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Incentive Mechanism of Enterprises Energy-saving and Emission Reduction Based on Rank Order Tournaments

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Abstract

The article establishes the analytical framework of incentive mechanism and the rank order tournaments model that based on the relative performance for developing energy-saving and emission reduction by using the theory of principle-agent and the Malcomson model. We systematically analyzes the model, and proposes the corresponding policy suggestions.

Key words: energy-saving and emission reduction; rank order tournaments; incentive mechanism; principal-agent

1. Introduction

With the acceleration of industrialization process, socialization large production based on technology and machine brings great wealth to mankind, but consumes many fossil resources and weakens carrying capacity of environmental. All countries in the world start moral reflection on impaction of economic development to nature, and realize that energy-saving and emission reduction is best plan of solving the conflicts among environment, resources and economic development. The development goal of enterprises in China usually focused on reducing costs, increasing production or pursuing maximize profits, and seldom consider the effective utilization of resources. The current research literatures main focus on how to improve energy-saving and emission reduction policy supporting, Wu Liya(2003) proposed that government should levy the production tax for monopoly industries and modify the external diseconomies of natural monopolies through intervention[1]; Shi Jianhua (2004) studied the financial and tax policy of

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promoting energy-saving and emission reduction[2]; Ni Hongri (2005) suggested that gradually raise the rate of consumption tax on petrol, or levy extra petrol tax in order to raise energy price gradually[3]. Research literatures on the incentive mechanism for energy saving and emission reduction is still quite inadequate. Therefore, the writer establishes the analytical framework of incentive mechanism and the rank order tournaments model that based on the relative performance for developing energy saving and emission reduction by using the theory of principle-agent and the Malcomson model, and systematically analyzes the model, finally want to provide the corresponding theory basis.

2. Model construction on incentive mechanism of enterprises' energy-saving and emission reduction.

Rank order tournaments that based on the relative performance explains the principal-agent theory from the angle of competition, In the rank order tournaments mechanism, each agent's income is only relate with the sequence, and is not directly related to degree of absolute effort. m agents have m prize $w_i(i=1,2,\cdots m)$,$w_1 \geq w_2 \geq \cdots \geq w_m$, the agents with the best performance receives w_1, the second agents receives w_2, the last one receives w_m, and so on. The article establishes the incentives mechanism model on enterprises' energy-saving and emission reduction based on this idea and research literature [4-5].

2.1 Principal-agent relationship on energy-saving and emission reduction incentive

Principal-agent relationship is a contractual relationship that Principal entrust agents to complete some work and corresponding granted some decision-making power to the agents. Principal is granting side, the agent is the action side. But in the principal-agent relationship, it is possible that principal does not keep the contract promises, principal also has a "moral hazard." If there is a rank order tournament which means a certain proportion of agents will obtain a higher return, then the dominant choice of the principal will be pay the higher return to an agent of the higher performance, because it promotes agents to work hard. The dominant strategy of agent will also be work hard to strengthen incentives. For the principal-agent problem on energy-saving and emission reduction, the agent is incentive target, namely enterprises; the principal is incentive main, namely government.

2.2 Construction of incentive model on enterprises' energy-saving and emission reduction

2.2.1 Model assumptions

①There are some many same types of enterprises in a region.

②The other all are same in addition to method of energy-saving and emission reduction for all enterprise, and no game between enterprises.

③In a certain period, each enterprise can get subsidies policy formulated by the local government on energy-saving and emission reduction, the time is divided into two stages, indicated by $t=1,2$.

④The utility function of generated by energy-saving and emission reduction is $U(a_1, w_1,a_2,w_2)$,which a_t is expressed as the efforts level of energy-saving and emission reduction in t period, w_t is expressed as policy or financial support that the government has given enterprise according to efforts effect in t period ,Nature assumed that $\partial U/\partial a=Ua<0$, $\partial U/\partial w=U_w>0$, $\partial^2 U/\partial a_2=U_{aa}<0$, $\partial^2 U/\partial w_2=U_{ww}<0$,. The reservation utility of each enterprise is $\bar{U}$.

