Proceedings of the 2nd International Conference on Business and Policy Studies
DOI: 10.54254/2754-1169/11/20230542

The Impact of Government Policies on Natural Monopoly Markets Based on Evolutionary Games

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Abstract: Financing is difficult during the post-epidemic era. A lot of industries occupied by monopolies are so large that the goods they produce are often "over-priced" and this will have a number of adverse effects on market equilibrium. This paper constructs a game model in which the government, the monopolies and the SMEs wishing to enter the monopoly market are the main actors, and this article analyzes the impact of the government's actions on the monopoly market and make conclusive recommendations. The final choice of three sides of the game can be obtained by discussing whether the government chooses to regulate the monopoly market with subsidies and taxes, whether the monopolies set high or low prices and whether the Small and medium-sized enterprises are willing to enter the monopoly market. The final analysis of the evolutionary game model concludes that: the strength of government regulation is the decisive factor in the final Nash equilibrium point of the game.

Keywords: post-epidemic era, monopoly, regulation, evolutionary game

1. Introduction

During the past ten years, industry monopolies were created because a trend in the market for business giants to merge with SMEs appeared. In addition, the impact of the epidemic has continued to tighten the domestic investment and financing environment in China, slowing down capital flows. Small and medium sized enterprises feel powerless when face the industry barriers formed by monopolies and many companies choose to exit the market in order to stop their losses in time. When the number of companies in a market gradually decreases and eventually a monopoly is formed to operate this business, consumers are often the ones that suffers the damage, resulting in a loss of social welfare [1]. Therefore, in the post-epidemic era, when it has been recognized that a widespread epidemic can cause incalculable damage to the entire economic system, the effectiveness of government regulatory instruments on monopolies in reducing the loss of social welfare has become a matter of public concern.

Chinese scholars Sun and Zhao, in their article "The Coexistence of Oligopolies and SMEs", mention that when an industry is newly created, low barriers to entry and exit lead many firms join

DOI: 10.54254/2754-1169/11/20230542

the competition, but the competitive market will eventually favor the most efficient and well-positioned firms [2]. When the quest for efficiency evolves into unproductive over-competition, most markets will respond logically by restructuring, merging or exiting numerous times, eventually moving towards monopoly. At this point, oligopoly will become the ultimate choice of industrial structure. For example, General Motors (GM), Ford and DaimlerChrysler in the US automotive industry, ExxonMobil, Texaco and Chevron in the US oil industry, and Philips in the European semiconductor industry. Philips, SCS-Thomson and Siemens in the European semiconductor industry, among others.

A study by foreign scholars Parente and Prescott found in a comparison of competitive and monopolistic markets that, controlling for the overall environment being the same, the relative GDP of monopolistic markets was 2.72% lower than that of free markets, and the relative price of a basket of goods was 4.3 times higher than that of competitive markets [3]. 4.3 times the price of a basket of goods than a competitive market and a series of data supporting the claim that monopoly markets are bad for economic growth, Parente and Prescott conclude in their final conclusion that it would be a good policy to help economic development that prevent monopolies and promoting competition [4]. Domestic scholars Hu and Guo studied the move from monopoly markets to competitive markets in China, concluding from estimates of the size of monopolies in various industries and interviews with entrepreneurs [5]. And local cadres about the perception of corruption in various industries that the government has largely become the gatekeeper representative. In describing the benefits of breaking up administrative monopolies and promoting competition, the author mentions the State Council's adoption in 1990 of a plan to restructure China's telecoms companies and subsequently to allow multiple companies to compete in the market, thus ultimately benefiting the people by significantly reducing the cost of the electricity grid. Ultimately Hu and Guo propose in their paper the separation of government and enterprises to cut off the root of administrative monopoly. Ma and Ding compared the size of social welfare before and after private enterprises enter the monopoly market by establishing a game model between the government, private enterprises and monopolies, arguing that when the cost of regulation is small, the government will choose to break the monopoly and guide private enterprises to enter the monopoly market to promote competition to increase social welfare [6].

