Research on the Chinese Fossil Energy and New Energy Subsidy Policy from the Perspective of Game Theory

Ju Keyi¹, Li Changle^{2,*}

^{1,2} School of Economics and Management, Jiangsu University of Science and Technology, Zhenjiang, Jiangsu 212000, China

*Email:1728178105@qq.com

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ABSTRACT

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At present, despite the government have higher subsidies for the energies, the efficient energy subsidies are not adequate. In this paper, Cournot game was built based on the government subsidies for fossil energy and new energy power generation enterprises, about electricity production from fossil energy and new energy enterprises and market prices using the game analysis. The subsidies according to relationship of size among national level of carbon emissions M_0 and fossil energy carbon emission levels M_1 and new energy carbon emission levels M_2 , can be classified three situation: $M_0 > M_1 > M_2, M_1 > M_0 > M_2, M_1 > M_2 > M_0$. Then compare three situations, so that provide basis and reference for the government subsidies.

1. Introduction

Planning for its 13th Five Year Plan put forward seven major strategic task: increasing energy production at home, pressing ahead with energy conservation, optimizing energy structure, vigorously develop hydro, nuclear, wind, solar and geothermal, encouraging international energy cooperation, promoting the innovation of energy technological and system, improving energy supervision. The target is find a right balance between energy security, efficiency and cleaner, achieve the sustainable energy development.

(Lin et al, 2016)¹studies prove that China has been reducing energy subsidies since 2013 and subsidies have been fully cancelled at financial sense to 2015. Nevertheless, not only cross-subsidy still very serious but also mountains of coal consumption caused high externality environmental cost, makes energy subsidies in the aspect of externality environmental cost still exist. Thus it can be seen that we are still a long way to go in the process of elimination energy subsidies.

At present, there already had some references have discussed the game question between government, fossil energy and new energy in the subsidies. (Zhu and Dou 2011)²established a three-stage game model of that considered product green level and government subsidies analysis in the green supply chain management, and through numerical simulation discussed the effects of various parameters. (Liu 2013)³under the condition of reasonable supposition, the government and enterprises income opportunity function of developed new energy industries determines their developing wishes. When Nash Equilibrium strategies are both government and business develop new energy industries, can make social welfare maximizing. (Zhang et al 2014)⁴explored government and business strategies choice and dependence change in the course of energy conservation and emissions reduction application and issue through signal game. Then using MATLAB made numerical simulation to verify the effectiveness of the model. (Zhang 2014)⁵after by analysis of collusion between government and firms, they think that establish a more comprehensive, much dimensional examination index and give full play inquiries and supervision of the public and medium can effective restrict collusive behaviors. (He and Wang 2014)⁶focused the subjects of the game on the government and the low carbon supply chain core enterprise, and analyzed the costs and gains of both government and core enterprise under the different game strategies. Then constructed the dynamically evolutionary game model, and acquire the evolutionarily stable strategy of monitor game between the government and enterprise. (Hammond D · Beullens P 2007)⁷established the Cournot game model based on whole

information, analyzed function in reverse supply chain management about wasted electrical and electronic equipment directive(WEEE directive) of the government especially the European Union.(Rui Zhao and Gareth Neighbour 2012)⁸ put forward a strategy choices of manufacturers use game theory analysis under the background of green supply chain management, to reduce the life cycle of materials and carbon emissions of environmental risk.

Overall, on content, existing researches are mainly focused on the questions of subsidies rationality or not and role of how, subsidies times, subsidies types. On the microscopic level, multitudinous researches for these questions like government subsidies and concrete behaviors in specific areas. In this paper, for different carbon emission standards were used to classify reviewed studies. Aimed at elaborate analysis the fossil fuels and new energy subsidies of changes when unit of carbon emissions subsidies line change.

2. Model Building

2.1 Model Assumes

This research mainly contains two enterprises: fossil energy (producer 1) and new energy (producer 2) enterprises. In the process of electricity generation, fossil energy produced by the unit of carbon emissions is higher than new energy. But because of fossil energy generation enjoys mature technology, new energy generation technology is not mature, so fossil energy costs less than new energy power generation costs. Set unit cost respectively C_1 and C_2 , so $C_2 > C_1$. Through the above understanding, this paper based on the assumptions:

- (1) The power on the market is mainly provided by fossil energy and new energy.
- (2) Two-type enterprises are simply obeys relevant policy-systems by government.
- (3) Electricity price adopt sales price, and there is no difference in the electricity price.
- (4) Government revenue is the synthesis of enterprises benefits, government subsidies and taxes.
- (5) Direct subsidies to new energy t_2 is greater than the direct subsidies for fossil fuels t_1 , so $t_2 > t_1$.
- (6) Fossil energy unit carbon emissions M_1 is greater than the new energy unit carbon emissions M_2 , so $M_1 > M_2$.

