theory and practice of Chinese regulatory system of emissions trading operational status, from the perspective of the industry total social costs and total revenue and the introduction regulatory costs as a measure factor of the maturity of the market, do some research on government pricing transactions about the secondary market price of emission rights. It turns out when market transaction costs and regulation fees are very low, the government can through a comprehensive monitoring system to monitor the actions of the Emission Trading of the sewage enterprises, by adjusting the surplus amount of margin emissions trading and it can reduce the total social costs and reduce pollutant emissions, thereby improving the efficiency of environmental pollution.

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