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National Supervision of Third Party Hazardous Chemical Inspection Institution by Evolutionary Game

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Third party chemical inspection help enterprises implement the supply-side reform and respond to consumer demands. As violations of hazardous chemical inspection Institution happen occasionally, and there are few analyses on the national supervision on hazardous chemical inspection institution. The paper discussed national supervision on hazardous chemical inspection Institution by evolutionary game. After establishing evolutionary game model, the paper conducted equilibrium analysis, and then discussed evolution stability parameters, finally reached the conclusions and put forward some specific measures from the angle of national supervision and hazardous chemical inspection Institution.

1. Introduction

Any technology that uses chemical methods to change the composition, structure of substances or synthesize new substances belongs to chemical production technology, i.e. chemical process. The products obtained are called chemicals or chemical products. According to the American Chemical Abstracts, there are 7 million kinds of chemicals in the world. Among them, more than 10 kinds of chemicals have been listed as commodities. There are more than 70 thousand kinds of chemicals that are commonly used, and there are more than 1000 new chemicals appearing worldwide every year. Hazardous chemicals refer to highly toxic chemicals and other chemicals with toxic, corrosive, explosive, combustion and combustion-supporting properties that are harmful to human beings, facilities and the environment. Third party chemical inspection help enterprises implement the supply-side reform and respond to consumers' demands, like a strong catalyst to enterprises vitality. False hazardous chemical inspection happens over and over again in China, damaging the interests of consumers and undermining the social credit mechanism. In response to the problem, the paper constructs a game model involving third party hazardous chemical inspection and supervision department. The research can provide certain reference for promoting the development of modern service industry and national strategic emerging industries. The inspection industry is an important tool and technical support for the national governance system, and also a modern service industry and high-tech service industry encouraged. According to the "13th Five-Year" Development Planning for National Strategic Industries issued in 2016, the inspection industry was included as a national strategic industry. In addition, this research is also of great significance to enhancing national supervision on hazardous chemical inspection bodies, and meanwhile provides reference for improving services of hazardous chemical inspection bodies.

There were lots of accidents and fatalities in hazardous chemical business. The number of casualty accidents fluctuated between 200 and 600/year, the number of fatality fluctuated between 220 and 1100/year. The accident rate in developed southeast coastal areas (Duan et al., 2011). Ploêncio et al., (2017) describes an innovative fast and multipurpose method for the chemical inspection of meat and fish products by liquid chromatography-tandem mass spectrometry. Wan et al., (2015) proposed an indicator based on ecological two-sidedness theory and Shannon entropy, which is intended for analyzing informational complexity in a decision network of the chemical insecticide pollution management. Lee et al., (2017) discuss the changes in approaches to handle chemical accidents from various perspectives and present a case in which the relevant agencies succeeded in responding relatively efficiently to a major chemical accident because of these changes. Roy and Khastagir (2016) explored role of green management in enhancing organizational efficiency

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in petro-chemical industry in India. Zuo and Tang (2017) gave research on influence of the effectiveness of such certifications as service quality of certification Institution on the enterprise performance. Wang et al., (2018) discussed game relationship between national supervision and water quality inspection Institution from the angles of static game and dynamic game. Game theory is the study of mathematical models of conflict and cooperation between intelligent rational decision-makers.

The game theory model consists of player, strategy and pay-off. The player is an agent who participates in the game and each player has his own strategies with different pay-offs. With this basic background, the main purpose of game theory is to derive an equilibrium in the game depending on the players and their strategies. A supply chain enterprises operating mechanism model from the perspective of game theory, used repeated game, individual game and group of evolutionary game and verified the importance of cooperation in creative products supply chain through theoretical proof and examples was established (Chen and Jiang, 2017). Chen et al., (2017) studied the political incentives of government officials to cooperate with one another to achieve a common goal through game theory. Babu and Mohan, (2018) using evolutionary game theory to evaluate sustainability in supply chains.

As violations of hazardous chemical inspection institution happen occasionally, and there are few analyses on the national supervision on chemical inspection Institution, this paper shall further analyze the game relation between national supervision department and chemical inspection institution from dynamic game of the two parties in bounded rationality and provide hazardous chemical inspection institution supervision with new thoughts.

