Research on Carbon Emission Reduction of Enterprises from the Perspective of Evolutionary Game

Dong Wang and Zhijun Liang

ABSTRACT

Global environmental issues have become the focus. The government is changing the status quo of enterprises in pursuit of their own profits without considering environmental costs by controlling their carbon emissions and promoting technological innovation. China is currently in the middle stage of industrialization, the degree of government regulation on the environment, take the perspective of evolutionary game model of government and enterprises, the government should intensify supervision, strengthen the punishment and to establish good corporate compensation mechanism, improve the reverse high emissions of the production cost of enterprises, the formation of effective supervision system. For the game of technology sharing between enterprises, the government should set up the third party platform to protect the rights and interests of shared enterprises, promote technology spillovers, and further expand social benefits.¹

INTRODUCTION

In recent years, China has studied the energy consumption and economic development of the countries and regions. It is inseparable. With the expansion of these studies, the research on carbon emissions has gradually increased, and a more mature theoretical and methodological system has been formed. However, the current research on issues related to provinces and regions in China is still in its infancy. Different scholars have different sample sizes, different research methods and influencing factors, and different conclusions; The relationship between the sharing of platoon technology and the impact of carbon emissions is also at the

¹Dong Wang, Zhijun Liang, Harbin Institute of Technology (Shenzhen) School of economics and management, Guangdong Shenzhen
initial stage and there is little research. Therefore, the study of carbon emission reduction issues of enterprises is of great significance for local government supervision and corporate "low-carbon" transformation. Government supervision and corporate pollution research have always been the focus of the game theory community. BERNARD et al. [1] and Zhao Lingru et al. [2] proposed the use of game theory to study carbon emission and carbon emission rights issues; Pan Feng et al. [3], Yu Binbin et al. [4], Shang Shuxiu [5], Zhang Wei et al. [6] and Xu Dawei et al.[7] scholars mainly conducted research on environmental pollution and government regulation game. Xu Hanlei et al.[8] studied the development game problem of sharing technology among enterprises and proposed that the government should support The common technology development of enterprises and the construction of a platform encourage enterprises to share innovative technologies. Therefore, this research has certain practical significance.

MODEL BASIC ASSUMPTIONS

At present, the issue of carbon emission reduction is a sensitive issue between enterprises and the government, specifically involving carbon emissions and low-carbon technologies. Carbon emissions are the product of public pollution in the sense of economics, but they are also the necessary output of economic growth in industrial countries and developing countries. Therefore, it is theoretically easy for both governments and enterprises to choose “failures”. From the perspective of the government, the issue of carbon emission reduction will directly relate to the negative externalities of regional economic development and environmental pollution. Based on the above analysis, the game model of business and government is assumed as follows:

Hypothesis 1: The news obtained by the government and enterprises in the game is limited.

Hypothesis 2: When governments and companies choose strategies in the game, both governments and companies should take absolute rationality from their own interests.

Hypothesis 3: The position of government and enterprises in the game is equal.

Hypothesis 4: The government’s revenue is externalized social benefits.

GAME ANALYSIS BETWEEN ENTERPRISE AND GOVERNMENT

The main content of the game is whether the government supports or does not support the regulation of enterprise carbon emissions, and whether the enterprise emissions should be reduced or not. Among them, the government benefits from the social and economic benefits and the external hand of the environment. The government’s strategy set is \( P \{ p_1, p_2 \} \), The enterprise policy set is \( Q \{ q_1, q_2 \} \).
On behalf of the government to regulate the carbon emissions of enterprises, \(p_2\) is the government does not regulate; \(q_1\) is low carbon emissions by enterprises, \(q_2\) is high carbon emissions by enterprises. \(r_1, r_2\) is means that the government chooses to regulate and firms also choose the benefits of low carbon emissions; \(c_1\) representing the costs of government regulation, \(c_2\) representing the cost of carbon emissions from an enterprise. If the government does not regulate but companies choose low carbon emissions, this is the cost of low carbon emissions. \(c_3\). Because the government does not supervise other enterprises to choose the high-carbon emission production mode for the benefit maximization, but the enterprises have no advantage in relation to other enterprises, they also face the competitive pressure of other enterprises and the risk of being squeezed out of the market. And this time the government’s revenue \(r_3\) and \(r_4\) represents the enterprise high carbon emission separately, the government supervises the enterprise and the government income, in which the enterprise income is also the social income part also belongs to the government income, consider not to lose the generality, \((r_1 - c_1) > (r_2 - c_2) > r_3 > r_4\) and \(c_3 > c_2\). Where government regulation and companies choose high emissions, we treat everyone’s earnings as zero, because there is no spillover benefit at this time.

