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Research on the analysis of interaction between small and medium sized enterprises and large enterprises based on evolutionary game theory

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Abstract. This paper constructs the basic game model and evolutionary game model, which derives the selection results of small and medium sized enterprises and large enterprises in the competition and cooperation strategies from the perspective of evolutionary game analysis, and studies the interactive relationship among different scale enterprises. The results show that the source of motivation for the development of small and medium-sized enterprises and large enterprises is their market environment. The interaction between small and medium-sized enterprises and large enterprises in a unified market environment is a long-term symbiotic relationship based on "competition + cooperation." The hybrid strategy Nash equilibrium will be the only equilibrium with steady and stable evolution of the model.

Key words. Market environment, interactive relationship, growth of small and medium-sized enterprises, evolutionary game model.

1. Introduction

Since the reform and opening up, the small and medium-sized enterprise(SMEs) groups have witnessed rapid development and have gradually become the major force in the economic development of our country. Up to now, more than 99% of the total number of enterprises in our country are SMEs. These SMEs provided nearly 80% of the work opportunities for the whole society, creating nearly 60% of national industrial output value and contributing nearly 50% of state revenue. Small and medium-sized enterprises play an important role in the economic development of our country and are an important part of our economy. In the "13th Five-Year Plan", it is clearly stated that it is necessary to give full play to the role of small and medium-sized enterprises in promoting the social and economic development of our country and a new situation in which all the people start their own businesses and innovate

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in many ways by promoting the development of small and medium-sized enterprises. The development of small and medium-sized enterprises has an important practical significance for the social and economic development of our country. However, the average life expectancy of small and medium-sized enterprises in our country is only 2.9 years. The extremely low survival rate has restricted the development of SMEs in our country and also limited the role of SMEs in the social and economic development of our country. Since the status of SMEs in the national economy of our country is of crucial importance, solving the problem of the "short life span" of small and medium-sized enterprises is one of the keys to promoting sound and rapid economic development in our country.

To promote the growth of small and medium-sized enterprises in the region is the key to solving the problem of short life of SMEs. The growth of SMEs can not be separated from the effective guidance and support of the government, nor can they ignore the overall coordination of regional economic development and environmental protection. With the advancing of the times, the growth of SMEs must ensure "continuity." This concept of continuous growth is constantly applied to various fields such as social organizations, enterprise production and management, and has derived various new meanings of divergence. "Continuous growth" gradually detached itself from the emotional, moral constraints, and has become an important strategic principle of business management. In the context of economic restructuring, Chinese enterprises should adopt "sustained growth" as a strategic guideline for their enterprises, and reasonably face opportunities and severe challenges brought by economic globalization and seek their own development and going-concern management.

SME growth is in the interactive relationship with large enterprises which continues to evolve. In reality, there are many factors that affect the interaction between SMEs and large enterprises. The research in this paper considers that the market environment which is the most important explanatory variable, and therefore it takes the market environment as the driving force for evolution. If the business is compared to ling things, its growth is closely related to the ecological environment. For the enterprise, the market environment in which the enterprise is located is an ecological environment inseparable from its growth. In order to understand the influence of market environment on the interaction between SMEs and large enterprises, this paper regards the relationship between enterprises and market environment as the relationship between living organisms and ecological environment, the establishment and bankruptcy of enterprises, and the growth and development of living entities And decay is very fit. Living organisms compete in order to survive in a particular ecological environment. When the ecological environment changes, the law of "survival of the fittest" acts on all living organisms in the ecological environment, and the living organisms that do not adapt to the environmental change will be eliminated and continue Living organisms are combined into new interactive relationships. Thus, the market relations directly affect the interaction between enterprises, interaction with the dynamic changes in the market environment, therefore, the market environment is the driving force for the evolution of interactive relationships.

Different market environments have different impacts on the interaction between

SMEs and large enterprises, resulting in different economic results of the growth of small and medium-sized enterprises, which have a direct impact on the gradual progress of SMEs. In an environment with relative shortage of market resources, the phenomenon of "in short supply" has induced the "symbiotic" interaction between SMEs and large enterprises. Both SMEs and large enterprises rely on each other to grow together in the same ecological environment. Large enterprises rely on their own strength for R & D , Accept the product orders, SMEs and with them, engaged in large-scale strategic outsourcing of special scientific research programs, product processing and production work. Under the circumstance of relative surplus of resources, oversupply has produced the relationship of "competition + cooperation". Small and medium-sized enterprises survive in the competition among large enterprises and the growth of SMEs is struggling. Under such circumstances, SMEs should adjust their development strategies, With the same market environment, large enterprises "more cooperation and less competition," not with large-scale production of large enterprises competing for product production capacity, but focus on product personalization services and other fields, the development strategy of SMEs and large enterprises form a benign and complementary .