2. The evolution game in the bounded rationality

Suppose that supervision department can select strict supervision and suppose the supervision cost as T, and it can also select no supervision without cost generated; Chemical Inspection Institution can select strict inspection and relaxed inspection simultaneously, and purposes of the two parties of the game are all the benefit maximization.When chemical inspection Institution selects strict inspection and supervisor selects strict supervision strategy, chemical inspection Institution could acquire normal earnings R1 and have no extra earnings, and the earnings can be measured by R_0 if strict supervision could be recognized and affirmed by the society; if supervisor does not give supervision and can not determine relaxed inspection of chemical inspection Institution, the Chemical Inspection Institution could acquire the excessive earnings R_2 for the relaxed inspection and suffer reputation influence L_2 for the inadequate supervision. If chemical inspection Institution relaxes inspection and suffers strict supervision of the supervisor, the loss shall be F+L by considering the paying cost F for the punishment suffered by relaxed inspection and the reputation influence L, paying cost of supervision department shall be T, and the probability of determining relaxed inspection of chemical inspection Institution shall be P. Payoff matrix can be seen in Table 1.

Table 1: Payoff Matrix of the Supervision of Supervision Department on Chemical Inspection Institution

		Chemical Inspection Institution	
		strict supervision	relaxed inspection
Supervision Department	Supervision	-T; R_1	R_0-T, R_2-P(F+L)
	no supervision	0, R_1	- L_2, R_2

Probability of selecting strict inspection of the hazardous chemical inspection institution is supposed as x, and that of selecting relaxed inspection is supposed as (1-x). Probability of selecting strict supervision strategy of the supervision department is supposed as y, and that of selecting ordinary supervision strategy is supposed as (1-y),

Then the expected earnings for strict supervision of supervision department is:

$$u_1 = -Tx + (R_0 - T)(1 - x) \tag{1}$$

the expected earnings for no supervision of supervision department is:

$$u_2 = -L_2(1 - x) \tag{2}$$

the expected average earnings of supervision department is:

$$u_3 = y(R_0 - T - xR_0) - (1 - y)(1 - x)L_2 \tag{3}$$

and the replicator dynamic equation for implementation of the strict supervision strategy of supervision department along with passing of the time t is:

$$F(y)=\frac{dy}{dt}=y(u_1-u_3)=y(1-y)[(R_0-T-xR_0+L_2(1-x)] \tag{4}$$

According to results of the dynamic equation, this model has three stable states. When the replicator dynamic equation reaches the equilibrium state, proportions of the two game parties adopting different strategies shall remain unchanged, namely that F(*y*)=0 shall refer to evolution stability equilibrium state of this game.
Firstly, when *x*=(1-T)/(R_0+L_2) and F(*y*)=0, namely that probability of selecting strict inspection of the Chemical Inspection Institution is *x*=(1-T)/(R_0+L_2), this game shall be in stable state whether supervision Institution selects supervision or no supervision. Secondly, when *x*≠(1-T)/(R_0+L_2) and F(*y*) =0, we can obtain y=0 or *y*=1; when x<(1-T)/(R_0+ L_2), F(0) ´>0 and F(1)´<0, so *y*=1 is the stable strategy;
when *x* >(1-T)/(R_0+L_2), F(0)´<0 and F(1)´>0, so y=0 is the stable strategy.When the expected earnings of strict inspection of chemical inspection Institution is supposed as u_4, that of relaxed inspection is u_5, and average earnings is u_6, we can obtain:

$$u_4=R_1y+R_1(1-y)=R_1 \tag{5}$$

$$u_5=y[R_2-P(L+S)]+(1-y)R_2 \tag{6}$$

$$u_6=xu_4+(1-x)u_4=xR_1+(1-x)y[R_2-P(L+S)]+(1-x)(1-y)R_2 \tag{7}$$

The replicator dynamic equation for strict inspection selection of the chemical inspection Institution is structured as:

$$F(x)=\frac{dx}{dt}=x(u_4-u_6)=x(1-x)[(R_1+yP(L+F)-R_2] \tag{8}$$

Firstly, when *y*=(R_2-R_1)/P(L+F), namely that supervisor gives strict supervision with the probability y=(R_2-R_1)/P(L+F), proportions of strict inspection and relaxed inspection of the chemical inspection Institution shall remain unchanged. Secondly, when y≠(R_2-R_1)/P(L+F) and F(x) =0, we can obtain *x*=0 or *x*=1, and we can give *x* derivation of *F(x)*. When *y*>(R_2-R_1)/P(L+F), F(0)‘>0 and F(1)’<0, so *x*=1 is the evolution stability strategy.
When *y* < (R_2-R_1)/P(L+F), F(0) ‘<0 and F(1) ‘>0, so x=0 is the stable strategy.
From F(x) and F(*y*) given above, we can obtain the Jacobian matrix:

