Diffusion of ESG Behavior Improvement Strategy for New Energy Enterprises under Weighted Benefit Risk Mechanism ——Based on Complex Network Evolution Game

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Abstract. In order to explore the impact of the enterprise's right, responsibility and profit risk mechanism on the enterprise's ESG behavior improvement strategy in the context of carbon emission reduction, this study uses Matlab to build a new energy enterprise cooperation game network model and establish the NW small world initial network. According to the process and result of multi-agent complex network game, this paper analyzes the strategic choice and development factors of ESG behavior in new energy enterprises. It is found that when the awareness of executives increases, the profits of enterprises will increase, but the spread of ESG behavior improvement is not significant; When the competitive intensity of enterprises increases, the profits of enterprises with ESG behavior improvement will decrease, and the diffusion of ESG behavior improvement strategy will be slow. When the price of carbon trading increases, the income of enterprises adopting ESG behavior will increase, but the sensitivity of carbon trading price to the expansion of enterprise network is not significant.

1. Introduction

The global climate issue makes the world further reflect on the relationship between human beings and nature, and the ESG value management concept of pursuing sustainable economic development has gradually become the consensus of all mankind. The scope of enterprise value creation extends from economic value to external environment and social value. The ESG concept requires enterprise managers to take into account economic, social and environmental benefits, and provide social and environmental responsibility and performance information that meets the needs of stakeholders. ESG evaluation system is an important means to promote enterprises to implement low-carbon transformation and achieve sustainable development. In recent years, with China's economy gradually shifting from high-speed growth to high-quality development stage, enterprises need to constantly strengthen the attention to external environment, social ethics and internal governance, and properly coordinate the relationship between human and nature, human and society, so as to achieve high-quality development of enterprises[1].

Therefore, how to spread the ESG behavior improvement strategy of China's new energy enterprises needs to be further explored. This paper starts with constructing a more perfect ESG evaluation system for new energy industry, and evaluates the ESG sustainable development ability of enterprises based on the enterprise right, responsibility, profit and risk mechanism.

2. Research design

This study determines the attributes of the firm body and studies the influence of individual firms' game decisions on themselves and their partners. The study design is as Figure 1：

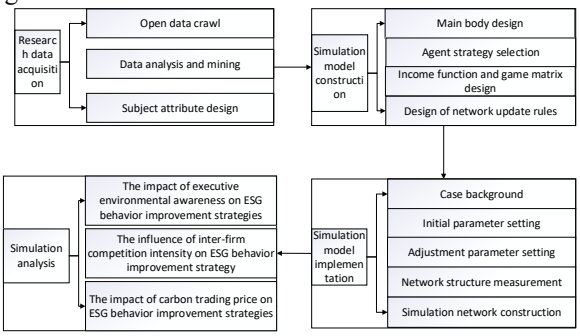

Figure 1. Research design

The research objects are new energy enterprises and government. The role of policy instruments is complex, it needs to consider the interactions between multiple agents, and system dynamics do not apply well to micro, individual decision changes. At the same time, the policy simulation process of this study focuses on discussing the effect of different right, responsibility, profit and risk mechanisms and their combinations on enterprise cooperation network. This is a dynamic adjustment process, so this study is more suitable for multi-agent simulation methods[2].

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3. Game model design

3.1 Game Model

3.1.1 Construction of small-world network model

With the rapid development of the Internet society, the relationship between enterprises is getting closer and closer, with the characteristics of a small world. In addition, the enterprises in this paper are universal, that is, there is no serious heterogeneity among enterprises. Businesses are connected through small-world networks, which reflects the impact of preference-attachment effects on business ecosystems. Firms are assumed to be profit maximizers, and by interacting with their immediate neighbors through the rules of evolutionary games, firms are able to provide profitable products[3]. The small-world network composed of enterprises is represented by G= (V, E), where V={V_i} represents the enterprise node in the network, and the element represents the edge V_i and enterprise V_j between enterprises in E, assuming that all connections in the network are undirected, if there is a connection between enterprise I and enterprise j, then (V_i, V_j) =1, otherwise (V_i, V_j) =0.