⑤The utility function on output level of each enterprise's energy-saving and emission reduction observed by government within the region in t period is assumed as:

$$\pi_t = a_t + \varepsilon_t, \quad t=1,2 \qquad (1)$$

π_t is the output of each enterprise's energy-saving and emission reduction observed by government, which can use indicators such as carbon emission reduction rate to measure, ε_t is a random disturbance

that mean be zero, which can be expressed as the government's observation error to enterprises' efforts level of energy-saving and emission reduction, a_t is expressed as each enterprise's efforts level of energy-saving and emission reduction.

⑥It is assumed that $F(\varepsilon_t)$和$f(\varepsilon_t)$ respectively are the distribution function and density function of ε_t, so the distribution function and density function of π_t is respectively are $F(\pi_t-a_t)$ and $f(\pi_t-a_t)$ if a_t is set down. It is assumed that whether the government provides support or subsidies for enterprise in the region, there is a minimum efforts level a_0 of energy-saving and emission reduction, and assuming that a minimum efforts level of energy-saving and emission reduction is given as $a> a_0$, or enterprise will not enjoy the preferential policy support of incentives mechanism.

2.2.2 Construction of Model

If enterprises can not confirm the output effect π_t of energy-saving and emission reduction, the incentive contract that the government paying subsidies for enterprise according to π_t is unfeasible. Because of $U_a<0$, so fixed subsidies can not encourage enterprises to choose efforts level more than $\underline{a}$. As follow, the paper will give rank order tournaments based on the relative performance, through which encourage enterprises in the region to energy-saving and emission reduction.

⑴1 - Phase contract designing

When the efforts level of enterprises' energy-saving and emission reduction is $a\geq a$, the support or subsidies that enterprises will gain is w_L or w_H $(w_L<w_H)$, and the percentage of enterprises that gain support or subsidy w_H is P. As long as the percentage of enterprises that gain w_H can be conformed, the contract is enforceable. Because π_t and a_t is positive correlation, as long as the enterprise gaining w_H is observed as the enterprise that efforts level of energy-saving and emission reduction be large, the contracts can encourage enterprises to energy-saving and emission reduction, which is because that the financial budget and policy for energy-saving and emission reduction provided by government is fixed, the average support or subsidies that each enterprise within the region expect to is equal to $Pw_H+(1-P)w_L$, the total amount of financial support pay by the government is $nPw_H+n(1-P)w_L=n[Pw_H+(1-P)w_L]$, n is the total number of enterprises within the region. So the dominant strategy of government is to pay high subsidies for the enterprises of which effect of energy-saving and emission reduction being better.

The government need formulate a "high performance" standard π^* before attract enterprise to take part in competition of energy-saving and emission reduction. The government will give enterprises high support or subsidies w_H under the circumstance of $\pi_t \geq \pi^*$, other enterprises will only obtain low support or subsidies w_L, the probability of enterprises' performance $\pi_t \geq \pi^*$ will be $1-F(\pi^*-a_t)$ when efforts level of energy-saving and emission reduction is a_t, There is the following formula when n is enough large

$$P=1-F(\pi^*-a_t) \quad (2)$$

⑵2 - Phase contract designing

In the 2 - Phase contract, P percentage of enterprises obtain high support or subsidies w_H in the second Phase, the other enterprises obtain low-support or subsidies w_L. The enterprises will accept the contract when only the expected utility is not less than the reservation utility $\bar{U}$ according to participation constraint. The enterprises work for w_1 in Phase 1 when accept the constraint. They will be special cared if the government observed that the output of enterprises efforts as $\pi_1 \geq \pi^*$, and enterprises will obtain support or subsidy w_H in phase 2. Otherwise the enterprises will not be special cared, enterprises will obtain support or subsidy w_L in phase 2. $\overline{w}$ is government reserves support that enterprises not taking part in competition on energy-saving and emission reduction, let $w^*_2=max\{w_L, \overline{w}\}$. On deciding the efforts level a_1 of energy-saving and emission reduction in phase 1, the enterprises will obtain support or subsidies w^*_2 in Phase 2 if they can not be special cared. $w_H > w^*_2$ is naturally assumed, otherwise the special care is meaningless. It is assumed that the phenomenon of special care not occur after the phase 2, then $a_2=a$. The expected utility for the enterprise is