2. The basic game model

Based on the previous theoretical analysis, this paper constructs an evolutionary game model to describe the interaction and evolution path between SMEs and large enterprises. Evolutionary game theory is a theory that combines game theory with dynamic evolutionary process analysis. Compared with classical game theory, evolutionary game theory does not focus on static equilibrium and static equilibrium, but emphasizes one dynamic equilibrium. The origin of evolutionary game theory is the theory of biological evolution, which can correctly explain the objective phenomena in the process of biological evolution. Here we use the evolutionary game method to analyze the evolution of the interaction between SMEs and large enterprises.

2.1. Construction of basic model

The establishment of the classic game model is the basis of evolutionary game. In the form of payment matrix, the interactive game relationship among different players in the game is described. The participants are divided into small and medium-sized enterprises and large enterprises. The strategy is divided into competition and cooperation, and the equilibrium is solved.

First of all, this paper uses the classical game model to describe the interactive game between different players. A classic game model includes elements such as participants, strategy sets, information, payment functions, etc. Therefore, we construct a payment matrix for the game model (see Figure 1). The payment matrix is composed of two types of participants, two kinds of participants of each type and eight kinds of payment functions of different returns. $TR_{ij}{}^{Z}$in the matrix indicates that when the other party selects the j strategy, player Z select I income.

Solve the classic game model to understand the relationship between the number

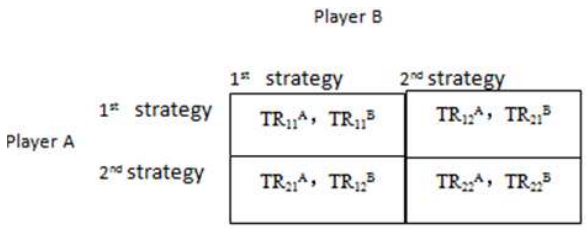

Fig. 1. The 2^{nd} strategy

of payment functions. According to the information of the payment matrix, there are 16 kinds of relations from the narrative point of view.

