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The Role of Social Media in Promoting Information Disclosure on Environmental Incidents: An Evolutionary Game Theory Perspective

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Abstract: Despite the expectation that social media use in the public sector contributes to enhancing government's transparency, few studies have been investigated whether social media use actually leads to more disclosure during environmental incidents in practice and how social media influence local governments and their officials' information disclosure. In this article, we model information disclosure during environmental incidents as an evolutionary game process between the central government and local government in social media context, and examine the internal mechanism that how social media influence the progress of information disclosure during environmental incidents. The findings indicate that social media plays an active constructive role in central-local government game relations. Specifically, social media can provides an efficient information channels for the central government supervise regional officials in environmental incidents, and thus improves its supervision efficiency, and it also provides an important means for internet mobilization and online-offline interaction by encouraging the public exchange information and express their views, and in turn forces local governments and their officials tend to disclosure ahead.

Key Words: Environmental incident; Information disclosure; Social media; Evolutionary game model

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1 introduction

In recent years, China has witnessed numerous environmental incidents, which have brought huge challenge for social stability and economic development. The latest data from Ministry of Ecology and Environment Protection(MEEP) of China reveal that 302 environmental incidents have happened in 2017[1], such as the serious environmental incident caused by the pollution discharge from Hanzhong Ziye Copper Mine Company, which caused thallium element in Guangyuan section of Jialing River to exceed the standard 4.6 times, and water supply interruption of Guangyuan city with 36 hours[2]. In fact, government department at all levels should take the initiative to disclose crisis information to the public during environmental incidents under the Environmental Protection Law(EPL), however the practice of government's information disclosure during environmental incidents is still severely limited. Namely, government officials, especially at the local level, prefer to provide crisis information to the public in a reluctant, superficial, delayed or selective manner(we define it as "limited disclosure"), especially those informations related to the possibility of threats to citizens' health and living conditions, rather than proactively response to citizens' information requirement(we define it as "full disclosure")[3-5]. For example, Harbin municipality informed the public only water and carbon dioxide came from the chemical plant explosion, and that no pollutant entered the river system at the early stage of the Songhua River pollution incident, which cause panic downstream with wide suspicion about the trustworthiness of information[6]. Similar cases are also found in the "8.12 Tianjin explosion" and "4.11 Lanzhou drinking water incident". Empirical research has shown whether all kinds of information in the stage of accident investigation, handing, response and disposal are actively open, to a large extent, can determine the quality and result of environmental emergency.

Previous literatures provide an explanation on the internal mechanism of information disclosure during environmental incidents: local governments' limited disclosure is essentially rooted in the information asymmetry between the central government(principal) and local governments and their officials

(agent) from the respective of principal-agent theory[7-8]. Specifically, regional governments and their officials control the major information sources during environmental incidents[9], and thus they have an incentive to report incidents information in a reluctant, superficial, delayed or selective manner for avoi -ding the large damage from the top-down accountability[6]. Meanwhile, the central government as the principal, often adopts various measures to supervise local officials to prevent their malpractice in environmental incidents, but in fact, it is often difficult to discover their limited disclosure due to the fact that the central government lack enough information to assess the effectiveness of information disclosure during environmental incidents[10]. In this regard, the central government would choose the strategy of "unsupervised" as its optimal choice, and local governments and their officials tend to adopt limited disclosure, which will trap them into "Prisoners' Dilemma"[11]. To deal with the dilemma, some literatures argued that the role of social media in alleviating the information asymmetry between the central and local government[12-13]. On one hand, social media in essence provides a timely and wide-spread information channel to supervise regional governments and their officials for the superior and central government, which can improve its supervision efficiency. For example, Chen shows that media criticism of the local governments and their officials would help the central government ensure local compliance and create favorable public opinion, and more importantly, such media criticism often can correct recalcitrance[12]. On the other hand, social media also plays the role of a carrier and tool for online and offline mobilization in environmental incidents, and people can use social media to actively mobilize online and organize collective actions of protest to maintain the interests of disadvantaged groups, which make local officials have to pay greater cost for limited disclosure, and thus tend to change their strategies from limited disclosure to full disclosure under the social media pressure[14]. In this regard, an effective and efficient social media is an important tool to urge regional governments to fully disclose information to the public during environmental incidents.