$$V(a_1,w_1,w^*_2,w_H,\pi^*)=F(\pi^*-a_1)U(a_1,w_1,\underline{a},w^*_2)+[1-F(\pi^*-a_1)]U(a_1,w_1,\underline{a},w_H) \quad (3)$$

The first term on right end of formula (3) corresponds to the case that enterprises not be special cared, the second term on right end corresponds to the case that enterprises be special cared. Enterprises select a_1 that maximize the formula (3) in phase 1, $a_1 \geq \underline{a}$ is the constraints condition. When the interior point solution exists, the first order conditions are:

$$\partial V/\partial a_1=-f(\pi^*-a_1)U(a_1,w_1,\underline{a},w^*_2)+F(\pi^*-a_1)U_{a1}(a_1,w_1,\underline{a},w^*_2)+f(\pi^*-a_1)U(a_1,w_1,\underline{a},w_H) +[1-F(\pi^*-a_1)]U_{a1}(a_1,w_1,\underline{a},w_H)=0 \quad (4)$$

When such a solution is only one, $a^*_1=r(w_1,w^*_2,a,w_H)$, there is the following formula

$$a_1=\max\{a^*_1,a\} \quad (5)$$

a_1 of formula (5) is the efforts level that enterprises selecting in phase 1. Let's analyze that w_1, w^*_2, w_H and π^* how to affect the optimal choice a_1 then. In the formula (2), contract dose not directly give π^* but provide P, by which to decide π^*. It is assumed that there is many enough enterprises in the region, namely n is large enough that single enterprise not considering influence of their choice on efforts level of energy-saving and emission reduction to π^*.The enterprise will think π^*as given in selecting a_1, P by formula (2) will in turn affect the efforts level of enterprises' energy-saving and emission reduction; other variables such as w_1,w_L and w_H are also similar. It is assumed that the utility function U has the property of time additive and separable, that is,

$$U(a_1,w_1,\underline{a},w_H)=U'(a_1,w_1)+U^2(\underline{a},w_H) \quad (6)$$

It may been known from the formula (4) that a^*_1 meeting the following equation

$$V_1=\partial v(a_1,w_1,w^*_2,w_H,\pi^*)/\partial a_1=0 \quad (7)$$

$\partial a_1^*/\partial x=-(\partial v_1/\partial x)/(\partial v_1/\partial a_1)$ can be gain according to implicit function theorems and formulas (7), x may be any variable among w_1, w^*_2, w_H and π^*.,then P will be used to replace π^*. The follow formula can be gain according to the formula (4) and formula (7) .

$$V_1=-f(\pi^*-a_1)[U^2(\underline{a},w_H)-U^2(\underline{a},w^*_2)]+F(\pi^*-a_1)U'_{a1}+[1-F(\pi^*-a_1)]U'_{a1} =f(h(P))[U^2(\underline{a},w_H)-U^2(\underline{a},w^*_2)]+U'_{a1}(a_1,w_1) \quad (8)$$

The follow formula can be gain according to the formula (2) ,formula (4) and formula (8).