Small and medium-sized enterprises entering monopolistic markets inevitably encounter a series of difficulties in financing and development, making it difficult to obtain an equilibrium outcome. In addition, Yao in a study on the pathways of government subsidies on SME innovation, mentions that the financing gap of SMEs reached over 80% under the impact of the new crown pneumonia [7]. This means that the government needs to strongly support these small and medium-sized private enterprises in order for them to resume innovation and contribute additional benefits to society. Cai and Chen argue that when the market fails, the government can regulate the market from a macro perspective, by subsidizing financial contributions to enterprises and supporting prices or revenues to achieve the ultimate goal, by listing three types of subsidies that the Chinese government is currently using, namely government grants and financial subsidies and tax rebates [8,9]. By explaining the three types of subsidies and the differences, the importance of government subsidies for businesses is illustrated. It is easy to find that there is still a gap in the analysis of the government's use of taxation plus subsidies to regulate monopolistic markets. This paper will use the construction of an evolutionary game model to obtain the payment matrix by setting appropriate parameters for the strategies of different players, and by analyzing the replication of the dynamic equations and the stability conditions of the model, finally arriving at a stable strategy for the three-party game and proposing corresponding policy recommendations.

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2. Methodology

Under the precondition of dynamic game, it's assumed that the government, small and medium-sized enterprises and monopoly enterprises are not fully rational subjects, but even though there are conditions of asymmetric information and incomplete rationality, all subjects can still clearly find all possible schemes to realize their objectives, so as to reach the optimal solution of some aspect they are hunting for, predict the implementation consequences of these schemes, and finally make the optimal choice[10].

Assumption 1: the game is composed of the government, monopoly enterprises as well as small and medium-sized enterprises attempting to enter the monopoly market. The government can choose whether to regulate or not: impose monopoly tax on monopoly enterprises and subsidize small as well as medium-sized enterprises; Small and medium-sized enterprises can choose whether to enter the monopoly market; The monopoly enterprise has the ability to set high prices to seek excess profits or set predatory low prices to drive away small and medium-sized enterprises. RM is the net profit of the monopoly enterprise that the small and medium-sized enterprises do not choose to enter the market, and Rm is the net profit of the monopoly enterprise that the small and medium-sized enterprises choose to enter the market. Rn is the net profit of small and medium-sized enterprises when the monopolist sets a high price.

Assumption 2: the probability of the government choosing non regulation is x, and the probability of choosing the regulation means of subsidies and taxes is (1-x); The probability of monopoly enterprises choosing to set high prices is y, and the probability of setting predatory low prices is (1-y); The probability that small and medium-sized enterprises choose to enter the monopoly market is Z, and the probability that they choose not to enter the monopoly market is (1-z).

Assumption 3: the regulation cost that the government departments must bear is E, the monopoly tax levied by the government departments on the monopoly enterprises is T, and S is the subsidy of the government departments to the small and medium-sized enterprises. Small and medium-sized enterprises must bear the entry fee F when entering the monopoly market. The time required for small and medium-sized enterprises to withdraw from the market when the monopoly enterprises make predatory low prices is A or a, assuming that one year is a natural cycle, if the monopoly enterprises formulate predatory low prices to expel the small and medium-sized enterprises from the market, it takes six months, then a equal 1/2; if it takes three months, then A equals 1/4.

Assumption 4: social welfare Wi is composed of the sum of producer surplus and consumer surplus. Assuming that the consumer surplus is CS1 when the commodity in the market is at a high price and CS2 when the commodity in the market is at a low price.

Assumption 5: C1 is the economic loss of the monopoly enterprise in a natural cycle after the predatory low price is set for the monopoly enterprise; When the monopoly enterprises formulate predatory low prices to expel small and medium-sized enterprises, the loss of small and medium-sized enterprises within a natural cycle is C2.

Based on the above assumptions, we choose to use evolutionary game theory to analyze this issue and build a game tree as shown in figure.1 to provides a visualization of game tree of three-party dynamic game:

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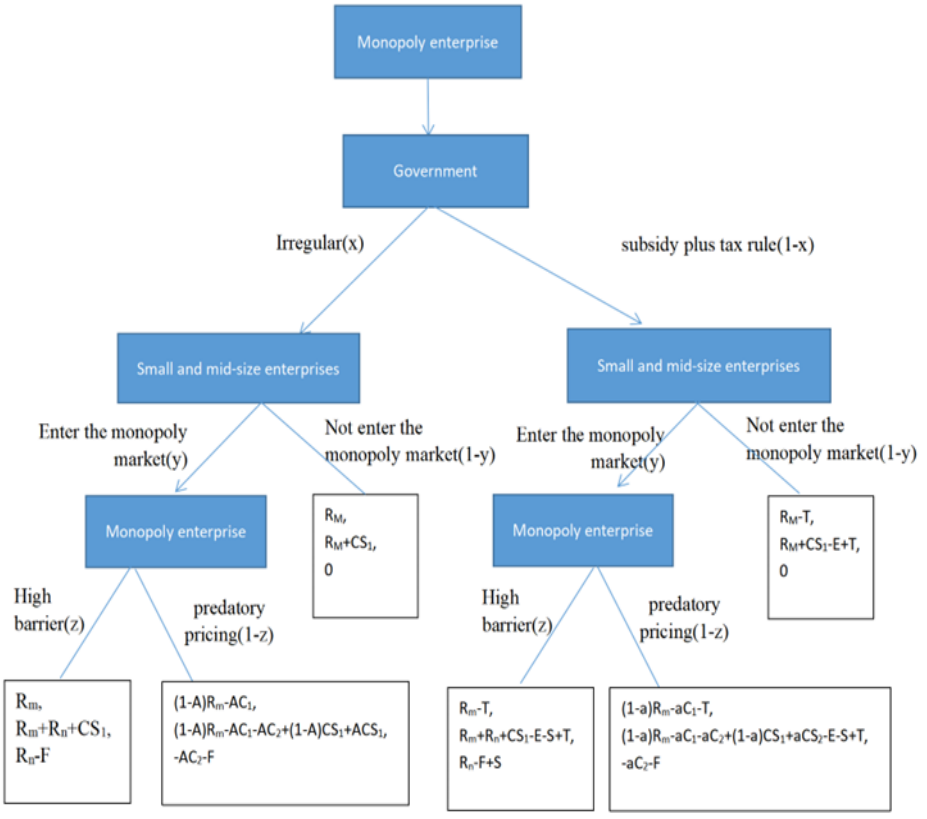

Figure 1: Game tree of three-party dynamic game.

3. Results and Discussion

The expected returns of government department that choose irregular, given by the formula:

$$\pi_{11} = yz(R_n + R_n + CS_1) + y(1-z)[(1-A)R_n - AC_1 - AC_2 + (1-A)CS_1 + ACS_2] + (1-y)(R_M + CS_1) \quad (1)$$

The expected returns of government department that choose subsidy plus tax rule, given by the formula:

$$\pi_{12} = yz(R_n + R_n + CS_1 - E - S + T) + y(1-z)[(1-a)R_n - aC_1 - aC_2 + (1-a)CS_1 + aCS_2 - E - S + T] + (1-y)(R_M + CS_1 - E + T) \quad (2)$$

The average expected returns of government department, given by the formula:

$$\pi_1 = x\pi_{11} + (1-x)\pi_{12} \quad (3)$$

The dynamic equation of government department chooses the regulated replication, given by the formula:

$$F(x) = \frac{dy}{dt} = (1-x)(\pi_{12} - \pi_1) = x(1-x)\{y(1-z)[(A-a)(R_m + C_1 + C_2 + CS_1 + CS_2) - E - S + T] - yS - E + T\} \quad (4)$$

The expected returns of SMEs choose to enter the monopoly market, given by the formula:

$$\pi_{22} = 0 \quad (5)$$

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The expected returns of SMEs choose not to enter the monopoly market, given by the formula:

$$\pi_2 = y\pi_{21} + (1-y)\pi_{22} \tag{6}$$

The average expected returns of SMEs, given by the formula:

$$F(y) = \frac{dy}{dt} = y(\pi_{21} - \pi_2) = y(1-y)$$
$$[xz(R_n - F) + x(1-z)(-AC_2 - F) + z(1-x)(R_n - F + S) + (1-z)(1-x)(-aC_2 - F)] \tag{7}$$

The dynamic equation of SMEs chooses to enter the monopoly market, given by the formula:

$$\pi_{31} = xy(R_m) + x(1-y)(R_y) + y(1-x)(R_m - T) + (1-x)(1-y)(R_y - T) \tag{8}$$

