Evolutionary game analysis of digital platform monopoly and market supervision from the perspective of system dynamics

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Abstract: In the context of the digital economy, to curb the monopolistic behavior of service digital platforms, guide and regulate the order of platform competition. This paper combines system dynamics and game theory to construct an evolutionary game model and a system dynamics model between the two subjects concerning the monopolistic behavior of digital platforms and the regulatory decisions of market regulators. This paper finds that: (1) market regulators will adopt an aggressive regulatory strategy as the level of punishment and additional revenue increases; in addition, for cases where the platform involves a smaller degree of monopoly and has a lower impact on the market, the regulator may decide to terminate the investigation and adopt a no-regulation strategy; (2) internet platforms will finally adopt a no-monopoly strategy as their overall revenue decreases due to the increase in punishment; they will also adopt a no-monopoly strategy as own opportunity gain loss increases and choose the monopoly strategy. Based on the above simulation conclusions, it provides reference and reference for the benign development of the platform market about the governance of platform monopoly and the protection of consumers' legitimate rights and interests.

Keywords: Digital platforms; Antitrust; Market regulation; Evolutionary games; System dynamics

1 INTRODUCTION

Since the beginning of the new century, with the support of policies, funds, and technologies, the digital platform economy has developed rapidly and become an important factor in global economic growth. At the same time, as the platform economy gradually reveals problems such as abuse of dominant market position and infringement of users' privacy, countries have also continued to increase anti-monopoly regulation of digital platform enterprises. As early as the end of last century, the US Department of Justice conducted an investigation into illegal bundling and tying by Microsoft; since 2010, digital platform companies such as Google, Amazon, eBay, Facebook, and Uber have all been subject to anti-monopoly investigations in different countries [25]. Also in China, in June 2022, the Annual Report on China's Anti-Monopoly Enforcement (2021) released by the State Administration of Market Supervision and Administration showed that 175 monopoly cases of various types were investigated and handled nationwide in 2021, an increase of 61.5% year-on-year, with the focus on monopolistic practices of "two-for-one" platform enterprises, Alibaba and Meituan

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alone imposed fines of 18.228 billion yuan and 3.442 billion yuan respectively [23]. On August 1, the newly amended Anti-Monopoly Law came into force. The frequent occurrence of monopolies by digital platform companies has also sparked widespread concern about the way platforms monopolize and their anti-monopoly regulatory policies. Therefore, it is of great practical significance to explore the factors affecting the monopoly of digital platforms, how to improve the business environment of Internet platforms, and strengthen the system construction of the market supervision system.

Echoing the practice of anti-monopoly regulation in the platform economy, there have been many discussions in academia around the manifestations of a digital platform monopoly, the causes of its formation, social hazards, and the path of governance. The current research on the manifestations of monopoly on digital platforms can be divided into three aspects: monopoly agreement, abuse of dominant market position, and concentration of operators. In particular, digital platform companies use data to analyze and forecast the sales prices of competing companies in advance, forcing them to collude, then adjust market prices in real time by sharing pricing algorithms and adopting new algorithms to monitor and track the implementation of monopoly agreements by competitors [5]. In addition, digital platform firms will consolidate their dominant market position by restricting competing firms' access to data resources, typically by entering into exclusivity clauses [15]. Digital platform companies may also use data to accurately profile users, implement precise recommendations based on consumption habits to kill familiarity, or force-tied sales [3]. The above monopolistic practices of digital platforms not only undermine the order of competition in the industry and harm the interests of operators and consumers within the platforms, but also hinder the optimal allocation of resources and weaken the innovation drive and development vitality of platform operators. To investigate the reasons for this, Li Yongjian et al [13] argue that platform companies have opaqueness in collecting and utilizing data, which is what leads to the monopoly of the use of data by platforms. Wang Chunying et al [20] argued that platforms have asset-light operations, low barriers to entry, and easy expansion of business, coupled with cross-network effects, self-network effects, and data concentration, thus making it easy to form monopolies. Meng Xiaofeng et al [16] found that the top 10% of platform companies collecting market data were able to obtain and monopolize 99% of the total market. The easy aggregation of platform data itself, coupled with the fact that large enterprises cover all business models and have a large number of users, are all reasons for platform monopolies.

