How Should Oil Companies and New Energy Companies Compete and Cooperate in the Context of Carbon Neutralization? A Strategy Analysis Approach Based on Cooperative Game Theory

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Abstract: The promulgation of "carbon neutrality" target has brought new impetus to the development of new energy enterprises, and also brought challenges to the development of traditional oil enterprises. The analysis of competition and cooperation between new energy enterprises and petroleum enterprises is of great significance to the optimization of energy structure. Based on this motivation, this paper establishes a game model to analyze the development strategy decision of oil enterprises and new energy industry, and constructs a cooperation–competition game model for new energy enterprises and oil enterprises under the government premise of supporting the development of new energy products. According to dynamics analysis of model parameters, the stability conditions of equilibrium points are obtained. Based on the analysis of evolutionary stable states, it is concluded that oil enterprises and new energy enterprises should chose the development strategy of cooperating with each other under the effect of "carbon neutrality" target.
***Keywords*:** carbon neutral, petroleum enterprises, competition and cooperation, game theory

1. Introduction

The meaning of "carbon neutralization" is a common term for energy conservation and emission reduction, which means that enterprises, groups or individuals calculate the total amount of greenhouse gas emissions directly or indirectly generated in a certain period of time, and offset their own carbon dioxide emissions through afforestation, energy conservation and emission reduction, so as to achieve "zero emission" of carbon dioxide. To put it simply, it is to make carbon dioxide emissions "make ends meet" (Nazim 2008). As a green environmental protection concept, "carbon neutral" has been supported by environmentalists from all walks of life. Many large-scale activities and conferences have also adopted the environmental protection concept of "carbon neutral", aiming to achieve green production and life in this way (Laura et al. 2019). In June 2020, novel coronavirus pneumonia, BP, the world's largest energy company, released the sixty-ninth edition of the BP world energy statistics yearbook (Hu 2020). It collated and analyzed the global energy related data since 2019, focusing on the global energy situation before the outbreak of the new crown pneumonia.The main conclusions are as follows: first, the growth rate of global primary energy consumption continues to slow down, from 2.8% in the previous year to 1.3%. Second, although the growth rate of carbon emissions has declined, the total amount is still very large. Compared with 2.1% in 2018, the carbon emissions caused by energy consumption has eased to 0.5%, but this figure is still higher than the growth rate of carbon emissions in the past 10 years. Third, the growth rate of renewable energy consumption also exceeded the previous data limit (3.2 EJ), accounting for 40% of the global primary energy growth rate, exceeding the proportion of other types of fuels. For the first time, the proportion of renewable energy used for power generation exceeded that of nuclear power generation.Fourth, the increment of oil consumption is lower than the historical growth rate, and the consumption is 900000 B / D, which is lower than the historical growth rate (Lu 2020).

The above analysis shows that low carbon economy has gradually become the general direction of global energy economy development, and the global oil energy consumption will continue to decline in the future. However, global carbon emissions are still high, so we need to continue to implement energy conservation and emission reduction, carbon neutralization and other mechanisms, reduce the use of traditional energy, and advocate the development and utilization of clean energy. This trend will undoubtedly pose new challenges to the development of oil enterprises. How should oil enterprises make decisions on competition and cooperation with new energy enterprises in order to make the two kinds of energy enterprises coexist harmoniously in the future and work together to maintain the stable order of the energy market? This problem is an urgent problem to be solved by the current global oil enterprises. Therefore, the study of competition and cooperation between oil enterprises and new energy enterprises can promote the adjustment of energy structure and improve the greenhouse gas emissions in the current global environment, and optimize the steady transformation of energy economy.

2. Literature review

The relationship between competition and cooperation between new energy industry and traditional oil enterprises has aroused the interest of scholars at home and abroad, and most scholars have conducted research on it.