(1)$TR_{11}{}^{A}>TR_{21}{}^{A}andTR_{12}{}^{A}>TR_{22}{}^{A}andTR_{11}{}^{B}>TR_{21}{}^{B}andTR_{12}{}^{B}>TR_{22}{}^{B}$
(2)$TR_{11}{}^{A}>TR_{21}{}^{A}andTR_{12}{}^{A}>TR_{22}{}^{A}andTR_{11}{}^{B}>TR_{21}{}^{B}andTR_{12}{}^{B}<TR_{22}{}^{B}$
(3)$TR_{11}{}^{A}>TR_{21}{}^{A}andTR_{12}{}^{A}>TR_{22}{}^{A}andTR_{11}{}^{B}<TR_{21}{}^{B}andTR_{12}{}^{B}>TR_{22}{}^{B}$
(4)$TR_{11}{}^{A}>TR_{21}{}^{A}andTR_{12}{}^{A}>TR_{22}{}^{A}andTR_{11}{}^{B}<TR_{21}{}^{B}andTR_{12}{}^{B}<TR_{22}{}^{B}$
(5)$TR_{11}{}^{A}>TR_{21}{}^{A}andTR_{12}{}^{A}<TR_{22}{}^{A}andTR_{11}{}^{B}>TR_{21}{}^{B}andTR_{12}{}^{B}>TR_{22}{}^{B}$
(6)$TR_{11}{}^{A}>TR_{21}{}^{A}andTR_{12}{}^{A}<TR_{22}{}^{A}andTR_{11}{}^{B}>TR_{21}{}^{B}andTR_{12}{}^{B}<TR_{22}{}^{B}$
(7)$TR_{11}{}^{A}>TR_{21}{}^{A}andTR_{12}{}^{A}<TR_{22}{}^{A}andTR_{11}{}^{B}<TR_{21}{}^{B}andTR_{12}{}^{B}>TR_{22}{}^{B}$
(8)$TR_{11}{}^{A}>TR_{21}{}^{A}andTR_{12}{}^{A}<TR_{22}{}^{A}andTR_{11}{}^{B}<TR_{21}{}^{B}andTR_{12}{}^{B}<TR_{22}{}^{B}$
(9)$TR_{11}{}^{A}<TR_{21}{}^{A}andTR_{12}{}^{A}>TR_{22}{}^{A}andTR_{11}{}^{B}>TR_{21}{}^{B}andTR_{12}{}^{B}>TR_{22}{}^{B}$
(10)$TR_{11}{}^{A}<TR_{21}{}^{A}andTR_{12}{}^{A}>TR_{22}{}^{A}andTR_{11}{}^{B}>TR_{21}{}^{B}andTR_{12}{}^{B}<TR_{22}{}^{B}$
(11)$TR_{11}{}^{A}<TR_{21}{}^{A}andTR_{12}{}^{A}>TR_{22}{}^{A}andTR_{11}{}^{B}<TR_{21}{}^{B}andTR_{12}{}^{B}>TR_{22}{}^{B}$
(12)$TR_{11}{}^{A}<TR_{21}{}^{A}andTR_{12}{}^{A}>TR_{22}{}^{A}andTR_{11}{}^{B}<TR_{21}{}^{B}andTR_{12}{}^{B}<TR_{22}{}^{B}$
(13)$TR_{11}{}^{A}<TR_{21}{}^{A}andTR_{12}{}^{A}<TR_{22}{}^{A}andTR_{11}{}^{B}>TR_{21}{}^{B}andTR_{12}{}^{B}>TR_{22}{}^{B}$
(14)$TR_{11}{}^{A}<TR_{21}{}^{A}andTR_{12}{}^{A}<TR_{22}{}^{A}andTR_{11}{}^{B}>TR_{21}{}^{B}andTR_{12}{}^{B}<TR_{22}{}^{B}$
(15)$TR_{11}{}^{A}<TR_{21}{}^{A}andTR_{12}{}^{A}<TR_{22}{}^{A}andTR_{11}{}^{B}<TR_{21}{}^{B}andTR_{12}{}^{B}>TR_{22}{}^{B}$
(16)$TR_{11}{}^{A}<TR_{21}{}^{A}andTR_{12}{}^{A}<TR_{22}{}^{A}andTR_{11}{}^{B}<TR_{21}{}^{B}andTR_{12}{}^{B}<TR_{22}{}^{B}$

In this paper, the 13th kind of relationship is taken as an example to explain the model. $TR_{11}{}^{A}<TR_{21}{}^{A}$ and $TR_{12}{}^{A}<TR_{22}{}^{A}$ and $TR_{11}{}^{B}>TR_{21}{}^{B}$ and $TR_{12}{}^{B}>TR_{22}{}^{B}$, which means that when participant B chooses to select the first strategy, participant A chooses the first strategy to have a lower return than the second strategy. When participant B selects When the second strategy is selected, the income that participant A chooses the first strategy is less than the second. When participant A chooses to choose the first strategy, participant B chooses the first strategy to gain more than the second strategy When participant A chooses to choose the second strategy, participant B chooses the first strategy to gain more than the second strategy. Using the superiority strategy selection method, we can see that under the 13th game relationship, (strategy 2, strategy 1) is the Nash equilibrium of the game. The equilibrium return at this time is ($TR_{21}{}^{A}??TR_{12}{}^{B}$)

2.2. Game tree model

In real life, the market information in which both sides of the game are located is not complete, and the decisions made by each other are also independent. In order to improve the convenience of evolutionary game analysis below, the model is

transformed into the form of a game tree, which is both Can help to reflect the impact of the real uncertainty on the dynamic process of economic evolution through the implementation of probability and also help to observe the decision-making process of participants. Introduce the game-based model of the identity, competition or cooperation between SMEs and large enterprises (Figure 2). Suppose the probability of SMEs choosing competitive strategy is p, the probability of selecting cooperation strategy is (1-p), the probability of large enterprises choosing competitive strategy is q, and the probability of selecting cooperation strategy is (1-q).