In terms of the current hazards of digital platform monopolies, Hu Jiye et al [9] argue that platform monopolies will not only affect the innovation of enterprises and the interests of users but also endanger the privacy of individuals and the political security of the state. Li Yongjian [13] argues that platform monopoly will lead to various disruptions in the trading market, disrupting the market order and reinforcing the oligopoly dominance of the platform. Cao Yang [2] similarly argues that the abuse of relative dominance by digital platforms not only harms the legitimate rights and interests of the enterprises concerned and the healthy development of the industry but also infringes on the legitimate rights and interests of consumers as well as the level playing field of the online market, affecting the improvement of the overall welfare of society and the healthy development of the economy, which must be regulated by law. Larsson [11] discusses how to detect and regulate abuse of dominance on digital platforms based on a competition law perspective, arguing that the governance of platforms poses significant challenges to regulators and may hurt the autonomy and

well-being of consumers and other companies that rely on them. Domestic scholar Cao Yang [3] explored the abuse of market dominance by digital platforms at the current stage, arguing that there are shortcomings in China in terms of legislation, enforcement, and regulation, suggesting a governance path of "anti-law-based, supplemented by industry regulation law", focusing on unified and coordinated, multi-dimensional regulation from the details. Sun Jin [19] suggested that the concept of modesty should be the guiding principle of governance and that modesty does not mean connivance, but rather the appropriate optimization of regulatory instruments, giving priority to arbitration mechanisms, etc. Guo Quanzhong [8] proposed that data governance should be the core, actively promoting the revision of the Anti-Monopoly Law, and also effectively curbing monopolistic practices by imposing a digital tax in the future. In contrast, Wang Chunying et al [20] argue that the regulatory model of the regulator should be changed to strengthen not only post-event regulation, but also ex-ante and in-event supervision, and on this basis, the vitality of market competition should be ensured by nurturing and introducing new platforms. Qi et al [17], on the other hand, believe that the process of regulation should focus on the scale, distinguish between reasonable competition strategies, innovative modes of enterprises, and unreasonable market behaviors, not choke on them, and never to block them for the whole industry. Concerned about the monopoly of data aggregation, the characteristics of data and the cost of errors must be fully considered in anti-monopoly investigations to prevent being dragged down by anti-monopoly and hindering its normal development. It also proposes a collaborative mechanism between regulators and digital platforms, which is fine-tuned according to the characteristics of digital platforms.

The aforementioned scholars have analyzed and discussed the monopoly of digital platforms, combined with relevant laws and regulations, discussed the monopolistic behavior of digital platforms and its hazards, as well as the challenges of anti-monopoly governance in China, and put forward corresponding countermeasures. However, most of the discussions on the monopoly of digital platforms are based on a macro perspective, and there is little literature to analyze in depth the causal loop of monopoly factors, explore the dynamic process of behavioral decision adjustment between digital platforms and regulatory authorities, and few analyze and discuss the monopoly behavior of digital platforms under regulation from the perspective of evolutionary game. Therefore, based on previous research, the article combines the evolutionary game model with system dynamics simulation to explore the problem of digital platform monopoly and market regulation decision-making, and analyses the main factors affecting the decision-making of market regulators and digital platform monopoly behavior by constructing a system dynamics causal chain, and finally observe the trend influence of both parties' decision making by adjusting the values of system parameters, and further proposes to market regulators that can The system is then adjusted to the values of the system parameters to observe the trend influence of both parties' decisions, and further suggest to the market regulators relevant suggestions that can effectively curb the monopolistic behavior of service platforms.

2 PROBLEM DESCRIPTION AND ASSUMPTIONS

2.1 Question Description

In an evolutionary game model consisting of a digital platform enterprise and a market

regulator, the digital platform enterprise is the initiator of the monopoly and the market regulator is the regulator of the monopoly. The market regulator decides whether to regulate the platform enterprise based on the nature of its illegal behavior, the degree of monopoly, and the impact on the trading market; while the platform enterprise also makes the decision whether to implement a monopoly or not based on maximizing its interests. Both parties cannot make optimal responses in the face of information, while evolutionary games differ from the assumption of perfect rationality and focus more on the adjustment process of dynamic analysis, so it is reasonable to use evolutionary games to study the game problem of market regulation and monopolistic behavior of digital platform enterprises.

2.2 Research Hypothesis

Hypothesis 1: Both sides of the game have two behavioral strategies: market regulators (regulation, no regulation); digital platform firms (monopoly; no monopoly).

Hypothesis 2: At the initial stage of the game, the probability that the market regulator regulates the monopolistic behavior of the platform enterprise is $x(0 \le x \le 1)$, then the probability that it does not regulate is $(1-x)$; the probability that the digital platform enterprise implements monopolistic behavior is $y(0 \le y \le 1)$, then the probability that it does not implement monopoly is $(1-y)$. Digital platform enterprises take maximizing their interests as their ultimate goal; market regulators take maintaining the order of competition in the industry, protecting the interests of operators within the platform and the rights and interests of consumers, and stimulating the innovative vitality and development momentum of platform operators as their ultimate goal.

Hypothesis 3: (1) C_1 is the cost of regulation by the market regulator, which is zero when the market regulator chooses not to regulate; and (2) C_2 is the cost of operating a digital platform company.

Hypothesis 4: (1) R_1 is the sales when the digital platform firm implements a monopoly; (2) R_2 is the sales when the digital platform firm does not implement a monopoly, and $R_1 > R_2$; (3) R_3 is the opportunity gain lost by the platform when the digital platform firm does not implement a monopoly and the market regulator does not regulate, and $R_3 = R_1 - R_2$.