Cao pointed out that the government should increase publicity, encourage consumers to buy, build public facilities for energy supply of new energy vehicles, and promote the industrialization of new energy vehicles (Cao 2009). Max pointed out that in the early stage of the market, the government's subsidy for R&D is an important guarantee for industrial development (Max 2006). In terms of policy, Li carefully studied the contents of green development in the report of the 19 th National Congress, and believed that petrochemical enterprises should thoroughly study and implement the spirit of the 19 th National Congress, turn the concept of green development into action, and actively explore the path to realize circular economy. Petrochemical enterprises should carry out key technological transformation in key areas of enterprises, promote clean production and processing, eliminate and update devices with high energy consumption and large pollution emissions, and realize the greening of the whole industrial chain of enterprises (Li 2020). Wang et al. studied the macro-control role of the government in the development of new energy automobile industry by constructing a two-stage dynamic model of government and enterprise (Wang et al. 2013). Rui et al. analyzed the problem of reducing carbon emissions in the supply chain by the decision-making of energy enterprises with the help of game theory, and put forward the necessity of supervising government participation in energy enterprises (Rui et al. 2012). Rocha et al. designed the driving mechanism of the game model, and achieved the goal of energy saving and emission reduction in power plants in developed countries such as the United States by limiting and controlling trading items (Rocha et al. 2015). Zheng et al. aimed at the operational efficiency of carbon emission reduction of two competing energy enterprises in the game of cooperation or not, and finally got the optimal decision of the two energy enterprises (Zheng et al. 2016). Ioanna et al. made a game analysis on the impact of carbon tax paid by major American airlines for carbon neutrality on ticket price changes (Ioanna et al. 2016). From the above literature review, it can be seen that the competition and cooperation between traditional fossil energy and new energy will become more and more fierce in today's global over-consumption of energy and increasingly serious environmental pollution problems. At present, most of the literature is based on the competition research of traditional energy industry, and the research on new energy is less. Moreover, most of the researches focus on the role played by the government. In fact, in recent years, the government has issued a number of policies and assistance measures to support the development of new energy industry. From the big environment, the government's support for the new energy industry is self-evident, so this article will not repeat them. At present, on the basis of the government's support for the development of new energy industry, the research on the price competition and cooperation between oil enterprises and new energy enterprises has not been studied, so the research in this paper is of great forward-looking significance.

In the research methods of competition and cooperation between oil enterprises and new energy enterprises, many predecessors have made outstanding contributions. Wang used SWORT analysis and fuzzy comprehensive evaluation model to study the competitiveness of China's new energy industry from the industrial planning and industrial technology route, and put financial input and government control measures into play to enhance the competitiveness of new energy industry (Wang 2015). Jia et al. put forward a cross diamond model based on diamond model for qualitative analysis, and took the United States as an example for game analysis (Jia et al. 2016). China needs to improve the use environment of new energy products and coordinate the communication between new energy enterprises and traditional energy enterprises. Sun et al. studied the government's camera choice in research and development subsidies and support prices by establishing a three-stage game model including the government, new energy enterprises and traditional energy enterprises (Sun et al. 2013). Furthermore, through the four-stage game model of production and consumption, Sun comparatively analyzed the difference between the optimal price and social welfare in three ways of new energy price subsidy (government commitment, traditional energy enterprise commitment and consumer commitment) (Sun 2014). Liu used cointegration test and Granger causality test to make an empirical analysis of the industrial competition between oil industry and new energy (Liu 2019). The results show that oil enterprises can maintain a long-term equilibrium relationship with new energy only by insisting on carbon emission reduction, and industrial equilibrium and energy conservation and emission reduction are both important factors that affect the competitiveness of oil industry. Li et al. studied the pricing strategy of new energy vehicles under the technological competition environment, and concluded that under the same environment, technology manufacturers generally provide technology to manufacturers with competitive relationship, so that they can reach a competitive model to optimize profits (Li et al. 2020).

Therefore, there are many methods and models for studying the competition and cooperation between traditional energy and new energy enterprises in academic circles, and there are also many literatures using game theory in recent years, most of which are qualitative analysis. In terms of research content, there are very few literatures about the competition

and cooperation between petroleum industry and new energy industry in new energy investment through the framework of evolutionary game theory. Different from the existing research, a symmetrical evolutionary game model between groups investing in new energy is established by using the basic principle of evolutionary game. By analyzing the key factors that influence the strategy selection of game subjects, the stable strategy of evolutionary game is sought, and then the competition and cooperation decision of two energy enterprises under the goal of carbon neutrality is explored.

3. Methodology

3.1 Game model between oil enterprises and new energy enterprises

In the case of government participation in carbon neutralization, oil companies and new energy companies should consider the same direction, that is to protect their own economic interests to the greatest extent (Stefan 2010). Under the policy of carbon emission reduction implemented by the government, there is not only competition between oil enterprises and new energy enterprises in traditional energy products. If oil enterprises start to invest in the development and investment of low-carbon products, they may also start to seize the market share of low-carbon products, that is, how much profit can enterprises obtain after the implementation of "carbon neutral". Therefore, the two decision-makers choose cooperation or competition Competition is a game.In this case, oil companies and new energy companies consider market share and make decisions at the same time. Therefore, this paper constructs the following game model.

3.2 Hypothesis and model construction

According to the literature analysis and present situation, the following assumptions are put forward.

H1: The two players in the game are oil enterprises and new energy enterprises, assuming that they are both bounded rational and have limited information. Because the products of oil enterprises and new energy enterprises can be converted into electricity at last, which is homogeneous in terms of products, the products of both sides are measured by energy generation, the price adopts standardized pricing method, and the production cost of products is measured according to the amount per unit generation.

H2: Both sides of the game have two strategic choices, cooperation or competition. Both sides of the game can compete or cooperate by adjusting the price.

