


Research Article

Study on the Optimization of the Synergy between the Regulatory Body, Social Body, and Market Body in the Transportation Industry

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The regulatory body, social body and market body of transportation are important participants in the transportation market, and their synergistic efficiency has an important impact on the development of the market. The regulatory body needs to improve regulatory efficiency to ensure the safe and stable development of the market; the market body needs to improve operational efficiency to promote the development of the market economy; the social body mainly implements guidance to the market, and the three complement each other. In order to optimize the business environment of transportation and promote the safe, stable and efficient development of transportation market, the game model of industry regulatory body and market body is established on the basis of sorting out the current situation of transportation market development, and the evolution game model of government regulation and social supervision is further established to analyze the relationship between the industry regulatory body, social supervisory body and market body, and put forward countermeasures for synergistic optimization. Measures are proposed to further improve the efficiency of transportation market operation and provide reference for market managers and operators.

1. Introduction

Since the founding of New China, China's transportation development has achieved a phase change from "bottleneck constraint" to "overall relief" to "basic adaptation" [1]. In the process of China's gradual transformation from a large transportation country to a strong transportation country, relatively crude investment in transportation development is not sustainable [2]. In the current process of transformation for our government from a management-oriented government to a service-oriented government, the role that transportation began to play in people's daily lives has undergone a new transformation and needs to further meet the people's diverse needs for a better life, and the requirements for transportation facilities, investment and other precision have become increasingly high [3]. At present, China's transportation market supervision and

management of the main responsibilities of the transportation management department, including the implementation of administrative licensing, administrative penalties, administrative coercion and other law enforcement work of the market operators. With the year-on-year increase in China's transportation volume, it is difficult to form a comprehensive coverage of the market by the supervision and management implemented by the transportation management department only, so the social supervision mechanism is gradually introduced to fill the regulatory gap and form a powerful supplement to the management department through the means of credit supervision. 2021, MOT on the "transportation credit management regulations (draft)" for public comment, to further strengthen the construction of the transportation credit system and accelerate the construction of a new credit-based regulatory mechanism.

1.1. Problems. At present, in the transportation market management, the first is transportation regulatory system needs to be further constructed. At present, the transport management department has assumed the main responsibility for market regulation, involving highway and waterway transport planning, construction, operation, safety and other areas, the scope of regulation is wider and the pressure of regulation is greater. For the market body, some small and medium-sized operators have failed to fully implement the "Safety Production Law," "Road transportation regulations," "Domestic waterway transportation regulations," and other relevant laws and regulations and have not established a complete safety management system themselves. For the social body, the current means of transportation credit supervision is still not fully effective, the relevant data from different fields have not been integrated, and the supporting reward and punishment mechanism is still not fully established. Transportation regulatory body, social body and market body to share the responsibility of regulatory pressure unevenly, there is poor coordination between each other, has not formed a mature, stable regulatory system.

Second, the interactions between the three relationships need to be further clarified. The industry regulatory body and market body are the two most important subjects within the market, the regulatory body to the implementation of supervision of market subjects, and the market body of the business behavior of industry regulators also have an impact on the mode of supervision, the two have a game relationship. By playing a supervisory function outside the industry, the social body have also formed a game relationship with the regulation within the industry. In the actual operation of the market, the regulators in the industry are bent on strengthening the regulation of transportation operators, which improves the safety of the market, but discourages the market operators. The regulators are too weak, the chances of market operators operating in violation of the law will increase, which will also have a detrimental effect on the benign development of the market and need to further find a balance for the benign development of the market. And from outside the transportation industry, external social regulatory functions and internal market regulations, which has a greater impact on the market players, the development of which direction to focus on, is also a difficult problem to be solved in the transportation industry.

Third, the direction of development of each of the three needs to be further clarified. From the transportation industry regulatory body, due to the rapid growth of the market volume, and limited by law enforcement officers, limited funding, some equipment can not be updated in a timely manner, so the overall regulatory capacity and the rapid development of the market can not form a match, resulting in the gradual weakening of regulation, so there is a need to focus on specific regulatory areas and scope. From the market body, the market body in which aspects of the transportation market may have a greater impact, the need to focus on improving which aspects of the supporting

system measures to be further proposed. From the social body, although some local use of social supervision means to strengthen the market management, but also the formation of some areas of duplication of supervision, and supervision of the main body has not formed an organic interface, affecting the market order.

1.2. Summary. In response to the aforementioned problems, one is in building a regulatory system. Le et al. [4] proposed that efforts should be made to build a service-oriented government system, change the management mindset and mode of the main body of market regulation, take the needs of market players as the guide, and reduce the impact of supervision and management on business operations. Xin [5] quantified the event risk by constructing a risk evaluation system for urban rail transit operations, and established a safety production responsibility system oriented to risk prevention and control. Shi et al. [6] proposed that as an important force to regulate the market and promote the development of the industry, it is necessary to further promote the formation of a benign interaction mechanism between relevant subjects inside and outside the industry, and establish a standardized and facilitated interactive communication channel. Wang et al. [7] proposed that in order to promote high-quality market development, it is necessary to build a common governance system in the transportation industry, with government entities further streamlining their functions, market operators doing a good job of implementing laws, regulations and policies, and the social body doing a good job of supervising the market management. The second is in the clarification of the three interrelationships. Bi et al. [8] proposed that the market body, regulatory body and social body should form a synergistic development, with the regulatory department carrying out supervision and inspection, the social body evaluating the work of the regulatory department, and the market body improving its own internal management efficiency. Li [9] proposed that the social body should build a bridge of communication and collaboration between enterprises and management departments, enhance industry cohesion, and strengthen the integration of information resources. Wang and Wang [10] proposed that the application of credit regulation means should be vigorously promoted, and credit regulation should be used as an effective means of social supervision to form a supplement to market regulation. By constructing an evaluation system for the whole life cycle regulation of TCM, Huang et al. [11] used internal and external regulation and supervision of the industry to achieve full management coverage, and used an evaluation method based on fuzzy group decision making to scientifically evaluate each factor and achieve whole life cycle management. Third, in terms of clear development priorities and measures. Li [12] summarizes and refines the car-free pilot by proposing to strengthen the application of assessment mechanisms, interviewing pilot enterprises that do not

meet the standards in consecutive assessments, and urging them to verify and rectify relevant abnormalities and other issues. Cui [13] proposed that the management should strengthen the revision of laws and regulations, and enterprises should strengthen the implementation of laws and policies. Liao and Huang [14] proposed to strengthen the application of “Internet+” regulation mode and strengthen the information sharing between management departments and enterprises. Therefore, rationalize the relationship between industry the regulatory body, social subjects and market subjects, strengthen the synergy of the three, and clarify the direction of market management optimization is an important grip to improve the efficiency of transport market operation and further promote the high-quality development of the transportation industry.