Hypothesis 5: (1) E_1 for the loss of social reputation of the market regulator, when the platform enterprise abuses its dominant market position to carry out monopoly causing market disorder when the market regulator does not regulate, it will result in the loss of its social reputation; (2) E_2 for the additional benefits of the market regulator, when the market regulator effectively curbs the platform enterprise to implement monopoly behavior, so that small and medium-sized enterprises grow rapidly and promote industry competition to stimulate market vitality, when it will come with additional benefits for the market regulator, and $E_2 > C_1$.

Hypothesis 6: θ is the level of penalty imposed by the market regulator when a digital platform company implements a monopoly and the amount of penalty θR_1. According to the latest implementation of the Anti-Monopoly Law, the penalty generally ranges from 1% to 10% of the total sales of the platform in the previous year, depending on the circumstances and degree of monopoly of the digital platform.

Exploring the behavioral decisions of the two-game subjects in the model requires the creation of an evolutionary game payoff matrix, as shown in Table 1 [12].

Table 1: Market regulators and digital platform companies revenue payment matrix.

		Digital platform companies	
		Monopoly (y)	No monopoly $(1-y)$
Market regulators	Regulation (x)	$\begin{pmatrix}\theta R_1 - C_1, \\ R_1 - C_2 - \theta R_1\end{pmatrix}$	$\begin{pmatrix}E_2 - C_1, \\ R_2 - C_2\end{pmatrix}$
	No regulation $(1-x)$	$\begin{pmatrix}-E_1, \\ R_1 - C_2\end{pmatrix}$	$\begin{pmatrix}0, \\ R_2 - C_2 - R_3\end{pmatrix}$

2.3 Modeling and stability analysis

Based on the research hypothesis and the payoff matrix, it is clear that the expected benefits to market regulators of choosing to regulate the monopolistic behavior of (x) digital platform firms are:

$$U_1 = y(\theta R_1 - C_1) + (1-y)(E_2 - C_1) \tag{1}$$

The expected benefits of market regulators choosing not to regulate the monopolistic behavior of ($1-x$) digital platform companies are:

$$U_2 = y(-E_1) \tag{2}$$

The average expected returns for the market regulator's regulated and unregulated strategies are:

$$\overline{U} = xU_1 + (1-x)U_2 \tag{3}$$

Based on the evolutionary game principle, the replication dynamics equation for the market regulator can be obtained as:

$$\begin{aligned} F(x) &= \frac{dx}{dt} = x(U_1 - \overline{U}) = x(1-x)(U_1 - U_2) \\ &= x(1-x)[y(\theta R_1 + E_1 - E_2) + E_2 - C_1] \end{aligned} \tag{4}$$

Similarly, the expected benefits of a digital platform firm choosing monopolistic behavior (y):

$$M_1 = x(R_1 - C_2 - \theta R_1) + (1-x)(R_1 - C_2) \tag{5}$$

The expected benefits of a digital platform firm choosing not to engage in monopolistic behavior ($1-y$):

$$M_2 = x(R_2 - C_2) + (1-x)(R_2 - C_2 - R_3) \tag{6}$$

The average expected benefits of monopolistic and non-monopolistic behavioral strategies of digital platform firms are:

$$\overline{M} = yM_1 + (1-y)M_2 \tag{7}$$

At this point, the replication dynamics equation for digital platform firms is:

$$\begin{aligned} F(y) &= \frac{dy}{dt} = y\left(M_1 - \overline{M}\right) = y(1-y)(M_1 - M_2) \\ &= y(1-y)\left[x(-\theta R_1 - R_3) + R_1 - R_2 + R_3\right] \end{aligned} \tag{8}$$

According to the Malthusian equation, such that $F(x)=0$, $F(y)=0$, the five equilibrium points of the system (0,0), (0,1), (1,0), (1,1), (A,B) are obtained.

According to Friedman's research theory, the stability of the equilibrium point of an evolutionary game can be determined by performing a local stability analysis of the Jacobian matrix. The Jacobian matrix of this dynamic system is:

$$J = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(x)}{\partial y} \end{bmatrix} = \begin{bmatrix} (1-2x)\left[y(\theta R_1 + E_1 - E_2) + E_2 - C_1\right] & x(1-x)(\theta R_1 + E_1 - E_2) \\ y(1-y)(-\theta R_1 - R_3) & (1-2y)\left[x(-\theta R_1 - R_3) + R_1 - R_2 + R_3\right] \end{bmatrix} \tag{9}$$

According to the principles of evolutionary games, the equilibrium point that replicates the dynamic equations is the evolutionary game stable strategy (ESS) if both of the following conditions are met.