2.2 Model Building

Cournot game was applied in this study, fossil energy generating capacity for q_1 and new energy generating capacity for q_2 . Set market inverse demand function for

$$P = P(Q) = a - bQ = a - b(q_1 + q_2), [a > 0, b > 0].$$

In this paper, state subsidies on fossil energy and new energy consist of two parts: direct subsidies to the enterprises, additional subsidies to the enterprises according to the unit carbon emissions. Subsidies size and unit carbon emissions exists linear correlation. National unit of carbon emission levels for M_0 , when enterprise unit carbon emissions than M_0 , need to tax; when enterprise unit carbon emissions than M_0 , need to subsidies.

3. Solve Model under Different Situation

3.1 Situation 1: $M_2 < M_1 < M_0$

The first situation: government subsidies for enterprise of unit carbon emissions less than M_0^A (to distinguish the different situation of M_0 , here with M_0^A ; unit of the coefficient of subsidies for t_0), at this moment, $M_1 < M_0^A$, $M_2 < M_0^A$, revenue function is:

$$\begin{aligned} \pi_1 &= q_1 [P(q_1 + q_2) - C_1 + t_1 + t_0(M_0^A - M_1)] \\ \pi_2 &= q_2 [P(q_1 + q_2) - C_2 + t_2 + t_0(M_0^A - M_2)] \end{aligned} ;$$

3.1.1 The optimal equilibrium output

Both producers choose their optimal equilibrium output, for the first order derivatives equal to zero, namely:

$$\begin{cases} \frac{\partial \pi_1}{\partial q_1} = a - bq_2 - C_1 - 2bq_1 + t_1 + t_0(M_0^A - M_1) = 0 \\ \frac{\partial \pi_2}{\partial q_2} = a - bq_1 - C_2 - 2bq_2 + t_2 + t_0(M_0^A - M_2) = 0 \end{cases}$$

To :

$$\begin{cases} q_1^{C1} = \frac{a - 2C_1 + C_2 + 2t_1 - t_2 + t_0(M_0^A - 2M_1 + M_2)}{3b} \\ q_2^{C1} = \frac{a - 2C_2 + C_1 + 2t_2 - t_1 + t_0(M_0^A + M_1 - 2M_2)}{3b} \end{cases}$$

3.1.2 The effects of variables on the equilibrium

The first derivative of $t_1, t_2, t_0, M_1, M_2, M_0^A$ for q_1^{C1} and q_2^{C1} , we can draw:

- (1) Direct subsidies is proportional to the output; fossil energy enterprise have the higher unit carbon emissions M_1 , the smaller market share; for t_0 , when $2M_1 > M_0 + M_2$, the first order derivatives is less than 0. So, with the increase of t_0 , fossil energy generating capacity will be reduced, this means that it will promote the development of new energy; when $2M_1 < M_0 + M_2$, the first order derivatives is more than 0. So, with the increase of t_0 , fossil energy generating capacity will increase, this means that it will restrain the development of new energy.
- (2) New energy enterprise has the higher unit carbon emissions M_2 , the smaller market share; for t_0 , when $2M_2 > M_0 + M_1$, the first order derivatives is less than 0. So, with the increase of t_0 , new energy enterprise generating capacity will decrease; when $2M_2 < M_0 + M_1$, the first order derivatives is more than 0. So, with the increase of t_0 , new energy enterprise generating capacity will increase.

Therefore, whether fossil energy or new energy enterprise, only reduce the unit carbon emissions as much as possible, is an important way to acquire more government subsidies and expand market occupancy.

- (3) If countries cancel direct subsidies for energy t_1 and t_2 , through the

optimal equilibrium solution can be obtain: New energy power generation decrease; for fossil energy enterprises, when $2t_1 > t_2$, electrical generating capacity is decreased, when $2t_1 < t_2$, electrical generating capacity is increased. But because of social gross generation reduce, thus, the government should be appropriate to adjust the size of t_0 after cancel the direct subsidies, so that meet the demand of social overall power generation.

3.1.3 The optimal market price

In this situation, according to the market inverse demand function can get the optimal price:

$$P_1 = \frac{a + C_1 + C_2 - t_1 - t_2 - 2t_0M_0^A + t_0M_1 + t_0M_2}{3}$$

Thus we can see that if countries cancel direct subsidies for energy, will cause the electricity prices. Because $2M_0^A > M_1 + M_2$, the first order derivatives of t_0 is less than 0, so, the size of the t_0 is inversely proportional to the market price of electricity.