Suppose, at the beginning of the game, the government considers the plan \(p_1\), and the specific gravity of \(x\), \(p_2\) is the proportion of the scheme considered \(1 - x\). Enterprise consideration scheme \(q_1\). The specific gravity of \(y\), then consider the scheme \(q_2\) and the specific gravity of \(1 - y\).

The game matrix between government and enterprise is as follows: For the mutual benefit and protection of Authors and Publishers, it is necessary that Authors provide formal written Consent to Publish and Transfer of Copyright before publication of the Book. The signed Consent ensures that the publisher has the Author’s authorization to publish the Contribution.

<table>
<thead>
<tr>
<th>Firm</th>
<th>Government</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(p_1(x))Supervision</td>
</tr>
<tr>
<td>(q_1(y))</td>
<td>(r_2 - c_2, r_1 - c_1)</td>
</tr>
<tr>
<td>(q_2(1-y))</td>
<td>(0, 0)</td>
</tr>
</tbody>
</table>

TABLE I. THE GAME MATRIX OF ENTERPRISE AND GOVERNMENT.
The copyright form is located on the authors’ reserved area. The form should be completed and signed by one author on behalf of all the other authors.

First of all, the game of the government is analyzed, which is used to $Q_1, Q_2, \bar{Q}$. When representing government options $p_1$, When options $p_2$, The composite earnings expectations As follows:

$$Q_1 = y (r_1 - c_1)$$

$$Q_2 = y * r_2 + (1 - y)r_4$$

$$\bar{Q} = xQ_1 + (1 - x)Q_2 = x * y(r_1 - c_1) + (1 - x)[y * r_2 + (1 - y)r_4]$$

For the benefit expectation of the government program choice, choose the support plan $p$, probability of $x$ is in a continuous interval $[0,1]$. In this paper, the concept of continuous time is introduced, and the Replicator Dynamic Mechanism is introduced.

$$f(x) = dx/dt = x(Q_1 - \bar{Q}) = x(1 - x)[y(r_1 + r_4 - r_2 - c_1) - r_4]$$

At this point, make $f(x) = 0$, the stability point of the replicator dynamic mechanism can be solved, represents government options in the replication dynamics $p$, probability of $x$. It is a relatively stable state within a certain interval. At this point, we can solve the stability point of replicon dynamic mechanism, which indicates that the probability $x$ of the government selection scheme is a relatively stable state in a certain region of the replicon dynamic process.

If $y = r_4/(r_1 + r_4 - r_2 - c_1)$, then $f(x) = 0$, $x$ belong $[0,1]$ the interval is a stable point, which has no significance for the study of this paper.

If $y \neq r_4/(r_1 + r_4 - r_2 - c_1)$, There must be $x^* = 1$ and $x^* = 0$, two stable points, according to ESS(Evolutionary Stabilization Strategy) Relevant meaning, the result of a stable choice under Nash equilibrium is to make a relatively optimal and stable decision to prevent external interference, that is, when the government chooses to deviate from the ESS strategy. The total revenue it chooses will inevitably be smaller than the total income selected under the ESS status strategy. So, to be satisfied $f(x)$ derivative $f'(x) < 0$. That is to say, only satisfying at the same time $f(x) = 0$ and $f'(x) < 0$ the point of two conditions is ESS. When
When the two equations are established at the same time, it shows that both sides can achieve the maximum benefit at the point of simultaneous satisfaction, that is, the optimal scheme choice at the peak of evolutionary game.

If \( 0 < y < \frac{r_4}{(r_1 + r_4 - r_3 - c_i)} \), then \( x < 1/2 \), so \( x^* = 0 \) is ESS.