The focus of this paper is to analyze and study the uncoordinated and unclear relationship between the regulatory body, social body, and market body in the transportation industry, in which the industry regulatory body and market body interact and influence each other in the industry, and the regulatory efficiency affects the market operation efficiency at the same time, the development status of the market also has influence on the choice of regulatory measures, so there is a game relationship between the two. Due to the limited management resources of the state, social supervision and intraindustry regulation in the management of the market there is a game competition, who dominates, who has a greater impact on the development of the market. In order to solve the relationship problem of related bodies, Cui et al. [15] discussed the evolution process of big data-assisted credit regulation, the stability point and the key points of policy implementation by constructing a game model of big data-assisted credit regulation evolution in a multibody simulation, and clarified the relationship between the market body and social supervision body, and created a good institutional environment by “weak regulation and strong service”. Li [16] constructed a game model of quality regulation between government quality regulatory departments and online shopping platforms, revealed the optimal strategy choice and role mechanism of government quality regulatory departments and online shopping platforms in the game process, explored and confirmed the key influencing factors that affect the regulation probability of government quality regulatory departments and the control probability of online shopping platforms. Game theory is the study of the interaction between unified subjects, a mathematical theory and method of studying phenomena of a struggle or competition nature, by considering the predicted and actual behavior of individuals in an environment and studying their optimization strategies, and now game theory is widely used in biology, economics, international relations, political science, etc. Therefore, this paper intends to use the game theory approach to analyze the relationship between the market body and regulatory body within the industry, and social supervision body outside the industry and body within the industry, to further clarify the relationship

between the three and propose the next direction of transportation market development.

2. Game Model Construction of Regulatory Mechanism within the Transportation Industry

According to the three steps of signaling game analysis, the basic game model of transportation market regulatory mechanism will be established, as shown in Figure 1. First of all, we must first determine the participants of the game, in the transportation market supervision, although some places use credit supervision and other models to strengthen social supervision, but because the transportation market involves a relatively complex field, so in the regulatory process, the participants are mainly regulatory bodies and regulatory bodies, that is, the relevant government regulatory departments and transportation market business entities [17].

In the construction of the basic game model, the first is the natural choice of regulatory types, including efficient regulation and inefficient regulation, including efficient regulation means the use of innovative technology to implement licensing, supervision, or the use of “double random” random checks and other innovative regulatory tools to implement supervision and management. Inefficient regulation mainly refers to the use of traditional means, such as the use of a single on-site enforcement means, off-line implementation of administrative licensing. Second, the regulator based on their own private information, choose two strategies: {administrative licensing means to lead the implementation of supervision and management A, the implementation of supervision and management S, led by means of postevent supervision}. The regulator can choose to implement supervision and management led by prior regulation, or regulation led by postevent supervision and management. For enterprises, if the management chooses to be led by ex-ante regulation, it represents a high entry barrier to the field, it will bring enterprises to the management supervision is efficient and appropriate doubt, if you choose to be led by ex-post regulation, enterprises to enter the market costs less, while the security of the market in the ex-poststage for security, will bring positive signals to enterprises. Third, firms observe the signals released by the strategies chosen by the regulator to revise their perceptions of whether the regulation is efficient or not. They have two strategies: active response to regulation and negative response to regulation. Operating entities will have a certain understanding and knowledge of the general policy of the state, but do not understand the specific regulatory process, whether the means are efficient, and can only observe the regulator’s strategy, so they have only two information sets. Both nodes of enterprises are within this information set when the regulator chooses {to implement supervision and management A by administrative licensing means} or

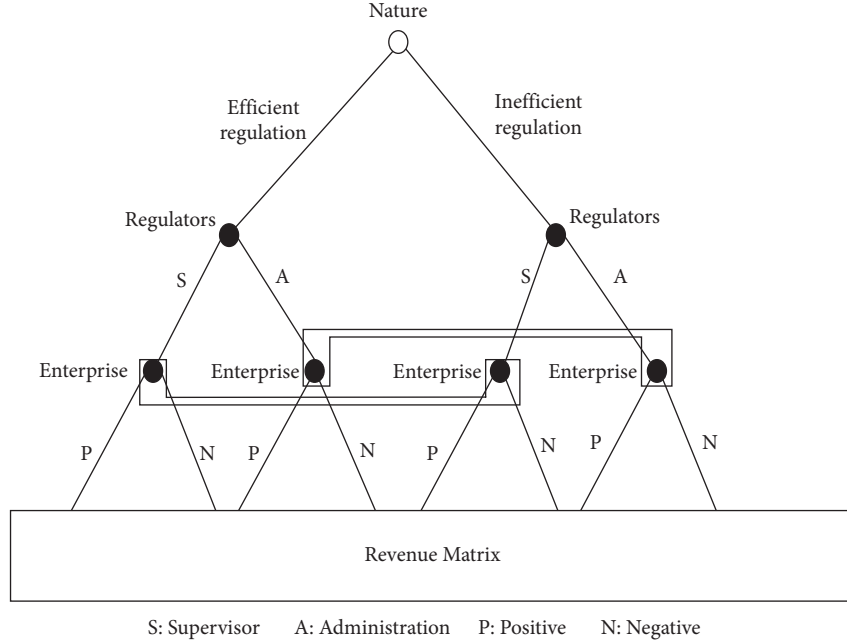


FIGURE 1: Basic game model of transportation market regulation mechanism.