Combined with the above formulas available the maximum benefit of fossil energy and new energy enterprises respectively:

$$\pi_1^{C1} = q_1^{C1} [P_1 - C_1 + t_1 + t_0(M_0 - M_1)];$$

$$\pi_2^{C1} = q_2^{C1} [P_1 - C_2 + t_2 + t_0(M_0 - M_2)]$$

3.2 Situation 2: $M_2 < M_0 < M_1$

The second situation: government subsidies for enterprise of unit carbon emissions less than M_0^B (to distinguish the different situation of M_0 , here with M_0^B), when enterprise of unit carbon emissions more than M_0^B , the government to the enterprise tax (the unit tax coefficient r). At this moment, $M_0^B < M_1, M_2 < M_0^B$, revenue function is:

$$\begin{aligned} \pi_1 &= q_1 [P(q_1 + q_2) - C_1 - r(M_1 - M_0^B)] \\ \pi_2 &= q_2 [P(q_1 + q_2) - C_2 + t_2 + t_0(M_0^B - M_2)] \end{aligned}$$

3.2.1 The optimal equilibrium output

Both producers choose their optimal equilibrium output, for the first order derivatives equal to zero, namely:

$$\begin{cases} \frac{\partial \pi_1}{\partial q_1} = a - 2bq_1 - bq_2 - C_1 - r(M_1 - M_0^B) = 0 \\ \frac{\partial \pi_2}{\partial q_2} = a - bq_1 - 2bq_2 - C_2 + t_2 + t_0(M_0^B - M_2) = 0 \end{cases}$$

To:

$$\begin{cases} q_1^{C2} = \frac{a - 2C_1 + C_2 - 2r(M_1 - M_0^B) - t_2 - t_0(M_0^B - M_2)}{3b} \\ q_2^{C2} = \frac{a - 2C_2 + C_1 + 2t_2 + 2t_0(M_0^B - M_2) + r(M_1 - M_0^B)}{3b} \end{cases}$$

By the Nash equilibrium solution can be obtained that t_2, t_0, M_1, r , are inversely proportional to the fossil energy capacity of enterprise, and is directly proportional to the capacity of the new energy companies; M_2 is proportional to the fossil energy enterprise output, and the new energy companies is inversely proportional to the output; M_0 is inversely proportional to the fossil energy enterprise output, but when $2t_0 > r$, M_0 is proportional to the new energy enterprise output; when $2t_0 < r$, M_0 is inversely proportional to the fossil energy enterprise output. Thus it is clear that fossil energy enterprise reduce unit carbon emission is a direct method for acquire state subsidies and expending market share.

3.2.2 The optimal market price

In this situation, according to the market inverse demand function can get the optimal price:

$$P_2 = \frac{a + C_1 + C_2 + r(M_1 - M_0^B) - t_2 - t_0(M_0^B - M_2)}{3}$$

Thus we can see that unit carbon tax coefficient r is larger, the higher the market price; but unit of carbon emissions subsidies coefficient t_0 is larger, the lower the market price. Thus the government should be prudent adjust t_0 and r .

Combined with the above formulas available the maximum benefit of fossil energy and new energy enterprises respectively:

$$\pi_1^{C2} = q_1^{C2} [P_2 - C_1 - r(M_1 - M_0^B)];$$

$$\pi_2^{C2} = q_2^{C2} [P_2 - C_2 + t_2 + t_0(M_0^B - M_2)]$$

3.3 Situation 3: $M_0 < M_2 < M_1$

The third situation: the government to the enterprise tax for enterprise of unit carbon emissions less than M_0^C (to distinguish the different situation of M_0 , here with M_0^C). At this moment, $M_0^C < M_1$, $M_2 > M_0^C$, revenue function is:

$$\pi_1 = q_1 [P(q_1 + q_2) - C_1 - r(M_1 - M_0^C)];$$

$$\pi_2 = q_2 [P(q_1 + q_2) - C_2 - r(M_2 - M_0^C)]$$

3.3.1 The optimal equilibrium output

Both producers choose their optimal equilibrium output, for the first order derivatives equal to zero, namely:

$$\begin{cases} \frac{\partial \pi_1}{\partial q_1} = a - 2bq_1 - bq_2 - C_1 - r(M_1 - M_0^C) = 0 \\ \frac{\partial \pi_2}{\partial q_2} = a - bq_1 - 2bq_2 - C_2 - r(M_2 - M_0^C) = 0 \end{cases}$$

To :

$$\begin{cases} q_1^{C3} = \frac{a - 2C_1 + C_2 - r(2M_1 - M_2 - M_0^C)}{3b} \\ q_2^{C3} = \frac{a - 2C_2 + C_1 - r(2M_2 - M_1 - M_0^C)}{3b} \end{cases}$$

The first derivative r is: $\frac{\partial q_1^{C3}}{\partial r} = \frac{M_2 + M_0^C - 2M_1}{3b}$ and $\frac{\partial q_2^{C3}}{\partial r} = \frac{M_1 + M_0^C - 2M_2}{3b}$.