Condition 1: $trJ = \dfrac{\partial F(x)}{\partial x} + \dfrac{\partial F(y)}{\partial y} < 0$ (trace condition).

Condition 2: $\det J = \begin{vmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} \end{vmatrix} = \dfrac{\partial F(x)}{\partial x}\dfrac{\partial F(y)}{\partial y} - \dfrac{\partial F(x)}{\partial y}\dfrac{\partial F(y)}{\partial x} > 0$ (Jacobean determinant condition).

Substituting the five local equilibrium points in turn into the above two conditions for calculation, the replicated dynamic equation equilibrium point stability analysis is obtained as shown in Table 2.

Table. 2: System stability analysis at each local equilibrium point

Partial equilibrium points	$\det J$	Symbol	trJ	Symbol	Characterization
(0,0)	$\left(E_2 - C_1\right)\left(R_1 - R_2 + R_3\right)$	+	$E_2 - C_1 + R_1 - R_2 + R_3$	+	Unstable
(0,1)	$-\left(\theta R_1 + E_1 - C_1\right)\left(R_1 - R_2 + R_3\right)$	+	$\theta R_1 + E_1 - C_1 - R_1 + R_2 -$	—	ESS
(1,0)	$-\left(E_2 - C_1\right)\left(-\theta R_1 + R_1 - R_2\right)$	+	$C_1 - E_2 - \theta R_1 + R_1 - R_2$	—	ESS
(1,1)	$\left(\theta R_1 + E_1 - C_1\right)\left(-\theta R_1 + R_1 - R_2\right)$	+	$C_1 - E_1 - R_1 + R_2$	+	Unstable
(A,B)	$2R_3\left(C_1 - E_2\right)\left(1 - \frac{-2R_3}{-\theta R_1 - R_3}\right)\left(1 - \frac{C_1 - E_2}{\theta R_1 + E_1 - E_2}\right)$	—	0		Saddle Point

Through the above system stability analysis we get that there are two equilibrium points (0,1) and (1,0) in the system, which correspond to the evolutionary stability strategies (no regulation, monopoly) and (regulation, no monopoly) respectively.

3 SIMULATION OF SYSTEM DYNAMICS

To validate the model and explore the dynamic evolutionary path between market regulators and digital platform companies, this paper models and simulates the decision-making behavior of both parties based on an evolutionary game model in combination with the system dynamics software Venism PLE.lnk. Assumptions are made about the system based on the evolutionary game parameter variables.

Hypothesis 1: The penalties imposed by market regulators on digital platform firms for monopolistic behavior are greater than the opportunity gains that would have been lost if the platform firms had not practiced monopoly.

Hypothesis 2: The cost of regulation for the market regulator is greater than the sum of the penalty for the monopolistic behavior of the platform firm and the loss of the social reputation of the market regulator.

Hypothesis 3: The sum of the loss of social reputation of the market regulator and the penalty for monopolistic behavior of the platform firm is less than the additional benefit to the market regulator.

3.1 Causality diagram

In the behavioral system, the internal connection between the two game subjects is explored through a causal chain. To conform to the logic of causality, this paper includes factors such as consumers' legitimate rights and interests, satisfaction with the regulator, other SMEs' earnings, the market development gap, and disorderly market competition into the scope of causality, which constitute the behavioral system of two interest subjects, the market regulator and the

digital platform enterprises.

In this paper, we take the degree of monopoly of digital platform enterprises and the willingness of market regulators to regulate as the main observed quantities and construct a causality diagram between market regulators and the monopoly behavior of digital platform enterprises [18, 24] as shown in Figure 1.

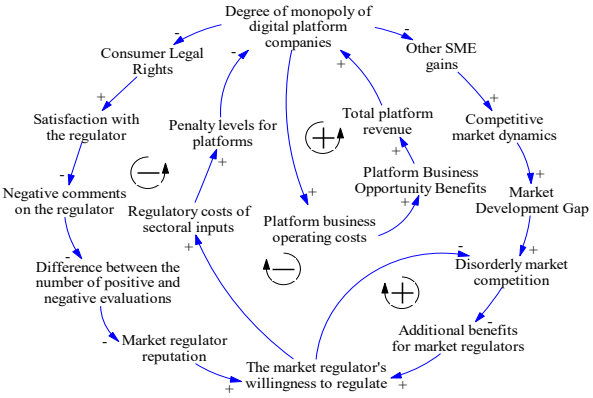

Figure 1: Causality diagram

A basic cyclic feedback loop with 4 subsystems exists in the diagram, containing 2 positive and 2 negative feedback loops, as follows.