TABLE 1: Symbol description of game model of transportation market regulation mechanism.

Symbol	Description
A	Probability of regulatory efficiency
F	The operating entity chooses to {actively respond} to the benefits of regulation to management
C_1	The cost of regulators choosing to actively improve regulatory efficiency
p	The operating entity chooses to {negatively respond} to regulation, once a major violation of the law, the regulator is held accountable
R	When the regulation is efficient, the operating entity chooses to {actively cooperate} with the benefits obtained from the regulation
C_2	The operating entity actively cooperate with the cost of regulation
q	The operating entity chooses to {negatively respond} to the regulation of the penalties received in the event of a violation

{to implement supervision and management S by ex-post supervision means}. When firms choose {active response to inspection}, it implies that their beliefs about the efficiency of regulation are positive and vice versa.

2.1. Matrix Determination and Solution. Based on the principle of “cost-benefit theory”, the function is assigned and calculated [18]. Table 1 is built to set different symbols to represent different result accord with the different option of enterprises and regulators, so that to analyze the relationship between relevant regulators and enterprises.

Each participant has two information sets, and each information set includes two strategy actions, so each participant has four strategies, for a total of 16 strategy combinations. According to the calculation, Table 2 shows the 16 strategy combinations calculation results as follows:

Let the benefit to the regulator be X_i , and under the condition that the firm chooses {active response to regulation}, then further calculation of the first column yields:

$$\begin{aligned}
 X_1 &= 2aC_1 + F - C_1, \\
 X_2 &= aC_1 + F, \\
 X_3 &= F, \\
 X_4 &= F - C_1 + aC_1.
 \end{aligned} \tag{1}$$

Since the data represented by the symbols are all greater than 0 and $0 < a < 1$, it is known that X_2 is the largest. In the second column, let the regulator {SS, PN}{SA, PN} gain be X_5 and {AA, PN}{AS, PN} gain be X_6 .

$$\begin{aligned}
 X_5 &= aF + aC_1 - p + ap, \\
 X_6 &= aF - p + ap.
 \end{aligned} \tag{2}$$

Therefore $X_5 > X_6$. For each strategy in the third column, the regulator’s revenue is $-p$. In the fourth column, suppose that the income of the regulatory agency {SS, NP}{AS, NP} is X_7 , and the income of {SA, NP}{AA, NP} is X_8 , then

$$\begin{aligned}
 X_7 &= -ap + F - aF - C_1 + aC_1, \\
 X_8 &= -ap + F - aF.
 \end{aligned} \tag{3}$$

TABLE 2: Bayesian game payoff matrix.

	PP	PN	NN	NP
SS	$(2aC_1 + F - C_1, aR - C_2^{(1)})$	$(aF + aC_1 + ap - p^*, aR - aC_2 - q + aq^{(2)})$	$(-p^*, -q^{(3)})$	$(-ap + F - aF - C_1 + aC_1, -aq - C_2 + aC_2)$
SA	$(aC_1 + F^*, aR - C_2^{(1)})$	$(aF + aC_1 + ap - p^*, aR - aC_2 - q + aq^{(2)})$	$(-p^*, -q^{(3)})$	$(-ap + F - aF^*, -aq - C_2 + aC_2)$
AA	$(F, aR - C_2^{(1)})$	$(aF + ap - p, aR - aC_2 - q + aq^{(2)})$	$(-p^*, -q^{(3)})$	$(-ap + F - aF^*, -aq - C_2 + aC_2)$
AS	$(aC_1 + F - C_1, aR - C_2^{(1)})$	$(aF + ap - p, aR - aC_2 - q + aq^{(2)})$	$(-p^*, -q^{(3)})$	$(-ap + F - aF - C_1 + aC_1, -aq - C_2 + aC_2)$

⁽¹⁾Maximum at $q > C_2$. ⁽²⁾ $q < C_2$, while $R > C_2$ or $R < C_2$, $C_2 - R < q < C_2$ max. ⁽³⁾Maximum at $R < C_2$, $0 < q < C_2 - R$

It is known that $0 < a < 1$, so $X_8 > X_7$. In the same way, suppose enterprise income is Y_j , then suppose

$$\begin{aligned}
Y_1 &= aR - C_2, \\
Y_2 &= aR - aC_2 - q + aq, \\
Y_3 &= -q, \\
Y_{41} &= -aq - C_2 + aC_2.
\end{aligned} \tag{4}$$

Therefore, if $q - C_2 > 0$, we can see that Y_1 is the largest; when $q - C_2 = 0$, we can see that $Y_1 = Y_2$ and is the largest; when $q - C_2 < 0$, then $Y_2 > Y_1$, $Y_3 > Y_4$. When $R > C_2$, Y_2 is the maximum; when $R < C_2$, if $C_2 - R < q \leq C_2$, Y_2 is the maximum, and if $0 < q \leq C_2 - R$, Y_3 is the maximum.

2.2. Model Analysis. Table 3 further refines the aforementioned game model. First, when $q > C_2$, that is, when the cost of illegal operating entities is much higher than the cost of cooperation with the supervision, there is a separation equilibrium point {SA, PP}, regardless of the regulatory authority to be dominated by ex-postsupervision, or by licensing means, operating entities will choose to actively respond to the supervision. The cost of violating the law is mainly stipulated by the relevant laws and regulations, which cannot be revised in the short term; therefore, it should be reduced from the perspective of reducing the cost of cooperating with the regulation to reduce the increase in operating costs caused by the regulators to the market players when implementing the regulation. In the premise of ensuring market safety, by reducing the frequency of on-site supervision, streamlining materials and other ways to ease the pressure on regulatory components while reducing the cost of market players and strengthening the main responsibility of market players in production safety.