In this vein, this study aims to investigate the role of social media in the information disclosure of local government during environmental incident. To achieve this goal, firstly, we would reconsider the information disclosure during environmental incidents based on agency theory. Secondly, an evolution-ary game model between the central government and local governments can be used to simulate the process of information disclosure in environmental incidents. More importantly, we would investigate the role of social media on the information disclosure strategy of the central and local government by using simulation, as well as examine the internal mechanism that how social media influence local governments and their officials' information disclosure.

2 Evolutionary Game Analysis between Central and Local Governments in Social Media Context

In this section, we firstly analyzes the information game between the central government and local governments in social media context. Thereafter, an evolutionary game model of the two stakeholders can be built to investigate the progress of crisis information disclosure during environmental incidents, and this model is solved based on the replication dynamics mechanism. Finally, we use the Jacobian matrix to analyze the stability of each equilibrium point.

2.1 Model Description

Central government and local government are two key stakeholders in the progress of information disclosure during environmental incidents based on the principal-agent theory. The central government, who represents public interests, and is responsible for social stability during environmental incidents. Thus, the central government as the principal often adopts various measures to stimulate local goverme -nts and their officials take the initiative in response to the public's information request in incidents. For instance, the top-down accountability system is an essential incentive tool to enforce local officials to its authority, which means that the central government would punish local officials once they involved in malpractice, such as limited disclosure during environmental incidents. Whereas local government mainly comprises the municipal and county governments, which is the executor of environmental incident information searching, gathering, saving, reporting and publishing, and should fully release crisis information to prevent panic downstream under the Environmental Protection Law (EPL). But in fact, local governments and their officials often have no motive to fully disclose crisis information with the great information asymmetry between the central and local government. Namely, it is difficult to find local officials' limited disclosure during environmental incidents for the central government by the Bottom-up information reporting mechanism. Fortunately, with widespread malpractice is exposed by social media, social media is playing an increasingly important role in the supervision of public authori -ty. On one hand, social media in essence provides an efficient information channel to supervise local

governments and their officials for the superior and central government, which can improve its supervision ability. On the other hand, social media also plays an important role of social supervision by reporting the government officials' activities, especially at the local level, which, in fact, reduce the pro-bability of limited disclosure during environmental incidents. For instance, a series of environmental incidents such as "oil spill event in China's Bohai Bay", "environmental incident of Zijin Mining Group Co." has examined the role of social media in local government's information disclosure. Furthermore, social media opinion even affected the investigation process of the incident at the central government level in the "8.12 Tianjin explosion".

Briefly, although driven by their respective interests, the central government and local government on the information disclosure during environmental incidents will run into a Prisoner's Dilemma under the Bottom-up information reporting mechanism, social media plays an active constructive role in the positive interaction between the central and local government under the current Chinese system, which contributes to change their strategies from a "negative situation" to a "positive" one. The forming complex game relationship is shown in Figure 1.

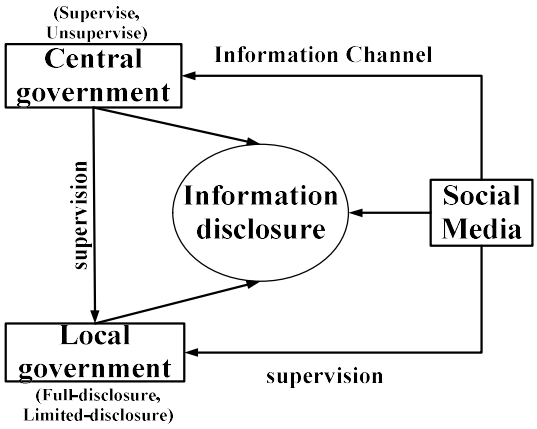

Fig. 1. Illustration of the game relationship between the central and local governments in the social media context

2.2 Symbol Descriptions and Model hypothesis

The two stakeholders involved in information disclosure during environmental incidents are all bounded rational. Based on the above-mentioned discussions, we assume that the strategies set for local governments are {full disclosure, limited disclosure}, while the optional strategies of the central govern-ment are {supervise, UN-supervise}.