H3: The government supports the development of new energy industry and encourages enterprises to develop low-carbon economy. The government can use carbon tax, subsidies and other means to intervene in enterprises to improve environmental quality and achieve "carbon neutral".

H4: New energy industry can reduce pollution from the source because of its low-carbon production advantages, and the future development prospect of new energy industry is good, with good environmental reputation and other indirect benefits, which has a positive effect on the development of energy enterprises.

3.3 Selection and setting of profit and loss variables

Select appropriate variables based on the above research.

(1) When oil companies and new energy companies do not cooperate, the income that oil companies can generate is recorded as ω_1; The income that new energy enterprises can generate is recorded as ω_2, and at the same time, the development of new energy industry has a certain degree of positive effect a.

(2) When the decision-making of oil enterprises and new energy enterprises is (cooperation, cooperation), oil enterprises can increase revenue $\Delta\omega_1$, while new energy enterprises can increase revenue $\Delta\omega_2$.

(3) When the decision-making of oil enterprises and new energy enterprises is (cooperation, competition), oil enterprises will reduce income A_1, while new energy enterprises will reduce income A_2.

(4) When the decision-making of oil enterprises and new energy enterprises is (competition, cooperation), oil enterprises will reduce revenue B_1 and new energy enterprises will reduce revenue B_2.

(5) When the decision of oil companies and new energy companies is (competition, competition), oil companies will reduce revenue C_1 and new energy companies will reduce revenue C_2.

(6) When the decision of petroleum enterprises is to choose cooperation, the tax charged by the government is D_1. if the decision of petroleum enterprises is to choose competition, the tax charged by the government is D_2.

(7) When the new energy enterprises choose to cooperate, the government subsidies them, which is recorded as E_1, when the new energy enterprises choose to compete, the government subsidies them, which is recorded as E_2.

(8) The probability of petroleum enterprises choosing cooperation is recorded as x, and the probability of choosing competition is recorded as $(1-x)$.

(9) The probability of new energy enterprises choosing cooperation is recorded as *y*, and the probability of choosing competition is recorded as (1-*y*). After the parameters are set, the profit matrix of the two kinds of energy enterprises is established, as shown in Table 1.

Table 1. Evolutionary game income matrix of oil enterprises and new energy enterprises

Players in the game		New energy enterprises(*i*=2)	
		Cooperation *y*	compete(1-*y*)
Petroleum Enterprises (i=1)	Cooperation *x*	$\omega_1 + \Delta\omega_1 - D_1$, $\omega_2 + \Delta\omega_2 + E_1 + a$	$\omega_1 - A_1 - D_1$, $\omega_2 - A_2 + E_2 + a$
	compete (1-*x*)	$\omega_1 - B_1 - D_2$, $\omega_2 - B_2 + E_1 + a$	$\omega_1 - C_1 - D_2$, $\omega_2 - C_2 + E_2 + a$

4. Results and discussion

4.1 Game model analysis

The following are the expected return function. The following is based on the evolutionary game income matrix.

(1) The expected income of petroleum enterprises when they choose cooperation is:

$$U_{11} = y(\omega_1 + \Delta\omega_1 - D_1) + (1-y)(\omega_1 - A_1 - D_1) \quad .$$

The expected income of petroleum enterprises when they choose competition is:

$$U_{12} = y(\omega_1 - B_1 - D_2) + (1-y)(\omega_1 - C_1 - D_2) \quad .$$

The average income of oil companies is: $\overline{U}_1 = xU_{11} + (1-x)U_{12}$.

(2) When new energy enterprises make cooperative decision, the expected income is:

$$U_{21} = x(\omega_2 + \Delta\omega_2 + E_1 + a) + (1-x)(\omega_2 - B_2 + E_1 + a) \quad .$$

When new energy enterprises make competitive decisions, the expected revenue is:

$$U_{22} = x(\omega_2 - A_2 + E_2 + a) + (1-x)(\omega_2 - C_2 + E_2 + a) \quad .$$

The average income generated by new energy enterprises is: $\overline{U}_{22} = xU_{21} + (1-x)U_{22}$.

The following are the analysis of game stability strategy. The following is the replication dynamic equation of petroleum enterprises:

$$\dot{x} = \frac{dx}{dt} = G(x) = x(1-x)(U_{11} - U_{12}) = x(1-x)\left[C_1 - A_1 + D_2 - D_1 + y(\Delta\omega_1 + B_1 + A_1 - C_1\right]$$

$$G'(x) = (1-2x)\left[C_1 - A_1 + D_2 - D_1 + y(\Delta\omega_1 + B_1 + A_1 - C_1\right]$$

Let $G(x) = 0$, get the results $x = 0$, $x = 1$, $y = \frac{A_1 - C_1 + D_1 - D_2}{\Delta\omega_1 + B_1 + A_1 - C_1}$.