$$\partial a_1^*/\partial w_1=\partial r/\partial w_1=-(\partial V_1/\partial w_1)/(\partial v_1/\partial a_1)=-(\partial U'/\partial w_1)/(\partial U'/\partial a_1)=-U_{12}/U_{11} \quad (9)$$

$$(\partial a_1^*/\partial w_1=-U_{12}/U_{11}\geq 0,\ U_{12}\geq 0;\ \partial a_1^*/\partial w_1=-U_{12}/U_{11}<0,\ U_{12}<0)$$

$$\partial a_1^*/\partial w_2^*=\partial r/\partial w_2^*=-(\partial V_1/\partial w_2^*)/(\partial v_1/\partial a_1)=+f(a^*-a_1)U_4/U_{11}<0 \quad (10)$$

The value of U_4 can be gain from w^*_2

$$\partial a_1^*/\partial w_H=\partial r/\partial_H=--f(\pi^*-a_1)\,U_4/U_{11}>0 \quad (11)$$

The value of U_4 can be gain from w_H

$$\partial a_1^*/\partial P=\partial r/\partial_H=(-f(\pi^*-a_1)((d\pi^*-da_1)/dP)(U^2(\underline{a},w_H)-U^2(\underline{a},w_2^*))/U_{11} \quad (12)$$

$$\partial a_1^*/\partial P\geq 0,\ if f'(\pi^*-a_1)\leq 0;\ \partial a_1^*/\partial P<0,\ if f'(\pi^*-a_1)>0;$$

It is assumed to $w_H > w^*_2$, and if $w_H = w^*_2$, then $\partial a_1^*/\partial P=0$

3. Analysis of incentive mechanism model on enterprises' energy-saving and emission reduction

3.1 Analysis of incentive mechanism model

Formula (9) means that $U_{12}=0$ and $\partial a_1^*/\partial w_1=0$ will be gain when the effect and the effort level in the utility function being additive. Apparently w_1 isn't affected by a^*_1; Formula (10) $\partial a_1^*/\partial w_2^*<0$ means that the increase of retain support or subsidies $\overline{w}$ and low subsidies or support w_L in phase 2 will reduce the optimal efforts levels of energy-saving and emission reduction; Formula (11) $\partial a_1^*/\partial w_H>0$ means that the support or subsidy w_H special cared the higher, the effort of enterprise' engaging in energy-saving and emission reduction the more; Formula (12) means that enterprises' response is not monotonous to the percentage P special cared and supported by the government. When the percentage special cared and

supported lead to $f'(\pi^*-a_1)<0$, a^*_1 rise accompanied by P rise, which means that the possibility special cared and supported by the government the larger the effort of enterprise' engaging in energy-saving and emission reduction the more. But when the percentage special cared and supported beyond certain declining critical point, we know that π^*-a_1 be small enough by the formula (2), $f'(\pi^*-a_1)$will normally be more than zero, a^*_1 decrease accompanied by P rise. The means of above analysis is that: the excessive higher or lower reward proportion will not mobilize the enthusiasm of enterprises engaging in energy-saving and emission reduction.

3.2 Government (social) return produced by enterprises' energy-saving and emission reduction

Government can not simply consider the economic benefits, but also considering the environmental and social benefits in the process of regulating social and economic development. If each enterprise within the region is committed to energy-saving and emission reduction, on the one hand, which can increase the energy efficiency and reduce carbon dioxide emissions to achieve good environmental benefits; the other hand, which can promote enterprises to technology innovation and improve production efficiency to achieve good economic returns? Energy-saving and emission reduction can increase income levels across the whole region, reflected such as the form of the environmental benefits and taxes. Therefore, the government revenue here referring means that an enterprise energy saving benefits to the entire region (including the environmental and economic benefits) minus the balance of government subsidies. The government's expecting revenue from each enterprise are:

$$\pi(w_1,w_L,w_H,P)=h(w_1,w_L,w_H,P)-w_1+\beta(\underline{a}-Pw_H-(1-P)w_L), if\ w_L\geq\overline{w}$$
$$\pi(w_1,w_L,w_H,P)=h(w_1,w_L,w_H,P)-w_1+\beta P(\underline{a}-w_H), if\ w_L<\overline{w} \quad (13)$$