$$J=\begin{bmatrix}(2x\text{-}1)[R_2-\mathrm{R}_1+yP(L+F)] & x(1-x)P(L+F)\\ y(y-1)(R_0+L_2) & (1-2y)[(R_0+L_2)(1-x)-T]\end{bmatrix} \tag{9}$$

Determinant of matrix J is:

$$\det J=(2x\text{-}1)[R_2-\mathrm{R}_1+yP(L+F)](1-2y)[(R_0+L_2)(1-x)-T]-xyP(\mathrm{y}-1)(R_0+L_2)(1-\mathrm{x})(L+F) \tag{10}$$

Trace of matrix is:

$$\mathrm{trJ}=(2x\text{-}1)[R_2\text{-}R_1+yP(L+F)]+(1\text{-}2y)[(R_0+L_2)(1\text{-}x)\text{-}T] \tag{11}$$

Determinant and trace of Jacobian matrix of each equilibrium point is as shown in Table 2.

Table 2: Determinant and Trace of Jacobian Matrix of the Various Local Equilibrium Points

Equilibrium Points	det J	trJ
a (0,0)	$(R_2-R_1)(R_0+L_2-T)$	$R_2-R_1+R_0+L_2-T$
b (0,1)	$-[R_1+P(L+F)-R_2](R_0+L_2-T)$	$[R_1+P(L+F)-R_2]-(R_0+L_2-T)$
c (1,0)	$(R_1-R_2)T$	$-(R_1+R_2)-T$
d (1,1)	$-[R_1+P(L+F)-R_2]T$	$R_2-R_1+R_0+L_2-\mathrm{T}$
e([(1-T) / (R_0+ L), (R_2-R_1)/P(L+F)])	$(R_0+L_2-T)T(R_2-R_1)[P(F+L)-R_1R_2]/P(R_0+L_2)$	0

As to the discrete dynamic system, when and only when $\det J > 0, \mathrm{tr} J < 0$, the equilibrium point shall be stable strategy. Next, we shall analyze phase diagram corresponding to stable state of each equilibrium point in the different conditions.

Table 3: List of Stability Analysis Results of the Local Equilibrium Points

Conditions	Local Equilibrium Points	Det. J symbol	Tr. J	Stability
$R_1+P(F+L)-R_2<0$, $R_0+L+F-T>0$	a (0,0)	-	uncertainty	instability
	b (0,1)	+	-	ESS
	c (1,0)	-	uncertainty	saddle point
	d (1,1)	+	-	saddle point
$R_1+P(F+L)-R_2>0$ $R_0+L+F-T<0$	a (0,0)	+	-	ESS
	b (0,1)	+	+	instability
	c (1,0)	-	uncertainty	saddle point
	d (1,1)	-	uncertainty	saddle point
$R_1+P(F+L)-R_2<0$ $R_0+L+F-T<0$	a (0,0)	+	-	ESS
	b (0,1)	-	uncertainty	saddle point
	c (1,0)	-	uncertainty	saddle point
	d (1,1)	+	+	instability
$R_1+P(F+L)-R_2>0$ $R_0+L+F-T>0$	a (0,0)	-	uncertainty	saddle point
	b (0,1)	-	uncertainty	saddle point
	c (1,0)	-	uncertainty	saddle point
	d (1,1)	-	uncertainty	saddle point
	(1-T)/ (R_0+L+F), y=(R_2-R_1)/P(L+F)	instability	0	central point

Firstly, when R1+P(F+L)-R2<0 and R0+L+F-T>0, Case 1 is as shown in Table 3, (0,1) is ESS. System shall finally converge at the point (0,1) no matter whether the initial state is. The evolution equilibrium stability means that the supervision department can certainly discover relaxed inspection of the Chemical Inspection Institution and give punishment in the condition of relaxed inspection of chemical inspection institution and powerful supervision of supervision department.