The information set for the participants is defined as follows. We assume that the probability of ad-opting the "full-disclosure" strategy for regional government is α, and the probability of selecting the "limited-disclosure" strategy is $1-\alpha$. The probabilities of supervised and unsupervised strategies for the central government are β and $1-\beta$, respectively ($0 \le \alpha, \beta \le 1$).

Corresponding parameters C_1, R_1, p, C_s, C_f and $C_2, R_2, R_3, F, \varepsilon, x_0$, for the central government and local governments are described in Table 1.

Table 1 Parameter definitions

Symbols	Stakeholders	Description
C_1	Central government	The supervision costs, which refers to the sum of costs involved in the supervision process of crisis information disclosure during environmental incidents, such as investigation cost.
R_1		The benefits that the central government obtains, when local governments adopt the "full-disclosure" strategy during environmental disclosure, which mainly includes invisible income from social stability and the central authorities etc.
p		The probability of discovering local officials' limited disclosure($0 \le p \le 1$)
C_s		The political and economic loss caused by the secondary risk event, when the central government and local governments adopts the unsupervised strategy and the limited disclosure respectively.
C_f		The loss of the administration authority when adopts the unsupervised strategy

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		$(C_f > C_1)$
C_2		The information disclosure costs, which mainly includes information searching, gath -ering, saving, reporting and publishing etc costs. Besides, for brevity, we assumed that the costs of limited disclosure is zeros.
R_2		The benefits when adopts the full disclosure strategy
ε	Local government	The extra benefits brought by the commendation and promotion from the central government, when it finds regional officials' full disclosure during environmental incidents($\varepsilon > 0$).
R_3		The potential benefits, such as local interests or benefits from corruption, when local governments adopt the strategy of limited disclosure.
F		The punishment from the central government when it finds local officials' limited disclosure during environmental incidents.
x_0	Central/Local government	The social influence on local officials' limited disclosure after social media expose local officials' malpractice during environmental incidents.

According to the above symbols, the payoff of stakeholders under different situations is shown as following.

Firstly, when local governments take the initiative to disclose crisis information during environme -ntal incidents, then they would obtains benefit R_2. Furthermore, if the central government discovers local governments and their officials' full disclosure during environmental incidents, the extra rewards can be obtained, which would be converted to an invisible income ε. In this case, local governments and their officials need to pay a certain cost for full disclosure C_2. While local governments still obtain a profit $R_2 - C_2$ without the central supervision.

Secondly, if local governments choose the limited disclosure as their optimal strategy, then they would obtain the potential benefits(eg., local interests or benefits from corruption) R_3. But once the central government discovers local officials' limited disclosure with the probability of p, which would trigger a great fine F. Besides, in the context social media, it also provides an efficient information channel to supervise local governments and their officials for the superior and central government, which can improve its supervision ability to some extent. Thus, in this case, local governments and their officials would obtain a net benefit $R_3 - (p + (1-p)x_0)F$. while local governments would obtain a net benefit R_3 without the central supervision.

Thirdly, under the central supervision, when local governments tend to select the strategy of full disclosure during environmental incidents, then the central government would obtain benefits R_1, but pay a supervision cost C_1. Besides, the central government still obtains a profit R_1, but pays the costs C_f caused by the loss of authority.

Fourth, according to the second hypothesis, we can deduced that the central government would obtain a benefit $(p + (1-p)x_0)F$ from a penalty to local governments, and pay a supervision costs C_1 under the central supervision, when they adopt the limited disclosure as their optimal strategy. While in social media context, the central government might has to take the political and economic loss $x_0 C_s$ caused by the secondary risk event, when it adopts the un-supervision strategy to response local official -s' limited disclosure.

Based on the above hypothesis, we can build the pay-off matrix between the central government and local governments, as shown in **Table 2.**

Table 2 The payoff matrix between central government and local government

Local \ Central	Supervised	UN-supervised
Full disclosure	$(R_2 - C_2 + \varepsilon, R_1 - C_1)$	$(R_2 - C_2, R_1 - C_f)$
Limited disclosure	$(R_3 - (p + (1-p)x_0)F, (p + (1-p)x_0)F - C_1)$	$(R_3, -x_0 C_s)$

2.3 The replicated dynamic equations of information game between the central government and local governments

According to the basic principle of replicator dynamics, the strategy better than the average level

will be gradually adopted in a game group with bounded rationality, which brings changing strategy proportions over time[15]. In this section, we would compute the replicated dynamic equations.