Degree of the monopoly of digital platform firms → + operating costs of platform firms → + opportunity revenue of platform firms → + total revenue of platform → + degree of monopoly of digital platform firms (positive feedback loop)

The willingness of market regulators to regulate → - disorderly market competition → - additional gains for market regulators → + willingness of market regulators to regulate (positive feedback loop)

Degree of the monopoly of digital platform enterprises → - legitimate rights and interests of consumers → + satisfaction with the regulator → - negative evaluation of the regulator → - the difference between the number of positive and negative evaluations → - the reputation of the market regulator → + willingness of the market regulator to regulate → + regulatory costs invested by the regulator → + penalties imposed on the platform → - degree of monopoly of digital platform enterprises (negative feedback loop)

The degree of monopoly of digital platform enterprises → - gains for other SMEs → + market competition dynamics → + market development gap → + market competition disorder → - additional gains for market regulators → + willingness of market regulators to regulate → + regulatory costs invested by regulators → + penalties for platforms → - degree of monopoly of digital platform enterprises (negative feedback loop)

Take (4) negative feedback loop as an example: the higher the degree of monopoly of the digital platform enterprises, the more gains to the detriment of other small and medium-sized enterprises, and the market competition gradually loses vitality, corresponding to a growing

gap in market development, causing the platform giants and small and medium-sized enterprises to develop in a polarized manner, intensifying the disorderly market competition, leading to a gradual reduction in the additional benefits of the market regulator, then the market regulator's willingness to regulate gradually increases, thus increasing the investment in the supervision costs of the platform enterprises, increasing the penalties on the platform enterprises, and ultimately reducing the degree of monopoly of the digital platform enterprises.

3.2 System flow diagram

The core of SD is to study the system structure by constructing structural flow diagrams and conducting simulation experiments using Vensim PLE [1, 7]. Based on the above causality model and system feedback loop analysis, a system dynamics flow diagram for digital platform enterprises and market regulators was constructed, which includes two flow level variables, two flow rate variables, four auxiliary variables, and eight constants, and the model is shown in Figure 2.

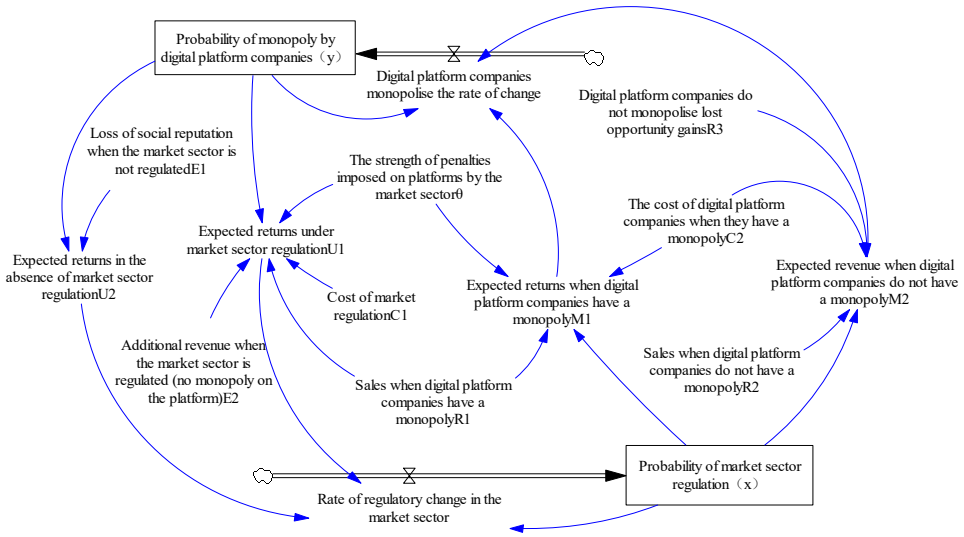

Figure 2: A flow chart of the evolution of digital platform monopolies and market regulation

4 NUMERICAL ANALYSES

Based on Venism PLE.lnk simulation analysis, the initial parameters of the model were set to INITIAL TIME=0, FINAL TIME=100, TIME STEP=1, and time units: months.

4.1 Initial value simulation analysis

Referring to the research data in the literature (Xu, 2019; Wang, 2020), the article determines the initial parameters to take values such that $x=0.8$, $y=0.7$, the constants take virtual values $C_1=3$, $C_2=3$, $R_1=5$, $R_2=4$, $R_3=1$, $E_1=2$, $E_2=5$, $\theta=3\%$, The results

are shown in Figure 3.

The simulation results show that the market regulator tends to adopt the initial strategy of regulation, which is conducive to reducing the probability of monopoly behavior of digital platform enterprises, and the evolutionary game of behavioral decisions of the two parties tends to be closer to the equilibrium strategy (regulation, no monopoly).