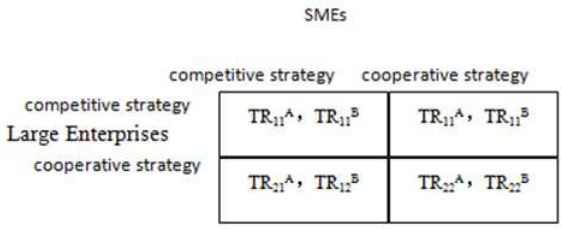

Fig. 2. Competition strategy game of different scale enterprises

The "Harsanyi Transfor mation" of the payment matrix of small and medium-sized enterprises and large enterprises in Figure 2 is converted into two kinds of game trees starting from small and medium-sized enterprises and large enterprises respectively (see Figure 3)

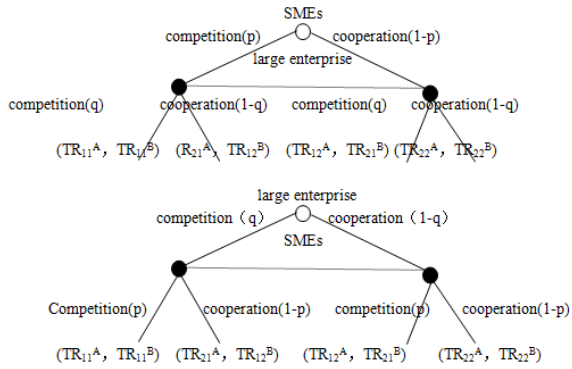

Fig. 3. Game tree of competing strategy for different scale enterprises

SMEs usually have three types of choices. If SMEs choose a competitive strategy, the expected return for SMEs is $qTR_{11}{}^B+(1-q)TR_{12}{}^B$. If SMEs choose a cooperative strategy, the expected return for SMEs is $qTR_{21}{}^B+(1-q)TR_{22}{}^B$. If small and medium- When companies choose a hybrid strategy, the expected return on SMEs is:

$p[qTR_{11}{}^B+(1-q)TR_{12}{}^B]+(1-p)[qTR_{21}{}^B+(1-q)TR_{22}{}^B]$

By analogy, we can see that the expected return of large-firm competition strategy is$pTR_{11}{}^B+(1-p)TR_{12}{}^B$, and the expected return of large-scale cooperation strategy

is $pTR_{21}{}^{B}+(1\text{-}p)TR_{22}{}^{B}$:
$q[pTR_{11}{}^{B}+(1\text{-}p)TR_{12}{}^{B}]+(1\text{-}q)[pTR_{21}{}^{B}+(1\text{-}p)TR_{22}{}^{B}]$

2.3. Nash equilibrium analysis

In the previous section, the quantitative relationship matrix of 16 payment under different payment functions is listed. According to the game model, an equilibrium solution is obtained. Different quantitative combinations result in different equilibrium results, even without Nash equilibrium. This also shows that the two sides of the game will make economic decisions through different quantitative relations.

As SMEs and large enterprises are all in the same market environment, many changes in the market environment will have an impact on the relationship between the two returns. The relationship between the returns under different influences will determine the strategy of "competition and cooperation" between SMEs and large enterprises, The two sides of the game will make the correct decision based on the known information of each other and their own payment function, resulting in different equilibrium results.

There are four pure strategies Nash equilibrium (competition, competition), (cooperation and cooperation), (competition and cooperation), (cooperation and competition) between SMEs and large enterprises. It also includes the "mixed strategy" balanced. In these Nash equilibriums, we should pay attention to the most stable strategy combination of the interaction between SMEs and large enterprises under the dynamic changes of the market environment. After practice observation, it is not difficult to find out that Nash equilibrium of "hybrid strategy" in the interactive relationship between SMEs and large enterprises is the mainstream strategy. Large enterprises or small and medium-sized enterprises will not choose a simple competitive strategy or cooperative strategy, but choose a mixed competition Cooperation strategy, interest-oriented No friends forever or no enemy forever, forming a special "competition + cooperation" competing relationship, so as to achieve symbiotic evolution.

3. Construction and Analysis of Evolutionary Game Model

Although we can see from the practice observation that "hybrid strategy" is the mainstream strategy for the interaction between small and medium-sized enterprises and large enterprises, it lacks effective proof. Therefore, this article builds an evolutionary game model to verify the previous conclusions from the theory and method.

3.1. model hypothesis

Hypothesis 1: Small and medium-sized enterprises and large enterprises are the representatives of the two parties in the game. Such "representation" reflects the general situation and average level of the enterprises. The game between "representative" enterprises can represent two types of small and medium-sized enterprises Game between enterprises.