By constructing a nearest-coupled network with N nodes, they form a ring in which each node is connected to its adjacent K/2 nodes, where K is even.

An edge is added to a pair of randomly selected nodes with probability P. There is at most one edge between any two different nodes, and no node can connect to itself.

3.1.2 Game Model under Market Mechanism

Based on the research framework of Huang et al, we studied how subjects such as new energy enterprises make appropriate strategic choices over time under government supervision. These decisions change the system environment, which in turn affects the policy choices of related agents. Their interaction continued until the end of the simulation[4]. Other types of parameters are shown in the Table 1:

Table 1. Variable definition

Variable	Defined
T1	Normal income of enterprise
T2	Corporate Extra Revenue
C1	Business normal input
C2	Improving Corporate Input
Q1	Enterprise carbon emissions
Q2	Carbon emissions after enterprise ESG behavior improvement
F	Penalties for companies that do not reduce carbon emissions
a	Executive environmental awareness
b	Competitive intensity
c	Carbon trading price

Potential adopters and adopted companies are participants in the diffusion network of ESG behavior policies. Each entity has two kinds of policies: adopting ESG behavior and not adopting ESG behavior. The revenue function and game matrix are shown in the Table 2:

Table 2. Enterprise game matrix under market mechanism

		New Energy Enterprise 1	
		adopt	reject
New Energy Enterprise 2	adopt	$T_1+T_2-C_2$； $T_1+T_2-C_2$	$T_1+T_2-C_2$； T_1-C_1
	reject	T_1-C_1； $T_1+T_2-C_2$	T_1-C_1； T_1-C_1

3.1.3 Game Model under Government Regulation

It is necessary for the government to take macro-control measures to motivate and guide enterprises to adopt ESG behavior improvement strategies. The government's environmental regulation mainly restricts enterprises through relevant policies, and the environmental awareness of executives, competition intensity among enterprises and carbon trading price will affect the change of income function. Set a company environmental awareness of a competition intensity of b, carbon trading price of c. In addition, enterprises reject ESG behavior improvement strategy when carbon emissions are Q, ESG behavior improvement strategy when carbon emissions are Q ', Q' < Q, the government limits enterprises that reject ESG behavior improvement to F. Therefore, based on the game model under the market mechanism, it is improved to obtain the game model of whether enterprises adopt ESG behavior improvement under government regulation. The revenue function and game matrix are as Table 3:

Table 3. Enterprise game matrix under government mechanism

		New Energy Enterprise 1	
		Adopted	Reject
New Energy Enterprise 2	Adopted	$T_1+T_2*(1-qd)-C_2-Q'c$;$T_1+T_2*(1-qd)-C_2-Q'*c$	$T_1+T_2*(1-qd)-C_2-Q'*c$; $T_1-C_1-Q*c-F$
	Reject	T_1-C_1-Qc-F; $T_1+T_2*(1-qd)-C_2-Q'c$	$T_1-C_1-Q*c-F$; $T_1-C_1-Q*c-F$

3.2 Evolutionary Rules

In each generation game, all nodes play against each of its neighbors once, and the proceeds accumulate. According to Fermi's rule, we get the following formula:

$$P_{(i\leftarrow j)} = \frac{1}{1+e^{\frac{U_i - U_j}{k}}}$$

Where, U_i and U_j are the average returns of the two nodes respectively, node i is the node with the highest average returns among the neighbors of node j, and k is the noise. Ui is the current round of revenue i, U_j is the current round of revenue j. This function indicates that when the return of individual i is lower than that of j, it is easy for i to accept j's strategy. However, if the return of i is higher than that of j, i will still adopt j's strategy with a weak probability. This irrational choice of individual i is described by k, which describes the noise factor of the environment and reflects the uncertainty of the individual when the strategy is updated. The closer the value of k is to 0, it means that the irrational choice of the individual is approaching zero, and the strategy update is certain. Will choose to learn, otherwise will stick to their original strategy; When the value of k approaches infinity, it means that an individual is in a noisy environment, unable to make rational decisions, and can only randomly update his own strategy[5].