As for local governments, we define their expect benefits when taking the initiative to disclose crisis information during environmental incidents as U_1. While denotes U_2 as the expect benefits of local government with limited disclosure. So the corresponding expected return for local government can be calculated as below:

$$U_1 = \beta(R_2 - C_2 + \varepsilon) + (1-\beta)(R_2 - C_2) = R_2 - C_2 + \beta\varepsilon \quad (1)$$

$$U_2 = \beta(R_3 - (p + (1-p)x_0)F) + (1-\beta)R_3 = R_3 - \beta(p + (1-p)x_0)F \quad (2)$$

Then, we can obtain the replicated dynamic equation for local government.

$$\begin{aligned} Z(\alpha,\beta) &= \frac{d\alpha}{dt} = \alpha(U_1 - \overline{U}) = \alpha(1-\alpha)(U_1 - U_2) \\ &= \alpha(1-\alpha)(R_2 - C_2 + \beta\varepsilon - R_3 + \beta(p + (1-p)x_0)F) \end{aligned} \quad (3)$$

Where $\overline{U} = \alpha U_1 + (1-\alpha)U_2$ is local governments' average expected benefits, and t in Eq(3) refers to the time of strategy changes in the evolutionary system.

Similarly, we denote V_1 and V_2 as the central government's expect benefits under different strategies. The expected benefits when adopting supervision are defined as V_1 and the expected benefits when adopting the UN-supervision are defined as V_2. The result is shown as below:

$$V_1 = \alpha(R_1 - C_1) + (1-\alpha)((p + (1-p)x_0)F - C_1) \quad (4)$$

$$V_2 = \alpha(R_1 - C_f) - (1-\alpha)x_0 C_s \quad (5)$$

The average benefits for the central government is computed by $\overline{V} = \alpha V_1 + (1-\alpha)V_2$. Then, the replicated dynamic equation for the central government can be achieved as follows:

$$\begin{aligned} D(\alpha,\beta) &= \frac{d\beta}{dt} = \beta(V_1 - \overline{V}) = \beta(1-\beta)(V_1 - V_2) \\ &= \beta(1-\beta)(-C_1 + \alpha C_f + (1-\alpha)(p + (1-p)x_0)F + (1-\alpha)x_0 C_s) \end{aligned} \quad (6)$$

The dynamics of evolution equations of the information disclosure system can be obtained from the combination of Equations(3) and (6).

$$\begin{cases} Z(\alpha,\beta) = \dfrac{d\alpha}{dt} = \alpha(U_1 - \overline{U}) = \alpha(1-\alpha)(R_2 - C_2 + \beta\varepsilon - R_3 + \beta(p + (1-p)x_0)F) \\ D(\alpha,\beta) = \dfrac{d\beta}{dt} = \beta(V_1 - \overline{V}) = \beta(1-\beta)(-C_1 + \alpha C_f + (1-\alpha)(p + (1-p)x_0)F + (1-\alpha)x_0 C_s) \end{cases} \quad (7)$$

Then, we can obtain five local equilibrium points from the dynamic equation by setting the first derivative equal to zero, that is $Z(\alpha,\beta) = D(\alpha,\beta) = 0$, which these points include $E_1 = (0,0), E_2 = (0,1)$, $E_3 = (1,0), E_4 = (1,1), E_5 = (\alpha^*, \beta^*)$. The equilibrium points may not be evolutionary stable strategies (ESS), thus, the local stability needs to be determined. According to Friedman[16], we can adopt the Jacobian method to investigate the stability of equilibrium points. Firstly, the Jacobain matrix J can be obtained from the set of Equation(7) as follows:

$$J = \begin{pmatrix} \dfrac{\partial Z}{\partial \alpha} & \dfrac{\partial Z}{\partial \beta} \\ \dfrac{\partial D}{\partial \alpha} & \dfrac{\partial D}{\partial \beta} \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \quad (8)$$

where

$a_{11} = (1-2\alpha)(R_2 - C_2 - R_3 + \beta F(1 - x_0\theta)\ln\varepsilon + F x_0\theta)$

$a_{12} = (1-\alpha)\alpha F(1 - \theta x_0)\ln\varepsilon$

$a_{21} = (1-\beta)\beta(-R_1 - (F - (F - C_s)\theta x_0)\ln\varepsilon)$

$a_{22} = (1-2\beta)((1-\alpha)R_1 - C_1\varepsilon + (1-\alpha)(F - (F - C_s)x_0\theta)\ln\varepsilon)$.