The expected returns of monopolies choose to set a high barrier:

$$\pi_{32} = xy[(1-A)R_m - AC_1] + y(1-x)[(1-a)R_m - aC_1 - T] \tag{9}$$

The expected returns of monopolies choose to set a predatory pricing, given by the formula:

$$\pi_3 = z\pi_{31} + (1-z)\pi_{32} \tag{10}$$

The dynamic equation of monopolies chooses to set a high barrier, given by the formula:

$$F(z) = \frac{dz}{dt} = z(\pi_{31} - \pi_3) = z(1-z)$$
$$[xy(AR_m) + x(1-y)(R_m) + y(1-x)(aR_m) + (1-x)(1-y)(R_M - T)] \tag{11}$$

Let $dx/dt = 0, dy/dt = 0, dz/dt = 0$, according to the definition of dynamic evolution, each subject has an ideal dominant strategy when formulating a strategy, obviously (0,0,0), (0,0,1), (0,1,0), (1,0,0), (1,1,0), (1,0,1), (0,1,1) and (1,1,1) are equilibrium points under all strategies.

3.1. Stability Conditions of Evolutionary Game

Firstly, the stable evolution analysis of the government department is performed, according to the replication dynamic equation calculated above, let $y(1-z)[(A-a)(Rm + C_1 + C_2 + CS_1 - CS_2) - E - S + T] - yS - E + T$ is equal to 0, then it can be known that F(x)=0 is established, which is the critical condition for the stable state of the evolutionary game. Then discussed in two cases under this equation, $y(1-z)[(A-a)(Rm + C_1 + C_2 + CS_1 - CS_2) - E - S + T] - yS - E + T$ is greater than 0 or less than 0.

If $y(1-z)[(A-a)(R_m + C_1 + C_2 + CS_1 - CS_2) - E - S + T] - yS - E + T$ is greater than 0, obtain $dF(0)/dx > 0$, $dF(1)/dx < 0$. According to the differential equation stability criterion at $dF(x)/dx \leq 0$, the evolution of the desirable stability strategy x=1, the government department will gradually evolve from "using subsidies plus tax regulation" to "unregulated", when the evolution is over, "unregulated" is the stability strategy of the government department in this case.

If $y(1-z)[(A-a)(R_m + C_1 + C_2 + CS_1 - CS_2) - E - S + T] - yS - E + T$ is less than 0, obtain $dF(0)/dx < 0, dF(x)/dx > 0$. At x=0 the evolves has a desirable stability strategy, the government department will gradually evolve from "unregulated" to "using subsidies plus tax regulations", when the evolution is over, "using subsidies plus tax regulations" is the stability strategy of government departments in this situation.

Then proceed a stable evolutionary analysis of SMEs, according to the replication dynamic equation calculated above, let $xz(R_n - F) + x(1-z)(-AC_2 - F) + z(1-x)(R_n - F + S) + (1-z)(1-x)(-aC_2 - F)$ equals 0, indicating the critical condition for the stability of the evolutionary game. Two scenarios are discussed below:

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When $xz(R_n - F) + x(1-z)(-AC_2 - F) + z(1-x)(R_n - F + S) + (1-z)(1-x)(-aC_2 - F)$ is greater than 0, obtain $dF(0)/dy > 0, dF(1)/dy < 0$. At the time of y=1, SMEs will gradually evolve from choosing "not to enter the monopoly market" to choosing "enter the monopoly market", and when the evolution is over, "entering the monopoly market" is the stable strategy of SMEs at this time.

When $xz(R_n - F) + x(1-z)(-AC_2 - F) + z(1-x)(R_n - F + S) + (1-z)(1-x)(-aC_2 - F)$ is less than 0, obtain $dF(0)/dy < 0, dF(1)/dy > 0$. At the time of y=0, SMEs will gradually evolve from choosing "enter the monopoly market" to choosing "not to enter the monopoly market", and when the evolution is over, "not to enter the monopoly market" is the stable strategy of SMEs at this time.