4. Simulation results analysis

4.1 Parameter Assignment

According to this paper, the initial probability (x) of new energy enterprises choosing production improvement ESG behavior strategy is 0.1[6].The Table 4 describes the initial parameters:

Table 4. Parameter setting

Parameter	Value taken	units
T1	0.04	Million
T2	0.04	Million
C1	0.025	Million
C2	0.035	Million
Q1	0.00002	Million
Q2	0.000012	Million
F	0.0003	Million
a	0.4	
b	0.3	
c	60	

4.2 Simulation case

4.2.1 Diffusion of Improving Strategies for ESG Behavior by Executive Environmental Awareness Levels

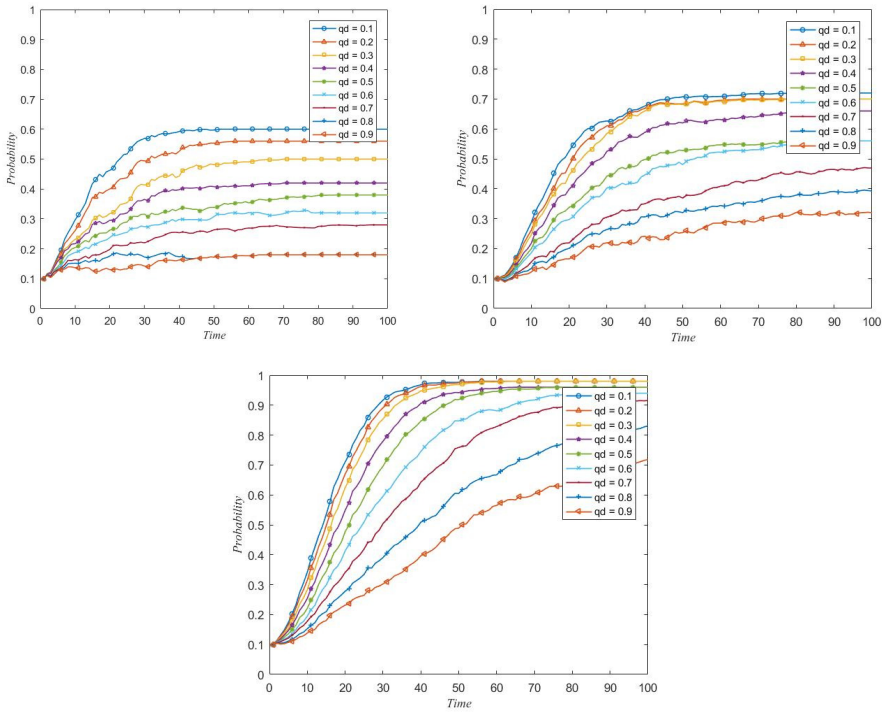

Figure 2. Diffusion chart of executive environmental awareness on ESG behavior improvement strategies

Figure 2 shows the spread of ESG behavior improvement strategies at the corresponding level of awareness level of executives of new energy enterprises. It can be seen that the efforts of enterprises to improve the environmental awareness of executives can effectively improve the earnings of enterprises.

In particular, when executives have too high awareness of environmental protection, the improvement degree of ESG behavior of enterprises will decrease. This is because the excessive awareness of corporate executives leads to the high earnings of enterprises, which does not need to share with similar enterprises, making enterprises an isolated individual. Therefore, increasing the level of environmental awareness among executives alone will not achieve the goal of significantly increasing the proliferation of ESG behavior improvement strategies in enterprises.