Second, when $C_2 - R < q < C_2$, i.e., when the cost of illegal operation is lower than the cost of cooperating with the regulation, but greater than the net benefit obtained by the operating entity after cooperating with the regulation, there are two equilibria {SS, PN}{SA, PN}, forming a mixed equilibrium. According to the results, when the regulation is efficient, when the regulator chooses to regulate in-post as the main regulatory tool, enterprises will choose to actively cooperate; and when the regulation is inefficient, no matter what regulatory means, the business entity will choose to respond negatively. Therefore, the regulator should further take postevent supervision as the main means to establish a regulatory system with postevent regulation to improve regulatory efficiency, and at the same time, in addition to punishment, should consider other ways to increase the cost of market players to violate the law, such as publishing the

list of penalized subjects through social media and increasing the frequency of random checks to improve the enthusiasm of enterprises to cooperate with regulation.

Third, when $0 < q < C_2 - R$, i.e., when the cost of illegal operation is much lower than the cost of cooperating with regulation, enterprises always choose to respond negatively, i.e., a semiseparate equilibrium is formed. From the perspective of the transportation industry, the areas where enterprises have higher costs of violating the law are mainly those involving public safety, such as loading and unloading of dangerous goods, passenger transport, etc., whether administrative penalties, or losses to enterprises caused by accidents, are higher than those caused by the transportation of general cargo. Therefore, in the construction of transportation regulatory system, regulatory departments can be moderately relaxed in the field of low-risk regulation, and in dangerous goods, freight and other high-risk areas to implement key regulation, to further clarify their own scope of responsibility, while the market players in the field of general cargo moderately strengthen their own supporting measures, system construction, and regulatory work to further complement each other.

3. Evolutionary Game Model Analysis of Government Regulation and Social Supervision Mechanism

Both external supervision of the industry and industry regulation have advantages and also face the problem of mutual coordination. To enhance the analysis of the boundary and equilibrium points of the two management models, an evolutionary game model will be used to further compare the total systemic benefits of the two regulatory operating mechanisms.

3.1. Establishment of Evolutionary Game Model. Accord with the transportation industry management situation, Figure 2 describes that in the context of social supervision, industry regulators have two strategies {active optimization of business environment, negative optimization of business environment}, while society also has two strategies {supervision, no supervision}. In the context of industry regulation, industry regulators still have two strategies: {efficient industry regulation and inefficient industry regulation}, while society also has two strategies {implement credit regulation and no credit regulation}.

Based on the "cost-benefit theory" principle, the function is assigned and calculated. Let the regulatory efficiency be a . First of all, look at the management gains, regardless of

TABLE 3: Extraction of Bayesian Nash equilibrium points and description.

Condition	Balancing point	Description	Types of balance
$q > C_2$	{SA, PP}	When regulation is efficient, the regulator chooses regulatory means dominant and the operating entity chooses active response to regulation When the regulation is inefficient, the regulator chooses licensing means dominant, and the business subject chooses {active response to regulation}	Separate equilibrium
$C_2 - R < q < C_2$	{SS, PN} {SA, PN}	When regulation is efficient, the regulator chooses {regulatory instruments dominate} and the operating entity chooses {active response to regulation} When the regulation is inefficient, the regulator chooses which strategy, the operating entity chooses to respond negatively	Mixing and balancing
$0 < q < C_2 - R$	{SS, NN} {SA, NN} {AA, NN} {As, NN}	Regardless of whether the regulation is efficient, or regulators choose to regulate after the fact or may means to dominate, enterprises always choose to respond passively	Semiseparate equilibrium