If $y = \frac{A_1 - C_1 + D_1 - D_2}{\Delta\omega_1 + B_1 + A_1 - C_1}$, then $G(x) = 0$. This shows that all levels are stable, that is to say, the choice of decision does not change with time.

If $y \neq \frac{A_1 - C_1 + D_1 - D_2}{\Delta\omega_1 + B_1 + A_1 - C_1}$.

(1) If $\frac{A_1 - C_1 + D_1 - D_2}{\Delta\omega_1 + B_1 + A_1 - C_1} < 0$, then $\frac{A_1 - C_1 + D_1 - D_2}{\Delta\omega_1 + B_1 + A_1 - C_1} < y$, $G'(x)\big|_{x=1} < 0, G'(x)\big|_{x=0} > 0$, so $x = 1$ is a stable strategy.

(2) $\frac{A_1 - C_1 + D_1 - D_2}{\Delta\omega_1 + B_1 + A_1 - C_1} > 1$, then $\frac{A_1 - C_1 + D_1 - D_2}{\Delta\omega_1 + B_1 + A_1 - C_1} > y$, $G'(x)\big|_{x=1} > 0, G'(x)\big|_{x=0} < 0$, so $x = 0$ is a stable strategy.

(3) $0 < \frac{A_1 - C_1 + D_1 - D_2}{\Delta\omega_1 + B_1 + A_1 - C_1} < 1$.

When $y < \frac{A_1 - C_1 + D_1 - D_2}{\Delta\omega_1 + B_1 + A_1 - C_1}$, and $G'(x)\big|_{x=1} > 0, G'(x)\big|_{x=0} < 0$,so $x = 0$ is a stable strategy.

When $y > \frac{A_1 - C_1 + D_1 - D_2}{\Delta\omega_1 + B_1 + A_1 - C_1}$, and $G'(x)\big|_{x=1} < 0, G'(x)\big|_{x=0} > 0$,so $x = 1$ is a stable strategy.

The replication dynamic equation of new energy enterprises is as follows:

$$\dot{y} = \frac{dy}{dt} = H(y) = y(1-y)(U_{21} - U_{22}) = y(1-y)\left[C_2 - B_2 + E_2 - E_1 + x(\Delta\omega_2 + B_2 + A_2 - C_2\right]$$

$$H'(y) = (1-2y)\left[C_2 - B_2 + E_2 - E_1 + x(\Delta\omega_2 + B_2 + A_2 - C_2)\right].$$

Let $H(y) = 0$, get the results $y = 0, y = 1$, $x = \frac{B_2 - C_2 + E_1 - E_2}{\Delta\omega_2 + B_2 + A_2 - C_2}$.

If $x = \frac{B_2 - C_2 + E_1 - E_2}{\Delta\omega_2 + B_2 + A_2 - C_2}$, then $H(y) = 0$,This shows that all levels are stable, that is to say, the choice of decision does not change with time.

If $x \neq \frac{B_2 - C_2 + E_1 - E_2}{\Delta\omega_2 + B_2 + A_2 - C_2}$.

(1) If $\frac{B_2 - C_2 + E_1 - E_2}{\Delta\omega_2 + B_2 + A_2 - C_2} < 0$,then $\frac{B_2 - C_2 + E_1 - E_2}{\Delta\omega_2 + B_2 + A_2 - C_2} < x$, $H'(y)\big|_{y=1} < 0, H'(y)\big|_{y=0} > 0$,so $y = 1$ is a stable strategy.

(2) If $\frac{B_2 - C_2 + E_1 - E_2}{\Delta\omega_2 + B_2 + A_2 - C_2} > 1$,then $\frac{B_2 - C_2 + E_1 - E_2}{\Delta\omega_2 + B_2 + A_2 - C_2} > x$, $H'(y)\big|_{y=1} > 0, H'(y)\big|_{y=0} < 0$,so $y = 0$ is a stable strategy.

(3) If $0 < \frac{B_2 - C_2 + E_1 - E_2}{\Delta\omega_2 + B_2 + A_2 - C_2} < 1$.

When $x < \frac{B_2 - C_2 + E_1 - E_2}{\Delta\omega_2 + B_2 + A_2 - C_2}$, and $H'(y)\big|_{y=1} > 0, H'(y)\big|_{y=0} < 0$,so $y = 0$ is a stable strategy.

When $x > \frac{B_2 - C_2 + E_1 - E_2}{\Delta\omega_2 + B_2 + A_2 - C_2}$, and $H'(y)\big|_{y=1} < 0, H'(y)\big|_{y=0} > 0$,so $y = 1$ is a stable strategy.