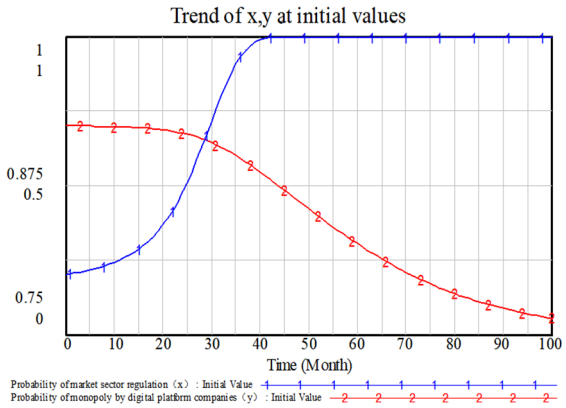

Figure 3: Simulation results for x, y at initial values

4.2 Impact of market regulator penalties θ on evolutionary outcomes

Keeping the original parameters unchanged, at this point by adjusting the value of θ, to observe whether the market regulator's penalty on the monopolistic behavior of digital platform enterprises has an impact on the behavioral decisions of the two-game subjects. Let $\theta=1\%$, $\theta=2\%$, $\theta=3\%$, $\theta=5\%$, $\theta=10\%$, $\theta=20\%$, get the simulation results x, y as shown in Figure 4 and Figure 5.

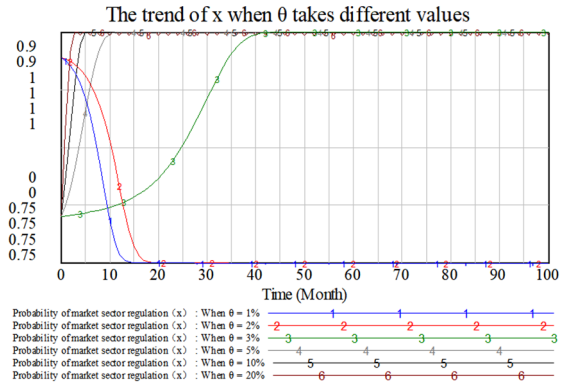

Figure 4: The trend of x when θ takes different values

Based on the trend x, it is clear that the change in the value θ does have an impact x. The simulation results show that: when the market regulator punishes the digital platform

enterprise with a value in the interval [3,10], the regulator will make the punishment according to the degree of a platform monopoly, and the impact caused to the trading market. The larger the value θ is, the greater the impact on the market, and then the market regulation will respond faster with the increase of the punishment, and will also take the regulation strategy earlier. For example, on 10 April 2021, the market regulator imposed a penalty on Alibaba for its monopolistic conduct, ordering it to cease its illegal conduct and imposing a fine of 4% of its sales in the previous year, amounting to RMB 18.228 billion. on 8 October 2021, after taking into account the nature, extent, and ongoing impact of the violation, the market regulator imposed a penalty on Meituan for its monopolistic conduct, ordering it to cease the illegal conduct and imposed a fine of 3% of its sales in the previous year, amounting to RMB3.442 billion.

When the penalty is taken in the [0,3) range, it means that the platform is involved in a smaller degree of monopoly and has a lower impact on the market. At that time, the regulator, in line with the principle of stable market development, will impose a fixed amount of fine on the platform involved in a less serious case, based on factors such as whether it has taken the initiative to report in writing, admit the violation and actively cooperate with the investigation after it has violated the law and implemented the monopoly. It is worth mentioning that in the current Anti-Monopoly Law, a new "suspension of investigation system" has been introduced, i.e. if a subject suspected of monopolistic conduct can eliminate the consequences of its conduct within a period approved by the regulatory authority, the regulatory authority may decide to suspend the investigation, and may terminate the investigation if it fulfills its commitment. This is in line with the stable strategy of the article (monopoly, no regulation). For example, the Beijing Municipal Administration of Market Supervision decided to terminate the investigation of an information technology company's monopoly case in March 2020. The company promised to organize legal training, strengthen the training of all employees, raise awareness of fair competition by the law by training on relevant competition laws and regulations and fostering a competition culture, strictly eliminate monopolistic practices, and make training on knowledge of the law a necessary condition for employees to start work.

And when θ is taken as 20%, it is in line with the new multiplier fine mechanism in the latest Anti-Monopoly Law implemented on 1 August 2022, which allows the regulator to draw up a fine by the prescribed penalty multiplied by 2-5 times for monopoly subjects with extremely bad influence.

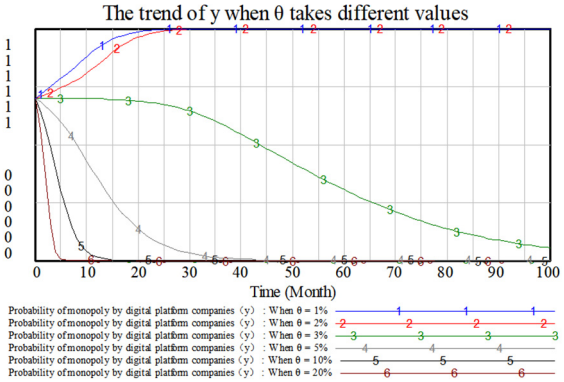

Figure 5: The trend of y when θ takes different values

Based on the trend of y, it is clear that the change in the value of θ does have an impact on y. The simulation results show that: when the penalties imposed by market regulators on digital platform enterprises are taken in the interval [3,10], as the value of θ increases, the more administrative fines digital platform enterprises receive, leading to a decrease in their overall revenue and finally converging to a non-monopolistic behavioral strategy; while when the penalties are taken in the interval [0,3), if the penalties imposed on the platform are smaller than their monopolistic revenue, digital platform enterprises will converge towards a monopolistic strategy.