Secondly, when R1+P(F+L)-R2>0 and R0+L+F-T<0, please refer to Table 3. It can be seen that (0,0) is the stable node, and the system shall finally converge at the point (0,0) no matter whether the initial state is. The equilibrium state means that supervision department may not give strict supervision for the too high T and hazardous chemical inspection institution may adopt relaxed inspection in this case to get higher earnings.

Thirdly, when R1+P(F+L)-R2 <0 and R0+L+F-T<0, according to table 3 ,(0,0) is the stable node, and the system shall finally converge at the point (0,0) no matter whether the initial state is. The equilibrium state means that chemical inspection institution adopts relaxed inspection and supervision of the main Institution of supervision department is improper, so the behavior of relaxed inspection of hazardous chemical inspection institution cannot be discovered and punished.

Fourthly, when R1+P(F+L)-R2>0 and R0+L+F-T>0, case 4 is as shown in table 3, and ((1-T)/(R0+L2), (R2-R1)/P(L+F)) is the central point. This means that: hazardous chemical inspection institution suffers more loss by comparing with the excessive earnings obtained when adopting relaxed inspection, and system shall operate by surrounding ((1-T)/(R0+ L2), (R2-R1)/P(L+F)) and there should be no ESS when the cost generated by supervision of the main Institution of supervision department is not too high. When the probability of determining relaxed inspection of hazardous chemical inspection institution by the supervision department is low, the hazardous chemical inspection institution shall be inclined to relaxed inspection. When P<(R2-R1)/(F+L), extra earnings of chemical inspection Institution shall be greater than the loss, and the extra earnings mainly comes from reduction of input cost and the false inspection conspired with the entrusted enterprise. When the probability P of determining relaxed inspection of chemical inspection institution by the supervision department remains unchanged, the greater (F+L) shall result in the smaller R2-R1, and hazardous chemical inspection Institution shall be more inclined to strict inspection. When T<R0+L+F, hazardous chemical inspection institution shall be inclined to strict inspection. When T is smaller, and R0+L+F is greater, hazardous chemical inspection institution shall be more inclined to strict inspection. When

T/(R0+L+F) is close to 0 and R1+P(F+L)-R2>0, evolutionary game shall tend to the strict inspection of hazardous chemical inspection institution.

From the angle of national supervision, we can take following measures.

Firstly, the inspection authorities shall be guided to conduct organic bond and complement in inspection and testing business so as to provide enterprises with tracking service of the whole industry chain. Although we have the largest number of certificates issued in the world, but still in the tracking research stage in new fields and technologies of accreditation in the world and passively accepts the evaluation standards and systems in Europe and the United States. We need to improve its capability of independent innovation in certification and accreditation, striving for taking the lead to put forward advanced evaluation standards and methods in the world.

Secondly, the associations shall give full play to their role in registration of personnel, training and development, membership service, self-discipline supervision, technical standards and inspection business exchanges and cooperation at home and abroad. Sales of inspection certificates, illegal operation and operation without certificates are strictly prohibited.

Thirdly, it is necessary to give full play to folk supervision. The hearing system shall be introduced and public participation will be encouraged in the adjustment and reform of the system to enhance the transparency of the work. The media of the industry shall be integrated and reformed to become popular among people so that people can deeply participate in the media. The application of big data and e-commerce in the certification industry shall be strengthened, and the in-process and post-mortem supervision mechanism should be perfected.

Fourthly, we shall integrate and correlate relevant data and build a big data supervision mode to enhance government scientific decision-making and risk prediction abilities. Supervision and random checking shall be conducted on the effectiveness and normalization of inspection authorities and special inspection shall be carried out on outstanding issues and weak links. Then the integrity files of the authorities should be established. Also, it is necessary to establish and improve social credit system and institutional improvement of inspection. Market economy is honest economy and institutional economy. To establish a long-term mechanism for inspection effectiveness, it is necessary to constantly improve the market economic system, and to establish and improve a social credit system according with national conditions and international practices, and the development of modern market economy.

From the angle of hazardous chemical inspection institution, we should take following measures.

Firstly, hazardous chemical inspection institution should form a risk-based way of thinking, build a proactive improving and forward-looking culture, pay attention to the risk management knowledge reserve and resources construction, strengthen the construction of risk-related information channels and timely collect relevant information for risk identification and evaluation.