Finally, the stability analysis of the monopoly enterprise is carried out, and according to the replication dynamic equation calculated above, let $xy(AR_m) + x(1-y)(R_M) + y(1-x)(aR_m) + (1-x)(1-y)(R_M - T)$ is equal to 0, which is the critical condition for the stability of the evolutionary game. Two scenarios are discussed below:

When $xy(AR_m) + x(1-y)(R_M) + y(1-x)(aR_m) + (1-x)(1-y)(R_M - T)$ is greater than 0, obtain $dF(0)/dz > 0, dF(1)/dz < 0$. At the time of z=1, the monopolies will gradually evolve from choosing "setting predatory low prices" to choosing "setting high prices", and when the evolution is over, "setting high prices" is the stability strategy of monopolies at this time.

When $xy(AR_m) + x(1-y)(R_M) + y(1-x)(aR_m) + (1-x)(1-y)(R_M - T)$ is less than 0, obtain $dF(0)/dz < 0, dF(1)/dz > 0$. At the time of z=0, the monopolies will gradually evolve from choosing "setting a high price" to choosing "setting a predatory low price", and when the evolution is over, "formulating a predatory low price" is the stability strategy of the monopoly enterprise at this time.

3.2. Stability Analysis of the Evolution of Tripartite Strategy

Based on the asymmetric information game, the game progressively evolves to a position where it must approach the rigorous Nash equilibrium when it is stable. According to the setting of this model, the two groups of equilibrium points (1,0,1), (1,0,0), (0,0,1) and (0,0,0) respectively represent the same returns. This article will consider the stability of pure strategy Nash equilibrium positions represented by six equilibrium points (0, 0, 0), (0, 1, 0), (1, 1, 0), (0, 1, 1) and (1, 1, 1).

Using the method proposed by Friedman to determine the stability of ESS, the evolutionary stability strategy (ESS) in this paper can be determined by con-structing Jacobian matrix and the eigenvalues in the matrix (λ). Accordingly, from the replication dynamic equations constructed above, the Jacobian matrix can be obtained as:

$$J = \begin{bmatrix} A & B & C \\ D & E & F \\ G & H & I \end{bmatrix}$$

Figure 2: Jacobian matrix of replication dynamic equations.

Assume that A represents $DF(x)/DX$; B represents $DF(x)/Dy$; C represents $DF(x)/DZ$; D represents $DF(y)/DX$; E represents $DF(y)/Dy$; f represents $DF(y)/DZ$; G represents $DF(z)/DX$; H represents $DF(z)/Dy$; I represents $DF(z)/DZ$.

DOI: 10.54254/2754-1169/11/20230542

By calculating the eigenvalues, the pure strategy equilibrium points of (0,0,0) is analyzed. The Jacobian matrix at this time is:

$$J_1=\begin{bmatrix} -E+T & 0 & 0 \\ 0 & -F-aC_2 & 0 \\ 0 & 0 & R_M+T \end{bmatrix}$$

Figure 3: The Jacobian matrix at pure strategy equilibrium.

When this matrix is brought into the eigenvalue calculation formula, it can be concluded that the eigenvalue of Jacob matrix is: $\lambda 1 = -E + T, \lambda 2 = -F - aC2, \lambda 3 = RM + T$. The eigenvalues of the remaining five equilibrium points are also the same. Ac-cording to the Lyapunov discriminant method, when all eigenvalues of the Jaco-bian matrix $\lambda<0$, the equilibrium point is a gradual stable point; when all eigen-values of Jacobian matrix $\lambda>0$, the equilibrium point is the saddle point; when the eigenvalue of Jacobian matrix is positive or negative or the eigenvalue is equal to 0, the equilibrium point is an unstable point. The symbol of the final characteristic value is shown in the following table:

Table 1: The symbol of the final characteristic value.

Equilibrium point	First Eigenvalue Value / symbol	Second Eigenvalue Value / symbol	Third Eigenvalue Value / symbol	stability
(0,0,0)	-E+T/ uncertain	-F-aC_2/ Negative	R_M+T/ Positive	instable
(1,0,0)	E-T/ uncertain	-AC_2/ Negative	R_M/ Positive	instable
(0,1,0)	(Aa)(R_m+C_1+C_2+CS_1-CS_2)-S-E+T/ uncertain	F-aC_2/ uncertain	aR_m/ Positive	instable
(1,1,0)	_[(Aa)(R_m+C_1+C_2+CS_1-CS_2)-S-E+T]/ uncertain	-AC_2/ Negative	-AR_m/ Negative	unknown
(0,1,1)	-S-E+T/ uncertain	-(R_n-F+S)/ Negative	-aR_m/ Negative	unknown
(1,1,1)	S+E-T/ uncertain	-R_n/ Negative	-AR_m/ Negative	unknown

Among the six equilibrium points, (0,0,0), (1,0,0), (0, 1, 0) are unstable points, (1, 1, 0), (0, 1, 1), (1, 1, 1) may be stable points considering the relationship be-tween the three equilibrium points and the parameters.