The following are the system stability analysis. Let $G(x) = 0, H(y) = 0$. Then five local stagnation points can be obtained: $F_1(0,0)$, $F_2(0,1)$, $F_3(1,0)$, $F_4(1,1)$, $F_5(x_0, y_0)$ ($x_0 = \frac{B_2 - C_2 + E_1 - E_2}{\Delta\omega_2 + B_2 + A_2 - C_2}$, $y_0 = \frac{A_1 - C_1 + D_1 - D_2}{\Delta\omega_1 + B_1 + A_1 - C_1}$). Calculate the determinant (det J) and Trace ($tr\ J$) of the matrix. Then according to the sign of det J and $tr\ J$ is "+" or "-" to judge the stability of the point.

Jacobian matrix is used to analyze:

$$K=\begin{bmatrix}\frac{\partial \dot{x}}{\partial x} & \frac{\partial \dot{x}}{\partial y}\\ \frac{\partial \dot{y}}{\partial x} & \frac{\partial \dot{y}}{\partial y}\end{bmatrix}=\begin{bmatrix}(1-2x)\left[C_1-A_1+D_2-D_1+y(\Delta\omega_1+B_1+A_1-C_1\right] & x(1-x)(\Delta\omega_1+B_1+A_1-C_1)\\ y(1-y)(\Delta\omega_2+B_2+A_2-C_2) & (1-2y)\left[C_2-B_2+E_2-E_1+x(\Delta\omega_2+B_2+A_2-C_2)\right]\end{bmatrix}$$

We infer the matrix according to the assumption of the game model. We can get the following relationships: because the information is not comprehensive, the government can only make the decision of subsidy and taxation according to the income of the enterprise operation, while the income of oil enterprises is different when they make different decisions. Choosing "cooperation" brings more income for oil enterprises than choosing "competition", so $D_1 > D_2$. The more the government is willing to give subsidies, the greater the profits of new energy enterprises, and new energy enterprises make more profits when they choose "cooperation" than "competition", so $E_1 > E_2$. When the new energy industry chooses "cooperation" and the oil industry chooses "competition", the loss of the new energy industry should be greater than the loss caused by both "competition", so $B_2 > C_2$, the same as $A_2 < C_2$, $A_1 > C_1$, $B_1 < C_1$. Only when both of them choose "cooperation", can the oil industry and new energy industry produce maximum benefits, that is, $\omega_1 + \Delta\omega_1 - D_1 > \omega_1 - B_1 - D_2$, $\omega_2 + \Delta\omega_2 + E_1 + a > \omega_2 - A_2 + E_2 + a$, so $\Delta\omega_1 + B_1 + D_2 - D_1 > 0$, $\Delta\omega_2 + E_1 + A_2 - E_2 > 0$. Therefore, when making decisions, oil companies should fully examine the government's subsidy policies for new energy, and actively participate in the cooperation with new energy companies when appropriate. The partial equilibrium analysis results of the matrix are shown in the table below.

Table 2. Matrix partial equilibrium analysis results

Equilibrium point	*Det J*	Symbol	*Tr J*	Symbol	stability
$F_1(0,0)$	$(C_1-A_1+D_2-D_1)(C_2-B_2+E_2-E_1)$	+	$C_1-A_1+D_2-D_1+C_2-B_2+E_2-E_1$	-	ESS
$F_2(0,1)$	$-(D_2-D_1+\Delta\omega_1+B_1)(C_2-B_2+E_2-E_1)$	+	$D_2-D_1+\Delta\omega_1+B_1-\ C_2-B_2+E_2-E_1)$	+	instable
$F_3(1,0)$	$-(C_1-A_1+D_2-D_1)(\Delta\omega_2+A_2+E_2-E_1)$	+	$-(C_1-A_1+D_2-D_1)+(\Delta\omega_2+A_2+E_2-E_1)$	+	instable
$F_4(1,1)$	$D_2-D_1+\Delta\omega_1+B_1)(\Delta\omega_2+A_2+E_2-E_1)$ $-(C_2-B_2+E_2-E_1)\ \Delta\omega_2+A_2+E_2-E_1$	+	$-\ D_2-D_1+\Delta\omega_1+B_1)-(\Delta\omega_2+A_2+E_2-E_1)$	-	ESS
$F_5(x_0,y_0)$	$(C_1-A_1+D_2-D_1)(D_2-D_1+\Delta\omega_1+B_1)/$ $\left[(\Delta\omega_2+B_2+A_2-C_2)(\Delta\omega_1+B_1+A_1-C_1)\right]$	-	0	Indeterminate	saddle point

According to the analysis, we can know that equilibrium point $F_1(0,0)$ (competition, competition) and equilibrium point $F_4(1,1)$ (cooperation, cooperation) are the equilibrium points of the above game model. Only when the equilibrium point $F_4(1,1)$ (cooperation, cooperation) is selected can the oil industry and new energy produce the maximum benefits, which is also the optimal solution of the game model.