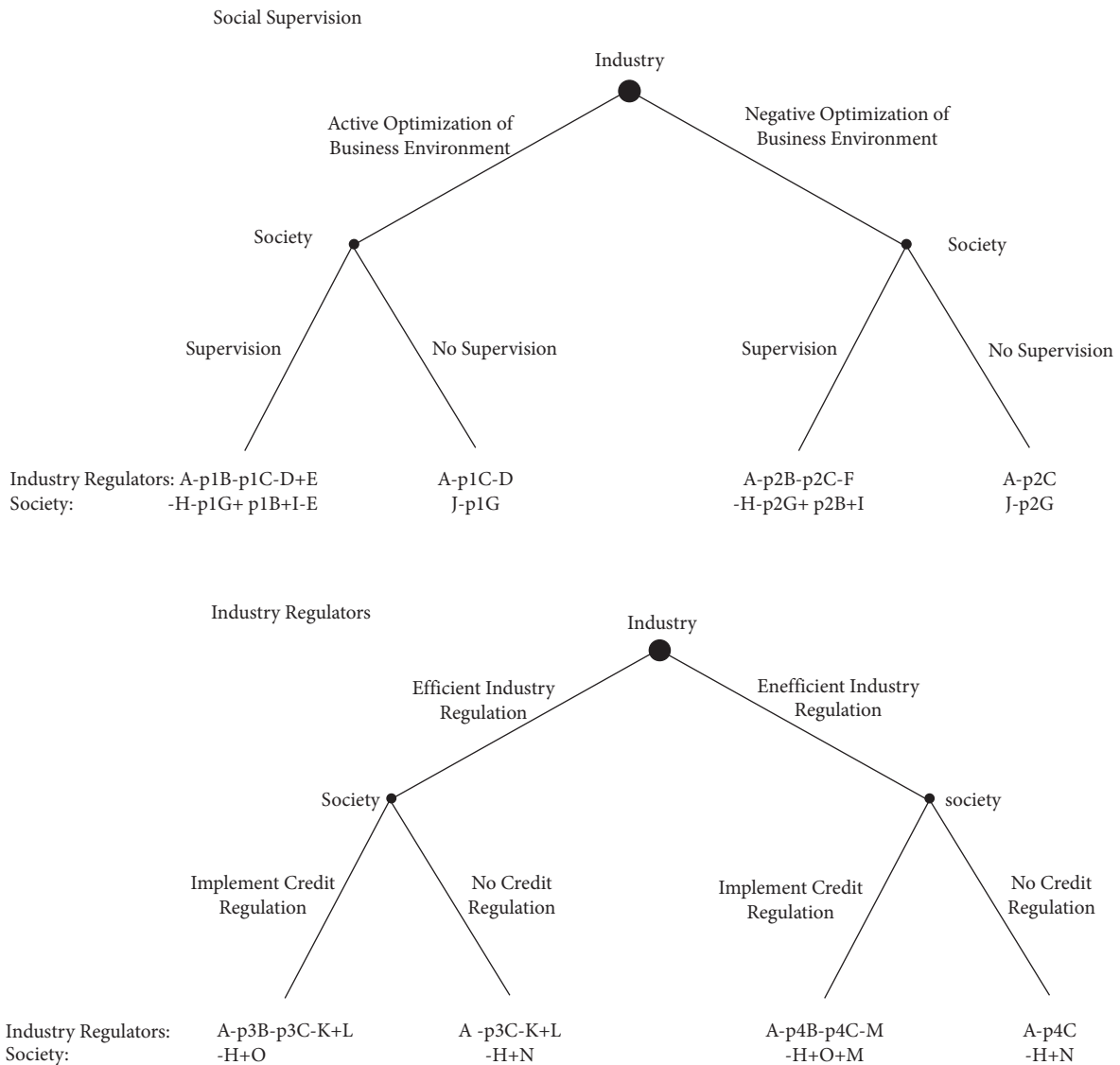


FIGURE 2: Extended game model under social supervision and industry regulation mechanism.

whether the regulation is efficient or not, the operating entity chooses {active response to regulation} to bring benefits to the management F, such as the virtuous circle of the market,

the management of the regulatory cost savings, etc. And, when the regulator chooses to actively improve regulatory efficiency, such as strengthening information technology

systems and integrating enforcement teams, the cost of C_1 . And, when the operating entity chooses {passive response to regulation}, once a major case affecting public safety and interests, in addition to the illegal operating entity by the appropriate penalty, the regulatory authorities will also be held accountable p . When the regulation is efficient, the business entity chooses {to actively cooperate with the regulation}, will get benefits, such as a better business environment, the formation of a virtuous competition cycle, etc., get benefits for R . If the operating entity actively cooperates with the supervision and inspection, it is necessary to submit relevant materials and carry out relevant rectification work in accordance with the relevant requirements, the cost incurred is C_2 . The operating entity chooses {negative response to supervision}, that is, not to carry out the corresponding rectification work, their own production and operation activities are not standardized, once the illegal events will be punished and held accountable q . Corresponding symbols are described in Table 4.

The extended game model is further transformed to form a strategy-based game model which is shown in Table 5.

3.2. Model Solving in Two Mechanisms. To solve the aforementioned evolutionary game model, the adaptation degrees of social subjects and industry regulators are first calculated under the mechanism of social supervision and industry regulation, and the average adaptation degree is obtained [19]. The adaptation degrees of industry regulators choosing both positive and negative strategies are

$$\begin{aligned} S_a &= b(A - p_1B - p_1C - D + E) + (1 - b)(A - p_1C - D), \\ S_{1-a} &= b(A - p_2B - p_2C - F) + (1 - b)(A - p_2C). \end{aligned} \quad (5)$$

Then, the average adaptation:

$$\begin{aligned} \bar{S}_1 &= a(-bp_1B + bE + A - p_1C - D) \\ &+ (1 - a)(-bp_2B - bF + A - p_2C). \end{aligned} \quad (6)$$

The dynamic equation formed is given by

$$\frac{da}{dx} = a(s_1 - \bar{S}_1). \quad (7)$$

Let the dynamic adjustment be 0, then from the value of a , there are two strategies with $a = 0$ and $a = 1$, which are steady states.

From the value of b , when $b = p_1C + D - p_2C/E - p_1B + p_2B + C + F$, then da/dx is 0 and the system is in a stable state and the replication dynamics is shown in Figure 3.

When $b < p_1C + D - p_2C/E - p_1B + p_2B + C + F$, $a = 0$ and $a = 1$ are two stable strategies to find the derivative of da/dx , it is known that when $a = 0$, the derivative of da/dx is less than 0; when $a = 1$, the derivative of da/dx is greater than 0. Choose $a = 0$, because when social subjects do not implement supervision, industry regulators are also reducing the enthusiasm of optimizing the business environment, so a tends to 0, replicating the dynamic diagram shown in Figure 4.

When $b > p_1C + D - p_2C/E - p_1B + p_2B + C + F$, $a = 0$ and $a = 1$ are two stable strategies, and the derivative of da/dx can be found that when $a = 0$, the derivative of da/dx is greater than 0; when $a = 1$, the derivative of da/dx is less than 0. Therefore, $a = 1$ is a stable strategy, and when social subjects implement social supervision, industry regulators optimize the business environment. The enthusiasm will be enhanced, and the probability will gradually converge to 1. The replication dynamic diagram is shown in Figure 5.

Similarly, under the social supervision mechanism, the average adaptation of industry regulators choosing both positive and negative strategies.

$$\bar{S}_2 = bS_b + (1 - b)S_{1-b}. \quad (8)$$

The replication dynamics equation further developed is

$$\begin{aligned} \frac{db}{dt} &= b(S_b - \bar{S}_2) = b(1 - b)(a(-E + p_1B - P_2B) \\ &+ I - J + p_2B - h). \end{aligned} \quad (9)$$

Let the dynamic adjustment be 0, i.e.,

$$\frac{db}{dx} = 0. \quad (10)$$

From the value of b , then there are two strategies with $b = 0$ and $b = 1$ for the steady state.

From the value of a , when $a = -I + J - p_2B + h/-E + p_1B - p_2B$, then db/dx is 0 and the system is in a stable state and the replication dynamics is shown in Figure 6.

When $a < -I + J - p_2B + h/-E + p_1B - p_2B$, $b = 0$, and $b = 1$ are two stable strategies, and the derivative of db/dx can be found that when $b = 0$, the derivative of db/dx is less than 0; when $b = 1$, the derivative of db/dx is greater than 0. Choosing $b = 1$, when the industry regulator chooses to negatively optimize the business environment, social agents will further strengthen social supervision in order to further optimize the market, so the probability of social supervision tends to 1. The replication dynamic diagram is shown in Figure 7.