4.3 The impact of additional benefits of market regulation on the outcome of the evolution of E_2

Keeping the original parameters unchanged, θ takes an initial value of 3%, at which point the additional benefit to the market regulator is observed to have an impact on the behavioral decisions of the two-game subjects by adjusting the value E_2. Let $E_2 = 3$, $E_2 = 4$, $E_2 = 5$, $E_2 = 6$, get the simulation results x, y as shown in Figure 6 and Figure 7.

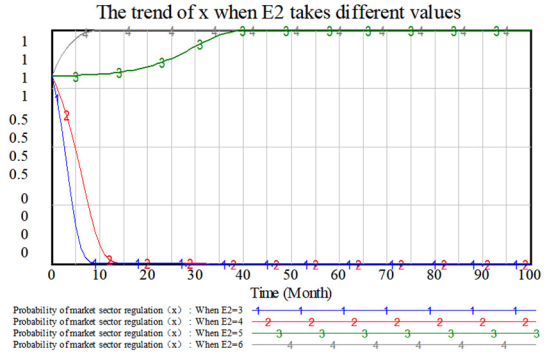

Figure 6: The trend of x when E_2 takes different values

According to the trend x, it can be seen that the change in the value E_2 does have an impact on it x. The simulation results show that the market regulator, by managing the monopolistic behavior of digital platform enterprises, enables the development of small and micro enterprises, thus stimulating market vitality and promoting economic development while also bringing positive effects to the market regulator. In this way, as the additional benefits of the market regulator increase, the speed of response to monopoly cases of digital platform enterprises also increases, and the willingness to regulate the market will converge to a steady state more quickly.

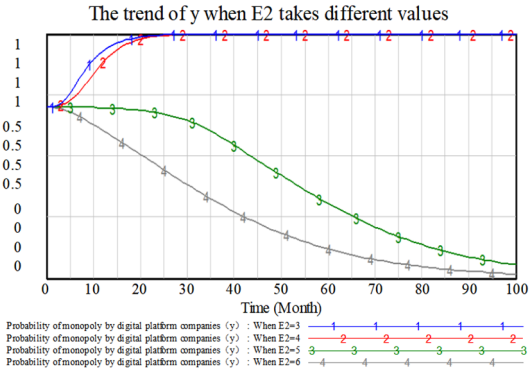

Figure 7: The trend of y when E_2 takes different values

According to the trend y, it is clear that the change in the value E_2 does have an impact on it y. The simulation results show that the willingness to regulate increases with the additional revenue of the market regulator and the regulation of input platforms is strengthened, making digital platform companies finally choose a no-monopoly strategy. As the monopolistic behavior of the platform is curbed, thus stimulating the innovative development of small and medium-sized enterprises.

4.4 The impact of lost opportunity gains R on evolutionary outcomes for digital platform firms

Keeping the original parameters unchanged, the initial value θ is 3% and E_2 takes the initial value of 5. At this time, by adjusting the value of R_3, observe whether the opportunity gain lost by the digital platform enterprise has an impact on the decision-making behavior of the two-game subjects. Let $R_3 = 0.5$, $R_3 = 1$, $R_3 = 1.5$, $R_3 = 2$, get the simulation results x, y as shown in Figure 8 and Figure 9.