4.2 Game analysis results

Figure 1 shows the evolution path of oil enterprises and new energy enterprises. It can be seen from the figure that all points in the $S_{F_4F_2F_5F_3}$ region will converge to point $F_4(1,1)$ after evolution, so as to achieve the optimal steady-state equilibrium. In other words, oil companies and new energy companies choose to cooperate in order to achieve maximum profits under government intervention. The point in $S_{F_4F_2F_5F_3}$ region will eventually converge to another steady-state equilibrium point $F_1(0,0)$, that is, when both oil companies and new energy companies choose to compete, there is a steady-state equilibrium point on the phase diagram, but because there is room for Pareto improvement such as social welfare in real

life, this equilibrium point is discarded. The areas of these two areas add up to 1.

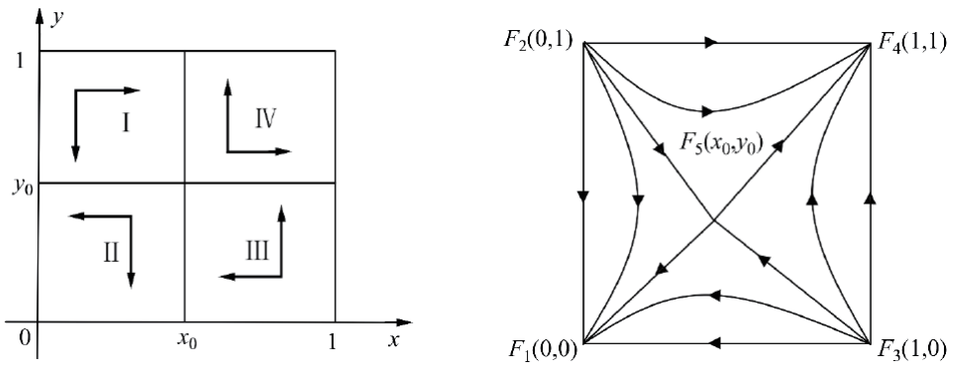

Figure 1. Evolution path analysis of oil enterprises and new energy enterprises

Oil companies and new energy companies will make decisions in the next period according to their development in the previous period, and use them to make future investment proportion. If the equilibrium of the game is in $S_{F_1F_2F_5F_3}$ area at the beginning, then the points in this area will continue to evolve until they approach the optimal equilibrium point (competition, competition). If the equilibrium of the game is in $S_{F_4F_2F_5F_3}$ area at the beginning, then the points in this area will continue to evolve until they approach the optimal equilibrium point (cooperation, cooperation). In real life, the evolution of the system depends on the concerted efforts of enterprises and governments of both sides.

$$S_{F_1F_2F_5F_3} = \frac{1}{2}(1-x_0+1-y_0) = 1-\frac{1}{2}(x_0+y_0)$$

In fact, the area of $S_{F_4F_2F_5F_3}$ region depends on the position of $F_5\ (x_0\ ,\ y_0)$. Therefore, the larger the area of $S_{F_4F_2F_5F_3}$ region is, the more likely the system will converge to $F_4\ (1\ ,1)$. Finally, with the help of the comparative static analysis method, the parameters are tested to find out their influence on the area of $S_{F_4F_2F_5F_3}$ region. Firstly, assume that any parameter is λ, and the change rate of the area of $S_{F_4F_2F_5F_3}$ region on the parameter is as follows:

$\frac{\partial S_{F_4F_2F_5F_3}}{\partial\lambda} = -\frac{1}{2}(\frac{\partial x_0}{\partial\lambda}+\frac{\partial y_0}{\partial\lambda})$,As can be seen from the previous content: $x_0 = \frac{B_2-C_2+E_1-E_2}{\Delta\omega_2+B_2+A_2-C_2}$, $y_0 = \frac{A_1-C_1+D_1-D_2}{\Delta\omega_1+B_1+A_1-C_1}$.

(1) Multinational oil companies.

The influence of multinational oil companies on game equilibrium is mainly reflected in $\Delta\omega_1$, B_1 and A_1-C_1.

Conclusion 1: When multinational oil companies make the decision of "cooperation", the more profits they can get, the more favorable the equilibrium point of the system will develop towards the evolutionary trend of (cooperation, cooperation).

Proof process: $\frac{\partial x_0}{\partial\Delta\omega_1}=0$, $\frac{\partial y_0}{\partial\Delta\omega_1} = -\frac{A_1-C_1+D_1-D_2}{\left(\Delta\omega_1+B_1+A_1-C_1\right)^2} < 0$,

So, $\frac{\partial S_{F_4F_2F_5F_3}}{\partial\Delta\omega_1} = \frac{1}{2}(\frac{\partial x_0}{\partial\Delta\omega_1}+\frac{\partial y_0}{\partial\Delta\omega_1}) > 0$,Get proof.