When $a > -I + J - p_2B + h/-E + p_1B - p_2B$, $b = 0$, and $b = 1$ are two stable strategies, and the derivative of db/dx can be found that when $b = 0$, the derivative of db/dx is greater than 0; when $b = 1$, the derivative of db/dx is less than 0. Choosing $b = 0$, when industry regulators choose to negatively optimize the business environment, social agents will weaken the social supervision, so the social supervision probability tends to 0. The replicated dynamic diagram is shown in Figure 8.

Thus, the equilibrium point of the equation in the context of social supervision is $(1,1)$ $(1,0)$ $(0,1)$ $(0,0)$ $(-I + J - p_2B + h/-E + p_1B - p_2B, p_1C + D - p_2C /E - p_1B + p_2B + C + F)$.

By constructing the Jacobi matrix, the local stability can be analyzed [20].

TABLE 4: Symbols of extended game model.

Symbol	Description
A	Probability of industry regulators actively optimizing the business environment of transportation
B	The probability of social body implementing supervision
C	Probability of efficient implementation of industry supervision by industry regulators
D	Probability of credit supervision by society
A	Total revenue of the industry
B	The industry does not form a virtuous circle and suffers the punishment of society (such as public opinion)
C	The loss of industry's benefits for not forming a virtuous circle in the industry
D	The industry's input to actively optimize the business environment
E	Industry actively optimizing business environment is rewarded by society (e.g., positive media publicity)
F	Negative impact (punishment, accountability, public opinion) on the industry's negative optimization of the business environment
G	Negative impact on society for not forming a virtuous circle in the industry (social and economic development, implicating related industries)
H	The cost of social implementation of supervision
I	The benefits of social implementation of supervision (industry development)
J	Costs saved by society not implementing supervision
K	Cost of implementing efficient industry regulation by industry regulators
L	Additional benefits for industry regulators to implement efficient industry regulation (superior affirmation, government credibility)
M	Penalty from society for implementing inefficient industry regulation by industry regulators (reduced credibility, public opinion)
N	Costs to society for implementing credit regulation ($N < H$)
O	Social implementation of credit regulation benefits
p_1	Industry regulators actively optimize the business environment, and the market does not form a virtuous cycle probability
p_2	Industry regulators negatively optimize the business environment, and the market does not form a virtuous cycle probability ($p_2 > p_1$)
p_3	Industry regulators implement efficient regulation, and the market has not formed a virtuous cycle probability
p_4	The probability that the industry regulator implements inefficient regulation and the market does not form a virtuous circle ($p_4 > p_3$)

TABLE 5: Strategy-based game under social supervision and industry regulation mechanism.

Social body Industry departments	Social supervision	
	Supervision	No supervision
Actively optimize the business environment	$(A - p_1B - p_1C - D + E, -H - p_1G + p_1B + I - E)$	$(A - p_1C - D, J - p_1G)$
Negative optimization of the business environment	$(A - p_2B - p_2C - F, -H - p_2G + p_2B + I)$	$(A - p_2C, J - p_2G)$
Industry regulation		
Social body Industry departments	Implement credit regulation	No credit regulation
Efficient industry regulation	$(A - p_3B - p_3C - K + L, -H + O)$	$(A - p_3C - K + L, -H + N)$
Inefficient industry regulation	$(A - p_4B - p_4C - M, -H + O + M)$	$(A - p_4C, -H + N)$

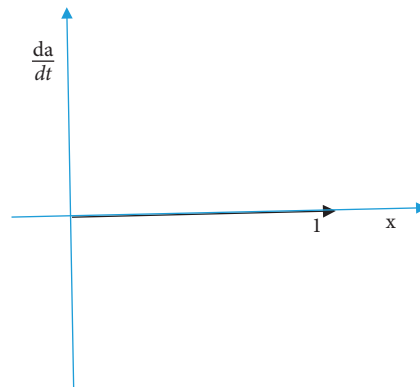


FIGURE 3: Replication dynamics of industry regulatory authorities Figure 1.

$$Z = \begin{bmatrix} (1-2a)(-bp1B + bE + A - p1C - D + bp2B + bF - A + p2C) & a(1-a)(p2B - p1B + E + F) \\ b(1-b)(-E + p1B - p2B) & (1-2b)(a(-E + p1B - p2B) + I - J + p2B - h) \end{bmatrix}. \quad (11)$$

Then,

$$\begin{aligned} \text{Det } Z &= \begin{vmatrix} (1-2a)(-bp1B + bE + A - p1C - D + bp2B + bF - A + p2C) & a(1-a)(p2B - p1B + E + F) \\ b(1-b)(-E + p1B - p2B) & (1-2b)(a(-E + p1B - p2B) + I - J + p2B - h) \end{vmatrix}, \\ \text{Tr. } Z &= (1-2a)(-bp1B + bE + A - p1C - D + bp2B + bF - A + p2C) + (1-2b)(a(-E + p1B - p2B) + I - J + p2B - H). \end{aligned} \quad (12)$$

According to the cost-benefit relationship between social supervision and industry regulation, one is high cost for society and high cost for industry regulators; the other is high cost for society and low cost for industry regulators; the third is low cost for society and high cost for industry regulators; the fourth is low cost for society and low cost for industry regulators. The stability is further judged by the determinant value with positive and negative traces, and there is local stability when $\text{Det } Z > 0$ and $\text{Tr } Z < 0$. Since both social subjects and industry regulators bear high costs when implementing social supervision, under this condition, the

first and second equilibrium points in Table 6 have local stability, and the attitude of industry regulators to optimize the business environment of the industry is negative regardless of whether social subjects implement social supervision or not.

Similarly, in the context of industry regulation, the equilibrium point of the equation is $(1,1)$ $(1,0)$ $(0,1)$ $(0,0)$ $(p3C + K - L - p4C / -p3B + p4B + M, O + M - N/M)$.