Among formula (13): $a^*_1=h(w_1,w_L,w_H,P)$, β is the enterprise's discount factor. The problem of the government becomes that how to choose (w_1,w_L,w_H,P) for making expected profit $\pi(w_1,w_L,w_H,P)$ maximization, and for meeting $U\geq\bar{U}$and $0\leq P\leq 1$. In real life, the government is representative of the whole region interests, as long as the payments balance may be maintained (environmental benefits can translate into economic benefits), the rank order tournament can be implemented. Therefore, for making $\pi(w_1,w_L,w_H,P)\geq 0$ on choosing (w_1,w_L,w_H,P), the government can implement the rank order tournament.Of course, the government can choose 1 -phase fixed subsidy contracts. The efforts level of enterprise's energy-saving and emission reduction in two phases within the region is $\underline{a}$, the Government expected profit is:

$$\pi(w_1,w_2)=\underline{a}-w_1+\beta(\underline{a}-w_2),\ w_2\geq\overline{w}\ ;\ \pi(w_1,w_2)=\underline{a}-w_1,\ w_2<\overline{w} \quad (14)$$

This contract is equivalent to the situation of $P=0$ in 2-phase contract. The 2-phase contract must be better than the contract. The optimal 2-phase contract will be strictly better than the fixed support or subsidy contracts when expected return selecting $0<P<1$ is greater than expected return of $P=0$. The expected return of 2 -phase contract will be strictly greater than the expected return of the fixed support or subsidy contracts $(0<P<1, w_H>w_2^*)$ as long as the marginal utility U_4 of income obtaining from energy-saving and emission reduction in the second phase is greater than the marginal utility change rate U_{11} of energy-saving and emission reduction in the first phase. In other words, according the comparative static analysis of enterprises' optimization phenomenon, $-U_4/U_{11}$will decide that a1 how to rise with the w_H increase for any $0<P<1$ given. If $-U_4/U_{11}$ is large enough, the increase of a_1 (then π_1) will be able to make up for cost $w_H-w_2^*)$ of additional support or subsidies supplied by the government.

4. Conclusion

According to the construction and analysis on incentives mechanism models of enterprises' energy-saving and emission reduction, some notion matters can be deduced:(1) The central government should

increase the intensity of financial transfer payments to support local energy-saving and emission reduction, should allocate special funds for promoting energy-saving and emission reduction(2)The local government should set up a special incentive fund of energy saving and emission reduction and implement financial budget management, the environmental subjects should been established in the expenditures subject of local financial budget, the funds should been special charged to support enterprises' technology innovation on energy-saving and emission reduction and the use of renewable energy.(3)The local governments should construct hierarchical policy support or financial subsidies which to form the ladder-like support structure, should special support a small number of enterprises with better energy-saving and emission reduction effect within the region. (4)The local government should establish a evaluation criteria of incentive that according to the efforts level of implementing energy-saving and emission reduction activity rather than enterprise's operating size, profitability and enterprise qualification within the region. The enterprise with better energy-saving and emission reduction effect should been special supported and cared in such policies as finance, taxation, procurement, credit by the local government.

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References:

[1] Wu Liya. Speed up Reform and Development of Natural Gas Industry in China[J]. Natural Gas Industry, 2003(6):4～7(in Chinese)

[2] Shi Jianhua. Measures and Reference on Supporting the Energy-Saving of Using Financial and Tax Policy in Foreign Countries [J]. International Taxation in China,2004(10): 50~53(in Chinese)

[3] Ni Hongri. A Study on Tax Policies of Economizing Energy Use[J]. Taxation Research, 2005(9):3～6(in Chinese)

[4] Lazear E.p., and Rosen, S., "Rank-order Tournaments as Optimum Labor Contracts", Journal of Political Economy, vol.89(1981),p 841~864

[5] James M. Malcomson.Work Incentives, Hierarchy and Internal Labor Markets[J]. The Journal of Political Economy , 92 (1984) :p486~ 507