In the same way $\frac{\partial S_{F_4F_2F_5F_3}}{\partial B_1} - \frac{1}{2}(\frac{\partial x_0}{\partial B_1}+\frac{\partial y_0}{\partial B_1}) > 0$.

Conclusion 2: When the new energy enterprises make the decision of "competition", the greater the gap between the two options of "cooperation" and "competition", the less conducive to the development of the system towards the equilibrium point (cooperation, cooperation).

Proof process: $\frac{\partial x_0}{\partial(A_1-C_1)}=0$, $\frac{\partial y_0}{\partial(A_1-C_1)} = -\frac{D_1-D_2-\Delta\omega_1-B_1}{(\Delta\omega_1+B_1+A_1-C_1)} > 0$,

so, $\frac{\partial S_{F_4F_2F_5F_3}}{\partial\ \ A_1-C_1)} = -\frac{1}{2}(\frac{\partial x_0}{\partial(A_1-C_1)}+\frac{\partial y_0}{\partial(A_1-C_1)}) < 0$,Get proof.

(2) New energy enterprises.

The impact of new energy industry decision on the equilibrium of the game model is mainly reflected in $\Delta\omega_2$, A_2 and $B_2 - C_2$.

Conclusion 3: When the oil companies make the decision of "cooperation", the new energy companies can generate more revenue. This decision is conducive to the evolution trend of the system towards the equilibrium point (cooperation, cooperation)

Proof process: $\frac{\partial x_0}{\partial \Delta\omega_2} = -\frac{1}{(\Delta\omega_2 + B_2 + A_2 - C_2)} < 0$, $\frac{\partial y_0}{\partial \Delta\omega_2} = 0$,

So, $\frac{\partial S_{F_4F_2F_3F_3}}{\partial \Delta\omega_2} = -\frac{1}{2}(\frac{\partial x_0}{\partial \Delta\omega_2} + \frac{\partial y_0}{\partial \Delta\omega_2}) > 0$,Get proof.

In the same way $\frac{\partial S_{F_4F_2F_3F_3}}{\partial A_2} - \frac{1}{2}(\frac{\partial x_0}{\partial A_2} + \frac{\partial y_0}{\partial A_2}) > 0$.

Conclusion 4: When the oil companies make the decision of "competition", the greater the difference between the new energy companies' choice of "cooperation" and "competition", the less conducive to the evolution path of the system towards the equilibrium point (cooperation, cooperation).

Proof process: $\frac{\partial x_0}{\partial (B_2 - C_2)} = -\frac{E_2 - E_2 - \Delta\omega_2 - A_2}{(\Delta\omega_2 + B_2 + A_2 - C_2)} > 0$, $\frac{\partial y_0}{\partial (B_2 - C_2)} = 0$,

So, $\frac{\partial S_{F_4F_2F_3F_3}}{\partial \quad B_2 - C_2)} = -\frac{1}{2}(\frac{\partial x_0}{\partial (B_2 - C_2)} + \frac{\partial y_0}{\partial (B_2 - C_2)}) < 0$, Get proof.

5. Conclusion

Based on the evolutionary game theory and assuming that the government supports the development of new energy, this paper analyzes and discusses the decision-making possibility of two kinds of energy enterprises, oil enterprises and new energy enterprises, under the condition of "carbon neutrality", and finds out the factors influencing the equilibrium strategy of the game model. It is concluded that under the premise of government intervention in energy development, only by choosing cooperation between oil enterprises and new energy enterprises can the system evolution move towards the optimal equilibrium point, that is, the two kinds of energy enterprises can achieve a win-win situation in the future.

Based on the above conclusions, the following suggestions are put forward. Firstly, the following suggestions are put forward to the government: the government aims to ensure the stable development of social economy, promote "carbon neutrality" and "carbon emission reduction", and promote the sustainable development of energy economy. Therefore, the government can consider giving certain incentives and subsidies to new energy and other clean energy, and encourage more enterprises to join in energy conservation and emission reduction. For some traditional energy industries, such as oil enterprises, in addition to encouraging them to participate in the cooperation with energy, it is also necessary to collect carbon tax on some traditional energy with high carbon emission to "carbon neutral". First of all, we can conduct a certain investigation on the development status of the new energy market, and according to the investigation results, we can give policy support to the oil enterprises that have the ability to invest in the market and can actively participate in the development of new energy. Secondly, for the oil enterprises that have the ability to invest but do not actively carry out in-depth cooperation with new energy, we should carry out certain management and control, pay attention to strengthen the guidance of oil enterprises, and promote their cooperation with new energy. Improve the financing environment of the current energy market, innovate and optimize the cooperation mechanism of energy enterprises, strengthen the policy support mechanism, improve the market environment for oil enterprises to carry out new energy cooperation, and encourage more oil enterprises to invest in the new energy field. Next, suggestions for oil enterprises and other traditional energy enterprises: the oil industry should pay attention to strengthening investment in the field of new energy, innovating and developing low-carbon commercial products with market competitiveness, and putting an end to disturbing the market environment and malicious competition. At the same time, multinational oil companies need to take the lead in building a viable and competitive international energy consumption market, set a good example for other small and medium-sized oil companies to cooperate with new energy, and inject innovation power.