Second, we can determine weather the equilibrium points is an ESS by computing the sign of the trace Tr(J) and the determinants Det(J) of matrix, which is calculated from the following form-

ula:

$$\begin{aligned} Det.J &= \frac{\partial F(X)}{\partial X}\frac{\partial F(Y)}{\partial Y} - \frac{\partial F(X)}{\partial Y}\frac{\partial F(Y)}{\partial X} = a_{11}a_{22} - a_{21}a_{12} > 0 \\ tr.J &= \frac{\partial F(X)}{\partial X} + \frac{\partial F(Y)}{\partial Y} = a_{11} + a_{22} < 0 \end{aligned} \tag{9}$$

Besides, the value $a_{11}, a_{12}, a_{21}, a_{22}$ in Jacobain matrix J under different situation are shown in **Table 3**. In this section, we only consider the equilibrium points $E_1=(0,0), E_2=(0,1), E_4=(1,1)$ because of the equilibrium resolutions of group evolutionary game as a strict Nash equilibrium. And three evolutionary scenarios about crisis information disclosure game during environmental incidents would be presented in **Table 4**.

Table 3 The analysis on Jacobian matrix in game model for the central government and local government

Equilibrium points	a_{11}	a_{12}	a_{21}	a_{22}
$E_1=(0,0)$	$R_2-C_2-\mathrm{R}_3$	0	0	$-C_1+(p+(1-p)x_0)F+x_0C_s$
$E_2=(0,1)$	$R_2-C_2-\mathrm{R}_3+(p+(1-p)x_0)F+\varepsilon$	0	0	$-(-C_1+(p+(1-p)x_0)F+x_0C_s)$
$E_3=(1,0)$	$-(R_2-C_2-\mathrm{R}_3)$	0	0	$-C_1+C_f$
$E_4=(1,1)$	$-(R_2-C_2-\mathrm{R}_3+(p+(1-p)x_0)F+\varepsilon)$	0	0	C_1-C_f
$E_5=(\alpha^*,\beta^*)$	0	0	0	0

Table 4 Local stability analysis of the equilibrium points

Stability balanced point	Stability analysis		
	Situation 1	Situation 2	Situation 3
	$R_2-C_2<\mathrm{R}_3$ $C_1-(p+(1-p)x_0)F-x_0C_s>0$	$R_2-C_2+\varepsilon<\mathrm{R}_3-(p+(1-p)x_0)F$	$R_2-C_2+\varepsilon>\mathrm{R}_3-(p+(1-p)x_0)F$
$E_1=(0,0)$	Stable	Unstable	Unstable
$E_2=(0,1)$	Unstable	Stable	Unstable
$E_3=(1,0)$	Unstable	Unstable	Unstable
$E_4=(1,1)$	Unstable	Unstable	Stable
$\mathrm{E}(\alpha^*,\beta^*)$	Saddle point	Saddle point	Saddle point

2.4 Simulation analysis for the role of social media in information disclosure game

To verify our theory and analysis, we adopt the MATLAB to simulate the evolutionary progress of information disclosure during environmental incidents. And the role of social media in influencing stakeholders' choices are also investigated by simulation. In this section, some numerical simulation examples would be shown as follows.

Scenario 1: when the system satisfies $R_2-C_2<\mathrm{R}_3$, $C_1-(p+(1-p)x_0)F-x_0C_s>0$, the equilibrium point $E_1=(0,0)$ is the ESS. The practical significance of **scenario 1** can be summarized as follows: when the costs of full disclosure (C_2) is great, local governments and their officials would tend to select limited disclosure as their optimal strategy; while the central government would prefer choose the strategy of un-supervision, if it finds that the greater loss (x_0C_s) under the situation of un-supervision need to be afforded than under the situation of supervision.