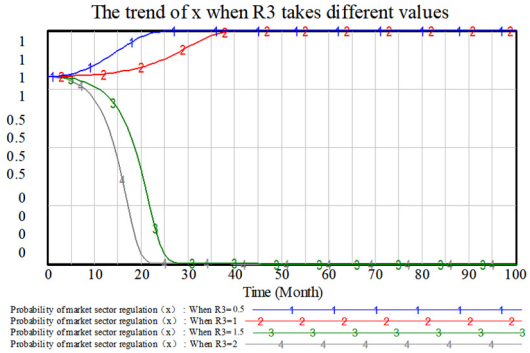

Figure 8: The trend of x when R_3 takes different values

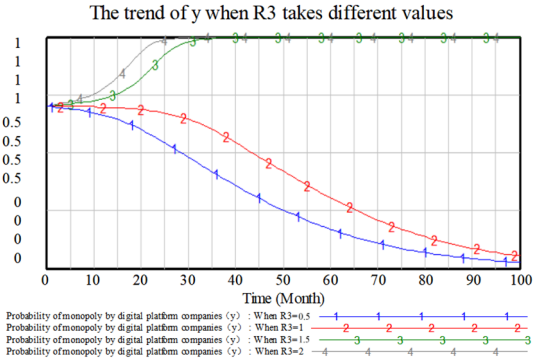

Figure 9: The trend of y when R_3 takes different values

Based on the trend of x and y, it is clear that the change in the value of R_3 does have an impact on x and y. The simulation results show that: as the opportunity gain lost when the digital platform enterprise is not a monopoly increases, it indicates that the platform can comply with regulations and fulfill its corporate responsibility and does not commit market-disrupting behaviors to maximize its interests, and thus the market regulator will converge towards the non-regulation strategy. When the lost opportunity gain of digital platform companies gradually decreases, it means that the revenue of the platform when it is not a monopoly is getting closer to the revenue when it is a monopoly, and the market regulator will adopt a regulatory strategy to examine whether the platform is a monopoly. Conversely, the lost opportunity gain increases, the overall gain of digital platform enterprises decreases, and according to the platform's goal of maximizing its interests, it will eventually choose the monopolistic behavior strategy.

5 RESEARCH CONCLUSIONS AND RELATED RECOMMENDATIONS

5.1 Conclusions

The article addresses the dynamic process of monopolistic behavior of digital platforms and the regulatory decisions of market regulators and draws the following conclusions.

(1) For x,y at initial values, the market regulator tends to adopt the initial strategy of regulation, which is conducive to reducing the probability of monopolistic behavior on digital platforms, and thus the more the behavioral decision evolution game of the two parties tends to be closer to the equilibrium strategy (regulation, no monopoly).

(2) By adjusting the value of the penalty θ, the market regulator makes the penalty according to the degree of monopoly of the platform and the impact on the trading market. The larger the value θ, the greater the impact on the market, when the market regulator will respond faster with the increase of the penalty, and will also adopt the regulatory strategy earlier. As the value θ increases, more administrative fines are imposed on the digital platform, leading to a reduction in its overall revenue and eventually converging into a non-monopolistic behavioral strategy; if the penalty imposed on the platform is less than its monopolistic revenue, the digital platform will converge towards a monopolistic strategy.

(3) The market regulator adopts an aggressive regulatory strategy in line with the increase in its additional revenue E_2; the platform will choose a no-monopoly strategy in line with the increase in additional revenue from market regulation.

(4) Market regulators will converge towards a non-regulatory strategy as R_3 increases; while digital platforms will choose a monopolistic strategy as their loss of opportunity gain increases.

5.2 Recommendations

Based on the above simulation findings, the following recommendations are made for market regulators to be able to effectively curb the monopolistic behavior of service platforms and to properly guide and regulate the order of platform competition.

(1) Enhance ex-ante regulation [4], increase administrative penalties, and promote a "top-down" platform compliance system. It is important to introduce a system of liability for platform companies so that they are clear that monopolistic corporate behavior can lead to many adverse consequences. For example, the loss of corporate reputation and the impact on investor confidence due to antitrust violations, the diversion of management time and effort, and the significant legal costs associated with crisis management in response to investigations by enforcement agencies.

(2) Enterprises update their algorithms and technologies promptly and regularly self-correct and self-examine to maintain the vitality of market innovation [10]. Due to the novelty and complexity of the platform economy, the process of obtaining, declaring, and approving market data is more difficult compared to other traditional industries, and the process may result in an inconsistent understanding of the connotation or extension of the same market by

platform operators and law enforcement agencies, etc. At this time, enterprises should regularly self-correct and examine whether the relevant business operations implemented by them using data and algorithms and technologies may constitute monopolistic acts.

(3) In line with the principle of lenient and prudent regulation [6], the regulator should differentiate the calculation of platform turnover according to its business model. As the market share of the platform economy changes rapidly and significantly, with frequent iterations and innovations, the traditional assessment of competitive impact based on "prior year" market share may be one-sided, and some specific transactions may be controversial in terms of whether they trigger the reporting criteria due to different turnover calculation methods. For platforms that charge commissions for providing information (e.g. online taxi platforms), turnover should primarily include platform service fees and other income, while for e-commerce platforms, such as the "platform+self-support" model, turnover should include the number of transactions involved in the platform and other income.

Overall, through the adjustment of regulatory instruments by market regulators and self-correction by digital platforms, the monopolistic behavior of platforms can be effectively curbed, purifying the competitive environment of the market, providing more space for the development of SMEs, and enhancing the vitality of market development. Of course, digital platform operation is a huge system, and the parameter variables involved in this paper are all the main variables considered in the evolutionary game model without considering other variables. In the future, based on the two-party game model between market regulators and digital platforms, consideration can also be given to adding operators within the platform or platform consumers to establish a three-party game model to explore the behavioral decision-making trends under the three-party game.

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