Secondly, the preconditions and prerequisites for the Effectiveness of inspection are to make reasonable arrangements to ensure the effective operation of inspection and continuously improve the quality of chemical inspection Institution. The resources needed for the implement and the continuous improvement are measured throughout management reviews, product requirements reviews, design and development reviews, unqualified or potentially unqualified causes investigations.

Thirdly, inspection Institution should identify all the processes, especially the key processes, and define the relationship between the processes to determine the quality control points in the process chain. The process of development and control is to determine the process of input, output, activities and resources, so as to effectively manage the process, conduct continuous control to the process, thus improve the performance level of enterprise. With the increasingly fierce market competition, inspection bodies need to examine the business process with a critical eye, to re-think, re-combine, re-sequence, re-position, re-quantify, re-assignment and re-assembly, to break the balance, and to achieve PDCA spiral rise.

Fourthly, to determine the suitability, adequacy and effectiveness of the inspection, managers need to conduct review on the management system according to the planned time intervals. The management review is also a value-added process. The input of the management review includes customer feedback, audit results, process performance and product conformity, follow-up measures of previous management review, suggestions for improvement, etc. The output of management review includes the improvement of the effectiveness of the inspection and its process, human resources monitoring and the supplement measurement resources. The internal audit is also very important and is to confirm the compliance and effectiveness of the inspection, and take corrective measures on the problems found to eliminate the nonconformity and the cause of it.

3. Conclusions

The game between the national supervision and the hazardous chemical inspection institution is analysed from the dynamic evolutionary game in bounded rationality and put forward specific measures. But the paper

does not give deep analysis on the dynamic game between the two parties in full rational conditions, or the game between supervision departments or the national supervision on hazardous chemical inspection institution.

References

Babu S., Mohan U., 2018, An integrated approach to evaluating sustainability in supply chains using evolutionary game theory, Computers and Operations Research, 89, 269-283, DOI: 10.1016/j.cor.2017.01.008

Chen T. G., Jiang Y. H., 2017, Research on operating mechanism for creative products supply chain based on game theory, Discrete and Continuous Dynamical Systems - Series S (DCDS-S), 8(6), 1103-1112.

Chen Y., Yeh A.G.O., Zhang Y., 2017, Political tournament and regional cooperation in china: a game theory approach, Annals of Regional Science, 58, 1-26, DOI: 10.1007/s00168-017-0809-6

Duan W., Chen G., Ye Q., Chen Q., 2011, The situation of hazardous chemical accidents in China between 2000 and 2006. Journal of Hazardous Materials, 186(2-3), 1489-1494, DOI: 10.1016/j.jhazmat.2010.12.029

Lee K., Kwon H. M., Cho S., Kim J., Moon I., 2016, Improvements of safety management system in Korean chemical industry after a large chemical accident. Journal of Loss Prevention in the Process Industries, 42(8), 6-13, DOI: 10.1016/j.jlp.2015.08.006

Mont O., Singhal P., Fadeeva Z., 2006, Chemical Management Services in Sweden and Europe: Lessons for the Future, Journal of Industrial Ecology, 10(1-2), 279-292, DOI: 10.1162/108819806775545295

Roy M, Khastagir D., 2016, Exploring role of green management in enhancing organizational efficiency in petro-chemical industry in India. Journal of Cleaner Production, 121, 109-115, DOI: 10.1016/j.jclepro.2016.02.039

Sun J., Zhang Y., Zuo Z., Chang Z., Guo J., 2017, Research on the Effectiveness Improvement Strategy of Quality Management System of Chemical Enterprises. Chemical Engineering Transactions, 62, 1603-1608, DOI: 10.3303/CET1762268

Wan N.F., Ji X.Y., Jiang J.X., 2015, An ecological indicator to evaluate the effect of chemical insecticide pollution management on complex ecosystems. Ecological Indicators, 53, 11-17, DOI: 10.1016/j.ecolind.2015.01.014

Wang Y, Zuo Z, Wu S., 2018, Research on the supervision of water quality inspection bodies in China[J]. Desalination and Water Treatment, 125, 132-136.

Zuo Z., Tang D. 2017, Research on the Impact of ISO9001 Certification Effectiveness on Organizational Performance in China, Boletin tecnico, 55(4), 644-655.