Because of the assumption that the government is an absolutely rational economic man, when the government chooses not to regulate the enterprise carbon emission strategy or when the government regulation is not strong enough, the enterprise still chooses the high-carbon emission strategy to gain additional benefits. Other negative environmental externalities, which can lead to market failure, are not what the government wants. Therefore, at this time the government should choose to supervise or strengthen the supervision.

It shows that the probability of enterprises choosing low emission is greater than that of industry \( r_4/(r_1 + r_4 - r_3 - c_i) \). It shows that enterprises have a strong sense of social responsibility to choose low carbon emission strategy is very enthusiastic, in order to encourage this motivation, the government will choose supervision to protect the interests of enterprises from other enterprises to choose high emission strategy. This is a strategic choice made by the government from the perspective of the economic man, which makes the social benefits greater, but the actual situation is that the government often chooses not to regulate or to regulate less intensively, because companies are very interested in low-carbon emissions. Governments will choose to shift regulatory energy and costs to other areas of need.

Similarly, the dynamic equation of the enterprise game is as follows:

If \( P = (c_i + r_4)/((r_1 + r_4 + c_3 - c_2)) \), then \( g(x) = 0 \), it means all of it \( y \in \{0,1\} \). There are stable points in the range, which is of practical significance to the study of this paper.

If \( g(x) = y(1 - y)[x(c_3 - c_2 + r_2 + r_4) - (r_4 + c_3)] \), and

\[ x \neq (c_3 + r_4)/(r_2 + r_4 + c_3 - c_2) \], Samereasoning, then \( y^* = 0, y^* = 1 \) two stable points, if \( 0 < x < (c_3 + r_4)/(r_2 + r_4 + c_3 - c_2) \) then \( y^* = 0 \) is ESS, Enterprises believe that the government's supervision is not high or it is not supervised. At this time, the high cost of enterprises to choose low-carbon emissions will make them in a disadvantageous position. Therefore, the strategy for enterprises to maximize their equilibrium returns is to choose high-carbon emissions.

If \( (c_3 + r_4)/(r_2 + r_4 + c_3 - c_2) < x < 1 \), It shows that if the probability of choosing high intensity regulation in government game is very high, and the high intensity supervision of government will make enterprises choose low carbon emissions, they will not be affected by other enterprises' choice of high emission and bear the extra cost. At this point, the enterprise's best option is low carbon emissions.
Among them \( t = \frac{r_4}{(r_4 + r_3 - r_3 - c_1)} \) and \( t' = \frac{c_3 + r_4}{(r_2 + r_4 + c_3 - c_2)} \)

According to the above analysis results, there are two evolutionary game equilibrium points in the phase diagram of RDM game between enterprise and government, one is the equilibrium point with negative externality effect is \((r_4, r_4)\), the other is the equilibrium point with positive externalities \((r_1 - c_1, r_2 - c_2)\). According to the evolutionary dynamics of evolutionary game theory, the final orientation of game strategy, that is, which result the game party chooses at the end of the game, is directly dependent on the starting point state of the game parties. That is to say, it depends on the size analysis of the optimal income and the lowest cost of the players who choose each scheme before the game, that is, the result of the game between the two parties depends on the conditions that both parties need before the game and the purpose they need to achieve.

**CONCLUSIONS**

Game government regulation and corporate carbon emissions analysis available; business is absolutely rational economic man, the purpose is to maximize profits, and the government as a rational perspective, but the main purpose is to want the lowest cost and allow enterprises to choose a low-carbon emission. For the emission reduction technology R&D game between enterprises, enterprises want to maximize their profits, share each other's technological spillovers, and obtain government subsidies. Therefore, on the basis of the previous game analysis, the following suggestions and countermeasures are proposed.

Gradually improve the government supervision system. As for the high emission and pollution of enterprises, it is necessary to improve the government supervision system. The third party's coordination should be added to the government's environmental supervision model to improve the third party's participation mechanism. At the same time, the contingent of government environmental supervision personnel has been continuously strengthened, and a high-quality law enforcement and supervision team is the key to improving supervision efficiency.

**REFERENCES**