Hypothesis 2: There are two strategies for the two sides of the game: strong competitive strategy and strong cooperative strategy.

Hypothesis 3: The payment matrix is the evaluation standard of game utility, which is not the standard of financial income. This shows that the game on both sides of the game is not based on financial benefits, but the game on their own effectiveness.

Hypothesis 4: The two sides of the game have different judgments on the utility of returns. The returns in the payment matrix represent the utility levels of the decisions of the enterprises. It is assumed that the market share obtained by the two parties in the cooperation strategy is equal to the utility of both parties and the same price is paid for the cooperation. This kind of game is usually called the symmetry game, and can get the typical conclusion.

Hypothesis 5: The game between the two parties takes place in a generalized market environment, which filters out the interaction between different markets and filters out random perturbations such as industry, time series and regional differences, and only considers the interaction between SMEs and large enterprises.

3.2. Model establishment

As SMEs and large enterprises have two kinds of pure strategy: competition strategy and cooperation strategy. From hypothesis 4, we can see that α is the return of competitive strategy of both players, representing the profit margin of the market, $\alpha > 0$. β is the loser on the losing side of the competition, $\beta > 0$. If both players choose a competitive strategy, assuming both parties fail at a probability of 1/2, the expected utility level of both sides is (α-β) / 2. If both parties adopt a cooperative strategy, the two parties will not lose the competition due to competition. Both parties will share the market profit margin α and obtain a α / 2 profit respectively. When one party chooses the cooperation strategy and the other party chooses the competition strategy, then the party that chooses the competition strategy will own the market profit space α, and the party who chooses the cooperation strategy will find nothing.

Therefore, the income matrix of SMEs can be summarized as (α-β) / 2, α; 0, α / 2). The game at this time is a symmetric game. The game model can be concretely divided into the form of the payment matrix, As shown in Figure 4.

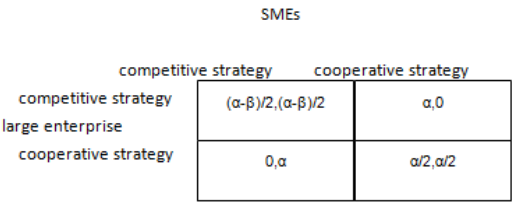

Fig. 4. Big Enterprises and Small and Medium Enterprises "Competition - Cooperation" Game

After the model is constructed, λ is set as the probability that SMEs choose

competitive strategy. Then the probability of SMEs selecting cooperative strategy is (1-λ) and μ is the probability of large firms choosing competitive strategy. Then SME choice The probability of cooperation strategy is (1-μ).

3.3. Model derivation and analysis

(1) Multiple Nash Equilibrium

When $\alpha > \beta$, it should be discarded. $\alpha > \beta$ is the result of the competition of the selection of competitive strategy is greater than the cost, at this time (α-β) / 2> 0, $\alpha > \alpha$ / 2. For small and medium-sized enterprises and large enterprises, the competitive strategy is superior to the cooperative strategy. (Competition, competition) is the Nash equilibrium of the game model. At the moment, the overall level of return is (α-β). However, in practice, long-term sheer competition is bound to result in the cost of failure is greater than the success of the proceeds, and the results of the model do not match, so the result is discarded.

When $\alpha < \beta$, there are two kinds of pure strategy equilibrium and one hybrid strategy Nash equilibrium. $\alpha < \beta$ indicates that the cost of selecting a competitive strategy is greater than the return of victory, and (α-β) / 2 <0, $\alpha > \alpha$ / 2. The Nash equilibrium at this time is the Nash equilibrium of two pure strategies (competition, cooperation) and (cooperation, competition).