4.2.2 Effect of Competition Intensity on ESG Behavior Improvement Strategies

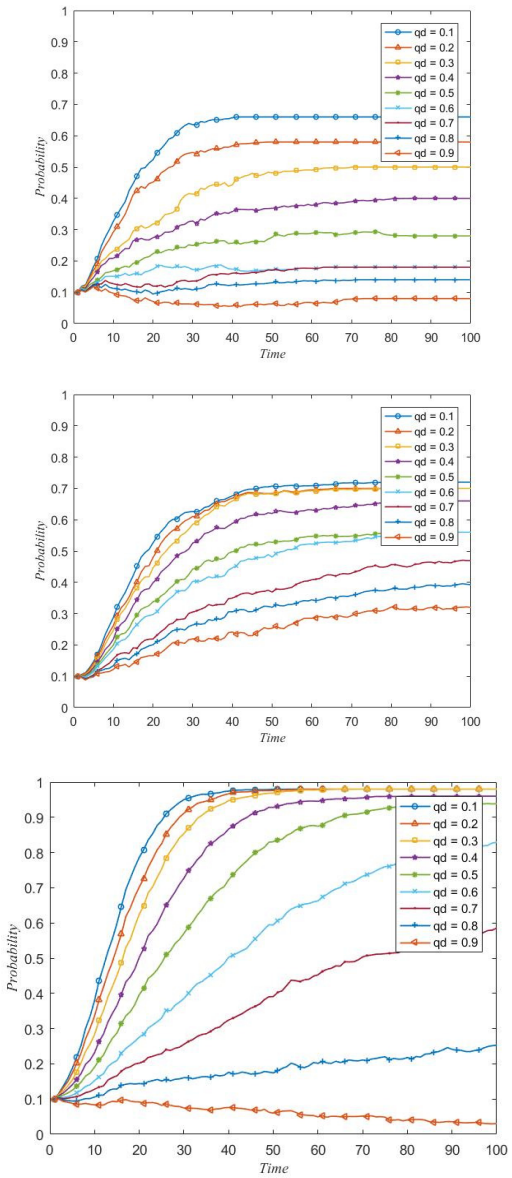

Figure 3. Competition intensity on ESG behavior improvement strategy diffusion graph

Figure 3 shows the improvement of ESG behavior under the corresponding degree of competition intensity b[0.1, 0.9] among new energy enterprises. With the increase of competition intensity in enterprise networks of different sizes, the improvement degree of ESG behavior decreases correspondingly. It can be seen that the increase of inter-firm competition intensity cannot improve the spread of inter-firm ESG behavior improvement strategies. This is because the increase in competition intensity will reduce the additional income of new energy enterprises adopting ESG behavior and increase the cost under the same income. When the benefits of new energy enterprises participating in the improvement of ESG behavior are greater than those that do not improve ESG behavior, more enterprises will be encouraged to adopt ESG behavior, thus increasing the intensity of competition. In addition, the larger the network size, the more sensitive the response to competition intensity. In other words, as the number of enterprises in the network increases, the diffusion of ESG behavior improvement strategies under the same competitive intensive increases.