The analysis of local stability by constructing the Jacobi matrix shows that

$$Z = \begin{bmatrix} (1-2c)(-dp3B - p3C - K + L + dp4B + dM + p4C) & c(1-c)(p4B - p3B + M) \\ b(1-b)(-E + p1B - p2B) & (1-2d)(O + M - cM - N) \end{bmatrix}, \quad (13)$$

and then

$$\begin{aligned} \text{Det. } Z &= \begin{vmatrix} (1-2c)(-dp3B - p3C - K + L + dp4B + dM + p4C) & c(1-c)(p4B - p3B + M) \\ b(1-b)(-E + p1B - p2B) & (1-2d)(O + M - cM - N) \end{vmatrix}, \\ \text{Tr. } Z &= (1-2c)(-dp3B - p3C - K + L + dp4B + dM + p4C) + (1-2d)(O + M - cM - N). \end{aligned} \quad (14)$$

As mentioned before, there is local stability when $\text{Det } Z > 0$ and $\text{Tr } Z < 0$. In the industry regulation mechanism, social agents mainly implement supervision of the industry through the model of credit regulation, which is low cost compared to the diversified means in the social supervision model, so the cost of the industry regulator is mainly considered. From Table 7 it can be seen that $(0, 1)$ has local stability, industry regulators will choose to implement inefficient industry regulation and social subjects will choose to implement credit regulation.

3.3. Comparative Analysis. Combined with the previous, when under the social supervision mechanism, $(0, 0)$ $(0, 1)$ has relative stability, the gains are respectively:

$$\begin{aligned} S_1 &= (A - p_2B - p_2C - F) + (-H - p_2G + p_2B + I), \\ S_2 &= (A - p_2C) + (J - p_2G). \end{aligned} \quad (15)$$

When in the industry regulatory regime, $(0, 1)$ has relative stability, the returns are:

$$S_3 + (A - p_4B - p_4C - M) + (-H + O + M). \quad (16)$$

Therefore, it is necessary to discuss the four situations of $S_1 > S_3$, $S_1 < S_3$, $S_2 > S_3$, and $S_2 < S_3$. When $S_1 > S_3$, then:

$$-p_2C - F - p_2G + I + p_4B + p_4C - O > 0. \quad (17)$$

From the social body, and industry regulatory body is divided into two parts for discussion, then:

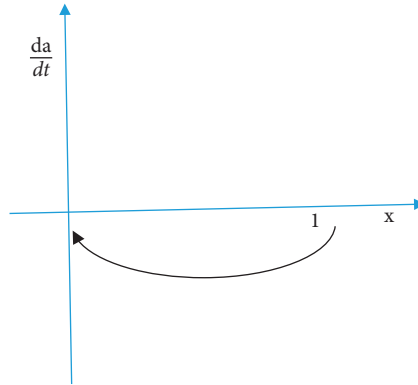


FIGURE 4: Replication dynamics of industry regulatory authorities Figure 2.

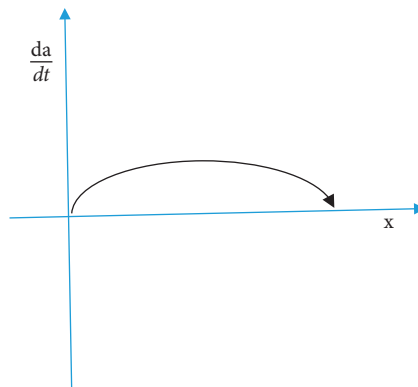


FIGURE 5: Replication dynamics of industry regulatory authorities Figure 3.

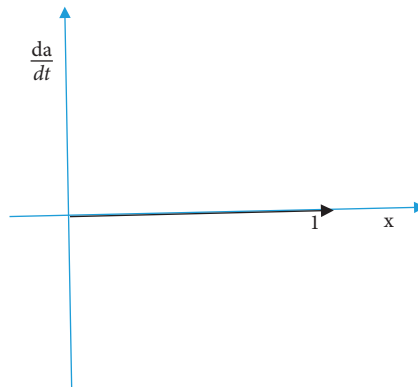


FIGURE 6: Replication dynamics of industry regulatory authorities Figure 4.

$$(p_4(B + C) - p_2C - F) + (I - p_2G) > 0. \quad (18)$$

When $S_1 < S_3$, it is the opposite of the above result.

When $S_2 > S_3$, then

$$(p_4(B + C) - p_2C)((J + H) - (O + p_2G)) > 0. \quad (19)$$

Therefore, from the perspective of both external supervision and intraindustry regulation, one is that the loss to the industry caused by the inefficient regulation implemented by the industry regulator is greater than the loss to the industry caused by its negative optimization of the business environment; and the second is that the positive

impact of socially implemented supervision on the development of the industry is greater than the sum of the gains from socially implemented credit regulation and the negative impact on society caused by the negative optimization of the business environment by the industry regulator.

The above is reversed when $S_2 < S_3$.

All the above four situations will exist in theory. Combined with the current state of development of China's transportation industry for analysis, first, the regulatory efficiency of industry regulators has a significant impact on the development of the industry, higher than the impact of other internal industry management tools on the

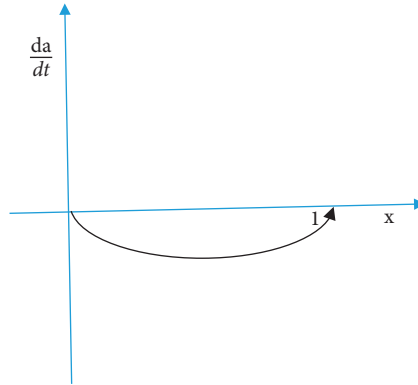


FIGURE 7: Replication dynamics of industry regulatory authorities Figure 5.

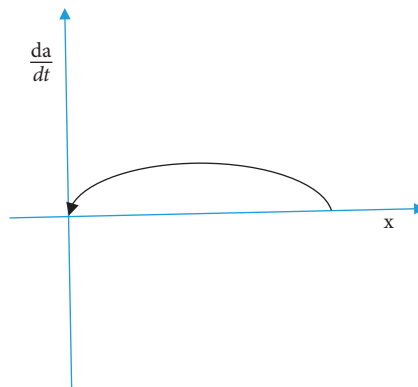


FIGURE 8: Replication dynamics of industry regulatory authorities Figure 6.