Mixed strategy means that the participants choose not the only strategy, but according to a certain probability in the strategic space evenly distributed. Mixed strategy Nash equilibrium makes both small and medium-sized enterprises and large enterprises can not benefit by changing their own hybrid strategy. The Nash equilibrium of the mixed strategy is the result that all parties in the game should achieve through the game. According to the above set of SMEs and large enterprises in the hybrid strategy of competition, the probability of cooperation strategy, so that large enterprises, SMEs choose the expected return of competition and choose the expected return of cooperation are equal.

$$\lambda * (\alpha - \beta)/2 + (1 - \lambda) * \alpha = \lambda * 0 + (1 - \lambda) * \alpha/2$$

$$\mu * (\alpha - \beta)/2 + (1 - \mu) * \alpha = \lambda * 0 + (1 - \mu) * \alpha/2$$

By solving the above equation, an equilibrium solution is obtained: λ=α/β??μ=α/β

When small and medium-sized enterprises and large enterprises select competition and cooperation strategies by (a / β, 1-α / β) probability combination, they can not improve their expected returns by changing their random choice probability distribution, Game Strategy Mixed Strategies Nash Equilibrium At this point, SMEs and large enterprises will adopt a "competition + cooperation" hybrid strategy, the formation of a "competing" stable interaction between the two. This can already explain the necessity of the existence of the interactive relationship between small and medium-sized enterprises and large enterprises. The expected return on SMEs at this time is:

$$\lambda * \mu * (\alpha - \beta)/2 + \lambda * (1 - \mu) * \alpha + (1 - \lambda) * \mu * 0 + (1 - \lambda) * (1 - \mu) * \alpha/2 = \alpha(\beta - \alpha)/2\beta$$

(2)Evolutionary Stability of Hybrid Strategies

Through the observation of the objective reality, the interactive relationship between SMEs and large enterprises is a sustained and stable symbiotic game in which competition and cooperation coexist. In the evolutionary game theory, this relationship means that the hybrid strategy Nash equilibrium is the Nash equilibrium strategy for the interaction between SMEs and large enterprises, both sides will take a mixed strategy of "competing + cooperation" under a specific probability distribution. At this time, Nash The equilibrium strategy is evolution strategy.

Set U1, U2, respectively, for SMEs select the competitive strategy, the expected utility of cooperation strategy, Us on behalf of the overall effectiveness of SMEs.

$U_1=\mu*(\alpha-\beta)/2+(1-\mu)*\alpha$

$U_2=\mu*0+(1-\mu)*\alpha/2$

$U_s=\lambda*U_1+(1-\lambda)*U_2$

According to the dynamic replication equation, three stable states can be solved in this paper: $\lambda_1=0$ $\lambda_2=1$ $\lambda_3=\alpha/\beta$, and $d\lambda_1/dt>0$ $d\lambda_2/dt>0$ $d\lambda_3/dt<0$, so only $\lambda 3 = \alpha/\beta$ among the three equilibrium points is the evolutionary stability strategy, so the evolutionary stability criterion excludes the pure competition strategy and the pure cooperation strategy. In the evolution of the long-term interaction between SMEs and large enterprises, both parties choose a hybrid strategy of competition and cooperation based on (α/β 1-α/β), and the strategy has sufficient stability in the evolution .

4. Conclusions

The evolutionary game model in this paper proves that the interaction between small and medium-sized enterprises and large enterprises is a long-term symbiotic relationship based on "competition + cooperation". Hybrid strategy Nash equilibrium will be the only equilibrium with evolutionary stable meaning. After the choice of history and laws of nature, small and medium-sized enterprises and large enterprises will choose the strategy of "competition + cooperation" while making development strategic choices.

From the perspective of the market environment is not difficult to find that the market environment as an ecological environment for business survival and growth is bound to be one of the driving forces for the evolution of the interactive relationship between small and medium-sized enterprises and large enterprises. Whether it is resource shortage market environment, relative surplus market environment or knowledge economy market environment, all are the motive bases for promoting the evolution of "competition + cooperation" between SMEs and large enterprises. Changes in the market environment induce micro-economic changes in the main decision-making, resulting in the occurrence of different equilibrium results. From this we can see that the changes in the market environment have promoted the evolution of the interactive relationship between SMEs and large enterprises. During the evolution, the interactive relationship between "competition + cooperation" is relatively stable and the specific forms of expression are constantly changing.

From the business point of view, we can see that different types of enterprises are

the foundation for the evolution of micro-level. In reality, large enterprises dominate the direction of market development, have sufficient capacity for product pricing and technological innovation, and can become the main body of induced behavior in the dynamic game. Many small and medium-sized enterprises follow the pace of large enterprises to imitate innovation or find their own development links in the industrial chain and large enterprises, and follow the dynamic changes in the market to adjust their own development. The two choose a mixed strategy of "competition + cooperation" in different market environments and operate symbiotic evolution mechanism in different manifestations.

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