4.2.3 Effect of Carbon Trading Price on the Diffusion of ESG Behavior Improvement Strategies

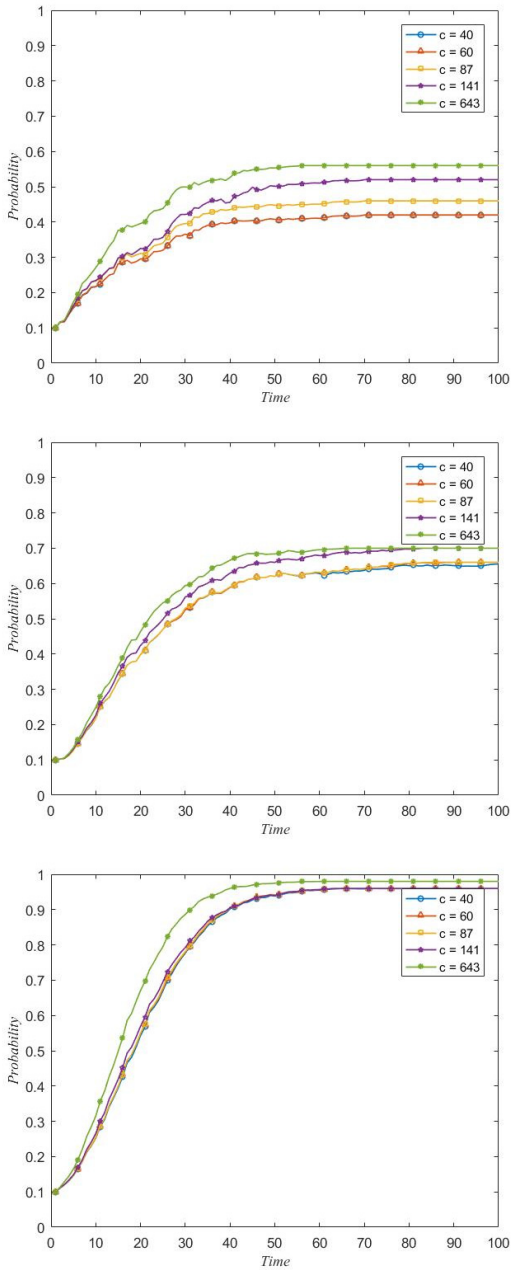

Figure 4. Carbon trading price on ESG behavior improvement strategy diffusion chart

Figure 4 shows the diffusion of ESG behavior improvement strategies at low (40 yuan/ton), medium (60 yuan/ton) and high (87 yuan/ton) levels in China, as well as Australia (141 yuan/ton) and the EU (653 yuan/ton) under corresponding carbon trading prices. Generally speaking, with the increase of carbon trading price in the network of different scales, the carbon emission trading between enterprises decreases, and the degree of diffusion increases accordingly. It can be seen that the increase in the price of carbon trading among enterprises is conducive

to improving the diffusion level of ESG behavior improvement strategies. This is because an increase in the price of carbon trading will reduce the profits of new energy companies. When the carbon emission income is higher than the emission reduction income, it encourages more new energy enterprises to adopt ESG behavior to improve and reduce carbon emission. Moreover, the larger network is even less sensitive to the price of carbon trading. Although with the increase of the number of new energy enterprises in the network, the diffusion degree of ESG behavior improvement strategy will increase correspondingly under the same carbon trading price, due to the increase of network scale, the increase of the number of new energy enterprises and the increase of carbon trading frequency among enterprises, carbon trading price will not be paid too much attention. On the other hand, the increase of new energy enterprises in the network increases the number of neighbors, thus expanding the cumulative benefits of participants. Therefore, the strategy of new energy enterprises with resource advantages will be emulated by more enterprises. On the other hand, with the increase of the number of optional learning objects, the learning and updating rate of enterprises will be more efficient, so enterprises will choose to improve ESG behavior, thus making ESG behavior improvement strategies spread. This paper discusses the choice of ESG behavior improvement strategy from the perspective of network characteristics, and reveals that strengthening the connection between enterprises in the industry is conducive to the dissemination of ESG behavior improvement strategy.

5 Comparison and summary of simulation cases

Comparing the game results of each scheme, it can be seen that enterprises should adopt ESG behavior and establish a model conforming to the standard to ensure the normal operation of the game network. When enterprises operate under the government mechanism, the network of evolutionary game can exist stably. In the meantime. For the network, there are some obvious different game results due to the different combination of enterprise's right, responsibility, profit and risk mechanism.

At present, the environmental awareness of corporate executives can bring additional benefits to enterprises, but it will not promote the spread of ESG behavior improvement strategies among enterprises. Meanwhile, with the increase of the scale of enterprises in the network, the degree of choice diffusion for ESG behavior improvement also increases.

Compared with the environmental awareness of corporate executives, the improvement of ESG behavior in the intensity of competition among enterprises has a better diffusion effect. The increase in the intensity of competition among enterprises will reduce the additional income of enterprises conducting ESG behavior. At the present stage, the small number of enterprises conducting ESG behavior will bring higher income to enterprises[7].

In the context of complex network evolution game, neither the carbon trading price for new energy enterprises nor the intensity of competition among enterprises can fully improve ESG behavior. Therefore, comprehensive ESG behavior improvement requires the integration of multiple measures.

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