TABLE 6: Stability achieved by the system in different cases under social supervision mechanism.

Equilibrium point	Value of row equation with trace	Case 1	Case 2	Case 3	Case 4	Stability
(0, 0)	$\text{Det } Z = (-p1C - D + p2C)(I - J + p2B - H)$ $\text{Tr } Z = (-p1C - D + p2C) + (I - J + p2B - H)$	$\text{Det } Z > 0$ $\text{Tr } Z < 0$	$\text{Det } Z < 0$ $\text{Tr } Z$ uncertain	$\text{Det } Z < 0$ $\text{Tr } Z$ uncertain	$\text{Det } Z > 0$ $\text{Tr } Z > 0$	(1) Stable ESS (2) Uncertain (3) Uncertain (4) Unstable
(0, 1)	$\text{Det } Z = -$ $(E - p1B - p1C - D + p2B + bF + p2C)(I - J + p2B - H)$ tr $Z =$ $(-p1B + E - p1C - D + p2B + F + p2C) - (I - J + p2B - H)$	$\text{Det } Z > 0$ $\text{Tr } Z < 0$	$\text{Det } Z < 0$ $\text{Tr } Z$ uncertain	$\text{Det } Z < 0$ $\text{Tr } Z$ uncertain	$\text{Det } Z > 0$ $\text{Tr } Z > 0$	(1) Stable ESS (2) Unstable (3) Uncertain (4) Unstable
(1, 1)	$\text{Det } Z = p1C + D - p2B - F - p2C - I + J + H$ $\text{Tr } Z = -(-p1C - D + F + p2C) - (I - J + p2B - H)$	$\text{Det } Z < 0$ $\text{Tr } Z$ uncertain	$\text{Det } Z > 0$ $\text{Tr } Z > 0$	$\text{Det } Z > 0$ $\text{Tr } Z < 0$	$\text{Det } Z < 0$ $\text{Tr } Z$ uncertain	(1) Unstable (2) Unstable (3) Stable ESS (4) Uncertain
(1, 0)	$\text{Det } Z = -(-p1C - D + p2C)(-E + p1B + I - J - H)$ $\text{Tr } Z = -(-p1C - D + p2C) + (-E + p1B + I - J - H)$	$\text{Det } Z < 0$ $\text{Tr } Z$ uncertain	$\text{Det } Z > 0$ $\text{Tr } Z < 0$	$\text{Det } Z > 0$ $\text{Tr } Z > 0$	$\text{Det } Z < 0$ $\text{Tr } Z$ uncertain	(1) Uncertain (2) Stable ESS (3) Unstable (4) Uncertain

development of the industry; second, the impact of social supervision on the development of the industry, higher than the impact of intraindustry regulation on the development of the industry, but currently there is still a certain degree of uncertainty. Therefore, to build a transportation regulatory system, it is necessary to further strengthen the coordination and cooperation of relevant bodies within and outside the industry, and build a new regulatory system led by social

supervision, industry regulation as the focus, complemented by the independent management of market players.

4. Policy Suggestions

Combined with the above conclusions, the development of the transport market, one is actively build a new regulatory system led by social supervision, industry regulation as the

TABLE 7: Stability achieved by the system in different cases under the industry regulatory mechanism.

Equilibrium point	Value of row equation with trace	Industry regulator costs	Case	Stability
(0, 0)	Det Z = $(-p3C - K + L + p4C)(O + M - N)$ Tr Z = $-p3C - K + L + p4C + O + M - N$	Low	Det Z > 0 Tr Z uncertain	Uncertain
(0, 1)	Det Z = $(-p3B - p3C - K + L + p4B + M + p4C)(O + M - N)$ Tr Z = $-p3B - p3C - K + L + p4B + p4C - O + N$	Low	Det Z > 0 Tr Z < 0	Stable ESS
(1, 1)	Det Z = $(-p3B - p3C - K + L + p4B + M + p4C)(O - N)$ Tr Z = $p3B + p3C + K - L - p4B - M - p4C - O + N$	High	Det Z < 0 Tr Z > 0	Unstable
(1, 0)	Det Z = $(-p3C - K + L + p4C)(O - N)$ Tr Z = $-p3C - K + L + p4C + O - N$	High	Det Z > 0 Tr Z > 0	Unstable

focus, complemented by the independent management of the market body, social body actively play a leading role in the establishment of a sound credit monitoring mechanism, and undertake the collection, collation and analysis of relevant data and information. Regulatory departments actively perform their regulatory duties and use “double random” “Internet + Regulation” and other means to improve their regulatory efficiency. The market body to further implement their own production safety responsibility system, within the enterprise to regularly carry out safety, laws and regulations and other aspects of training, improve the quality of personnel safety and legal awareness, the establishment of a sound risk prevention and control system, improve the internal management of enterprises supporting the assessment system, effectively linking the responsibility of production safety and personnel pay performance. The second is to further establish a coordination mechanism. To achieve social supervision, market regulation and enterprise management complementary coordination, in which social body implement supervision of the market body in the industry from the perspective of outside the industry, strengthen the sharing of relevant industry data information and establish credit disciplinary mechanism. The main body of market regulation focused on dangerous goods, passenger transportation, loading, unloading and barging, and the implementation of regulation in areas more closely related to public safety. Enterprises manage their daily operations and strictly implement the requirements of the Safety Production Law, the Maritime Traffic Safety Law and other relevant laws and regulations to further achieve full market coverage.

Third, to strengthen the interaction of information, promote the strengthening of data integration, the establishment of a large database, open up the market subjects, social supervision subjects, management subjects information channels, in order to transportation market management, the development of the current situation to make a correct diagnosis, the formation of scientific and rational decision-making deployment.

Data Availability

Statistical bulletin on the Development of the Transport Industry in 2020 published by the Ministry of Transport of China. Based on the relevant data, the authors establish the

game model and evolutionary game model of market body, regulatory body and social body, innovatively set the relevant symbols and describe them, and use the game method to make calculations.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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