When $M_1 > 2M_2 - M_0^C$, $\frac{\partial q_1^{C3}}{\partial r} < 0$ and $\frac{\partial q_2^{C3}}{\partial r} > 0$. With the increase of r ,

fossil energy enterprise of generating capacity is reduced, new energy enterprises of generating capacity increase;

When $\frac{M_2 + M_1}{2} < M_1 < 2M_2 - M_0^C$, $\frac{\partial q_1^{C3}}{\partial r} < 0$ and $\frac{\partial q_2^{C3}}{\partial r} < 0$. With the

increase of r , both fossil energy and new energy enterprise of generating capacity are reduced;

When $M_1 < \frac{M_2 + M_1}{2}$, $\frac{\partial q_1^{C3}}{\partial r} > 0$ and $\frac{\partial q_2^{C3}}{\partial r} < 0$. With the increase of r , new

energy enterprise of generating capacity is reduced, fossil energy enterprises of generating capacity increase. Thus, countries should be confirms rationally the value of r according to the relationship of M_1 and M_2 .

3.2.2 The optimal market price

In this situation, according to the market inverse demand function can get the optimal price:

$$P_3 = \frac{a + C_1 + C_2 + r(M_1 + M_2 - 2M_0^C)}{3}$$

Thus we can see that r is proportional to the market price.

Combined with the above formulas available the maximum benefit of fossil energy and new energy enterprises respectively:

$$\pi_1^{C3} = q_1^{C3} [P_3 - C_1 - r(M_1 - M_0^C)];$$

$$\pi_2^{C3} = q_2^{C3} [P_3 - C_2 - r(M_2 - M_0^C)]$$

3.4 Synthetic discussion government revenue under three kinds of situation

According to the set of M_0 range, can summarize three kinds of situations, as shown in table 1:

Table 1

The range of the M_0	The optimal equilibrium output	The optimal market price	Government revenues
$M_0^A > M_1 > M_2$	$\begin{cases} q_1^{C1} \\ q_2^{C1} \end{cases}$	P_1	$\pi_G^{C1} = q_1^{C1} (P_1 - C_1) + q_2^{C1} (P_1 - C_2)$
$M_1 > M_0^B > M_2$	$\begin{cases} q_1^{C2} \\ q_2^{C2} \end{cases}$	P_2	$\pi_G^{C2} = q_1^{C2} (P_2 - C_1) + q_2^{C2} (P_2 - C_2)$
$M_1 > M_2 > M_0^C$	$\begin{cases} q_1^{C3} \\ q_2^{C3} \end{cases}$	P_3	$\pi_G^{C3} = q_1^{C3} (P_3 - C_1) + q_2^{C3} (P_3 - C_2)$

Introductions: for the convenience of calculation, assuming that $t_0=r$. Through calculation and comparison, we can obtain that the relationships of size among the price are $P_1 < P_2 < P_3$, that the relationships of size among the government revenues are $\pi_G^{C1} > \pi_G^{C2} > \pi_G^{C3}$. Although the lower the value of the M_0 , the government revenues also declined, but it will prevent damage to the environment. In other words, it will bring environmental benefits for the country, can better protect the environment, thus to the road of sustainable development.

4. Conclusion and Prospect

Through the above calculation and analysis, I put forward several policy proposals:

- (1) Cancel the direct subsidies for energy, and only subsidies for enterprise according to the unit carbon emissions can effectively reduce the environment pollution.
- (2) The relationship between the M_0 and M_1 and M_2 , directly affect the market price, thus, countries should reasonable adjustment of electricity prices according to the relationships among M_0 and M_1 and M_2 .
- (3) t_0 and r size will directly affect the capacity of energy enterprises and production. Thus, countries should be confirms rationally the value of r and t_0 according to the relationship of M_1 and M_2 , so that can better development of new energy.
- (4) When M_0 is M_0^B , the comprehensive income is the largest of government. In other words, not only meets economic development, but also can protect environment. Thus, the government should adjust M_0 towards the M_0^B .

This paper is based on the model analysis, is a theoretical model, and lack of empirical analysis. Thus further on fossil energy and new energy enterprises for empirical analysis, not only good reaction fact, but also can enact correlatively more reliably and more reasonable policy.

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