In the future, the overall goal that Chinese energy enterprises need to achieve is to transform from a medium-high

carbon fossil energy system with coal as the main body and oil as the leading factor to a medium-low carbon energy system with clean fossil energy as the leading factor and multiple energy sources in parallel. In the future, we should ensure that the peak of carbon emissions can be achieved in 2030 and the goal of carbon neutrality can be fully realized in 2060, so as to win the strategic initiative in the era of nuclear energy. On the basis of the existing energy industry, a unified national comprehensive energy system will be built, and an industrial-grade national energy real-time dynamic monitoring system and strategic management platform will be established to support future strategic research, implementation and adjustment. The government vigorously develops renewable energy such as photovoltaic power generation, wind energy, biomass energy and geothermal energy, scientifically develops hydrogen energy, deepens energy conservation and emission reduction, and accelerates the industrialization of carbon capture and utilization.

References

[1] Nazim Z, Muradov T, Nejat V. "Green"path from fossil-based to hydrogen economy: An overview of carbon-neutral technologies. *International Journal of Hydrogen Energy*, 2008, 33(23).

[2] Laura T, Nicole K. Urban configurations of carbon neutrality: Insights from the Carbon Neutral Cities Alliance. *Environment and Planning C: Politics and Space*, 2019, 37(3).

[3] Hu M. BP World Energy Statistical Yearbook will be officially released in 2020. *Petroleum Refinery Engineering*, 2020, 50(08): 55.

[4] Lu Q. Europe is expected to bring the 2050 zero carbon emission target into law. *Energy saving in petroleum and petrochemical industry*, 2020, (3): 14-14.

[5] Cao X, Xing Z, Zhang L. Evolutionary game analysis of new energy vehicle industry development under government regulation. *Management review*, 2018, 30(009): 82-96.

[6] Max A. Government policy and the development of electric vehicles in Japan. *Energy Policy*, 2006, (34): 433-443.

[7] Li S S.Accelerate the "new gathering" of chemical industry parks and be the vanguard of high quality development of the industry. *PetroChina and chemical industry,* 2020, (11): 4-11.

[8] Wang T S, Miao X M. Game Study on R & D subsidies of new energy vehicles in China. *Soft science*, 2013, (06): 33-36.

[9] Rui Z, Gareth N, Jiao J H, Michael M G, Pauline D. Using game theory to describe strategy selection for environmental risk and carbon emissions reduction in the green supply chain. *Journal of Loss Prevention in the Process Industries*, 2012, 25(6).

[10] Rocha P, Das T K, Nanduri V, Botterud A. Impact of CO2 cap-and-trade programs on restructured power markets with generation capacity investments. *International Journal of Electrical Power and Energy Systems*, 2015, 71.

[11] Zheng L, Xu C, Wang X J. The role of co-opetition in low carbon manufacturing. *European Journal of Operational Research*, 2016, 253(2).

[12] Ioanna P, Voula P K. The impact of carbon emission fees on passenger demand and air fares: A game theoretic approach. *Journal of Air Transport Management*, 2016, 55.

[13] Wang Z L, Wang S X, Wang Z W. SWOT analysis and selection of patent strategy of new energy vehicle industry in China. *Academic forum*, 2015, 038(008): 63-68.

[14] Jia Z G, Sun T L. Analysis of industrial competitiveness based on "Cross Diamond Model" — from the perspective of electric vehicle industry. *Technological innovation and application*, 2016.

[15] Sun P, Nie P Y. New energy industry regulation: camera choice of R & D subsidies and support prices. *Contemporary finance and economics*, 2013, 000(004): 94-105.

[16] Sun P, Zhang L. Who should pay for the price subsidy of the new energy industry. *Finance and economics*, 2014, (02): 90-96.

[17] Liu Y S, Kou X Z, Hu X Q. Research on the relationship between energy saving and emission reduction, industrial agglomeration and industrial competitiveness of petroleum industry. *Science and technology management of land and resources*, 2019, 36(04): 17-26.

[18] Li S N, Chen K. Pricing strategy of new energy vehicle embedded technology service in competitive environment. *Journal of system management*, 2020, (3).

[19] Stefan G, Kim P S. Implementing carbon neutral destination policies: issues from the Seychelles. *Journal of Sustainable Tourism*, 2010, 18(3).