3.3. The Influence of SMEs Size (A and a) on Evolution

For the convenience of analysis, we set all data except a and a as a fixed quantity. From the definition of the above assumptions, it can be understood that the exit time of the enterprise represented by a is longer than that of the enterprise represented by A. in order to meet the equilibrium point (1, 1, 0) and reach evolutionary stability, it is obvious that the condition is satisfied when the value of A-A is greater than $(s + E - T) / (RM + C1 + C2 + cs1 - cs2)$. When the enterprise is larger, the sunk cost and fixed assets of small and medium-sized enterprises into production are correspondingly large. At this time, it will be more difficult for small-sized enterprises to exit the market than small-sized enterprises. Therefore, the larger the scale of small and medium-sized enterprises that want to enter the monopoly market, the closer the evolution is to (1,1,0).

DOI: 10.54254/2754-1169/11/20230542

3.4. The Influence of Government Regulation (S+E-T) on Evolution

In order to study the influence of government regulation on the evolution of monopoly market, this part will keep all other factors unchanged except S+E-T. Judging from the perspective of eigenvalue, when T-S-E<0, the evolution gradually tends to (0, 1, 1), that is, the government chooses to use tax and subsidy regulation, small and medium-sized enterprises choose to enter the monopoly market, and monopoly enterprises choose to set high prices. For small and medium-sized enterprises, the increase of the government subsidy will encourage them to enter the monopoly market and participate in competition. For monopoly enterprises, the high monopoly tax means that they must set a high price to earn excess profits to offset the tax paid so as to maximize profits. When S+E-T<0, the game evolution will tend to (1, 1, 1). At this time, the government chooses not to regulate, the small and medium-sized enterprises still choose to enter the monopoly market, and the monopoly enterprises choose to set high prices.

4. Conclusion

By establishing an evolutionary game model, this paper establishes a model of the behavior of government departments, monopoly enterprises and small and medium-sized enterprises that want to enter the monopoly market. By setting the probabilities of different strategy choices of the three parties, solving the replication dynamic equations and testing the stability of the system, we draw the following conclusions:

First, the impact of monopoly taxes and subsidies set by government departments on monopoly enterprises. By levying a large amount of monopoly tax on monopoly enterprises, the government will force monopoly enterprises to give up their pursuit of excess profits. At the same time, the government can draw a part of the monopoly tax as a subsidy to small and medium-sized enterprises to encourage them to enter the monopoly market. In the long run, several small and medium-sized enterprises will enter the market in each natural cycle. In order to maintain the high profits of the incumbent, the monopoly enterprises have to set predatory low prices to force these enterprises to leave the market. In order to maximize their profits, it is possible that the monopoly enterprises will choose to reduce the price of goods instead of setting low prices to drive out small and medium-sized enterprises.

Second, the impact of subsidies set by government departments on small and medium-sized enterprises. When the amounts of subsidies are low, SMEs have less incentive to enter the monopoly market, because once the monopoly enterprise finds that there are SMEs entering, the monopoly enterprise will take measures to drive out the entrants, and the small amounts of subsidies cannot support SMEs to survive the predatory low-price period or exit the market more efficiently to reduce losses. A large amount of subsidies will help small and medium-sized enterprises actively enter the market and face the barriers set by monopoly enterprises during the operation period by using the subsidized funds.

Third, the impact of the size of small and medium-sized enterprises that want to enter the monopoly market on the monopoly enterprises. From the above analysis, it can be concluded that if the scale of a small and medium-sized enterprise is larger, but the scale still cannot affect the market price, the larger the enterprise is, the more difficult it is to exit the market when the monopoly enterprise formulates the predatory low price. At this time, the large-sized small and medium-sized enterprises have to lose a larger operating loss than the small-sized enterprises.

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DOI: 10.54254/2754-1169/11/20230542

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