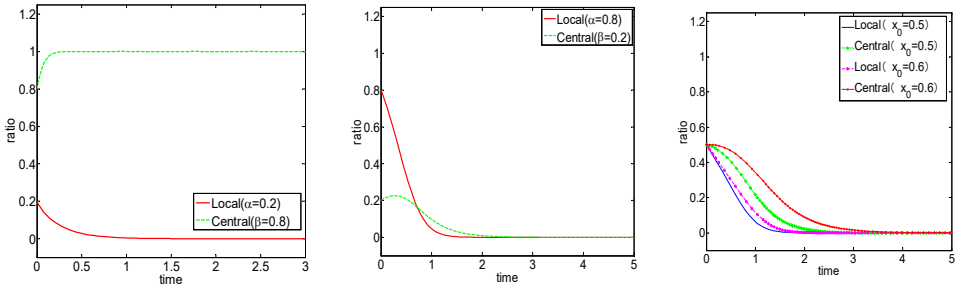

Figure 1 simulation process of information game between the central and local government under scenario 1

Next, we choose the related parameters in the information disclosure evolutionary game model, which satisfies the conditions of situation 1: $C_1=8; C_2=4; R_2=8; R_3=10; p=0.4; F=5; C_s=4; x_0=0.5; C_f=10; \varepsilon=5$, and the initial strategy ratios (α_0, β_0) of the two stakeholders are set as {0.8, 0.2} and {0.2,0.8} respectively. Besides, the influence of social media(x_0) is set to range from 0.5 to 0.6. As is shown in the left and middle image of **Figure 1**, the strategy ratio of limited disclosure of local governments decrease with the ratio decrease of the un-supervision strategy of the central government. Ultimately, all central governments choose the "un-supervision" strategy as their optimal strategy, and all local governments select the strategy of limited strategy, thus reaching the equilibrium point $E_1=(0,0)$. Namely, the stable equilibrium strategy $E_1=(0,0)$ is an optimal result in the practice of information disclosure during environmental incidents. In this case, the performance of crisis information disclosure is very poor. One important reason might be that local governments and their officials, who are motivated by self-interest, tend to adopt reluctant, superficial, selective or delayed disclosure manner to response to the central government and the public for avoiding potential costs(C_2), such as the costs of pollution governance, accountability cost and the costs of social governance caused by public panic. While the central government has to pay great cost(C_1) to investigate that whether local officials' limited disclosure under the Bottom-up information reporting mechanism, which will trap them into "Prisoners' Dilemma". But in fact, the public is always the biggest victim during environment -al incident, thus they has to resort to social supervision system(eg., protest, media exposure etc) to safeguard their rights, thus social benefits will reach the lowest point. Meanwhile, in the right image of **Figure 1**, although the strategy ratios of stakeholders ultimately tend to the equilibrium point $E_1=(0,0)$ with different convergence speed. But considering the role of social media to local officials' limited disclosure, we can find that the convergence speed of the system is different under different social media's influence(x_0). Specifically, social media can inhibit local officials' limited disclosure and the central government's un-supervision during environmental incidents to some extent, compared with no social media is involved in environmental incidents. For example, in the Songhua River Pollution incident, local officials deliberately covered up the real reasons that the water supply in Harbin city was suspended, which leads to rumors among citizens, and a diplomatic conflict. And the central government also kept silent on this issue at the early stage of the pollution incident because of the fact that the main information sources were controlled by local government. Besides, the role of social media in public sector was limited in 2005, because the developments in information and communication technology is still in the initial development stages, which make the central government and local governments actually reached a "conspiracy" in the progress of information disclosure during Songhua River Pollution incident.

Scenario 2: when the system satisfies $R_2-C_2+\varepsilon<R_3-(p+(1-p)x_0)F$, the equilibrium point $E_2=(0,1)$ is the ESS. The practical significance of **scenario 2** is: when the benefits of local governments obtained by means of full disclosure are smaller than that from the strategy of limited disclosure, local governments and their officials still stick to select limited disclosure as their optimal strategy, and the central government would tend to change its strategy from un-supervision to supervision.

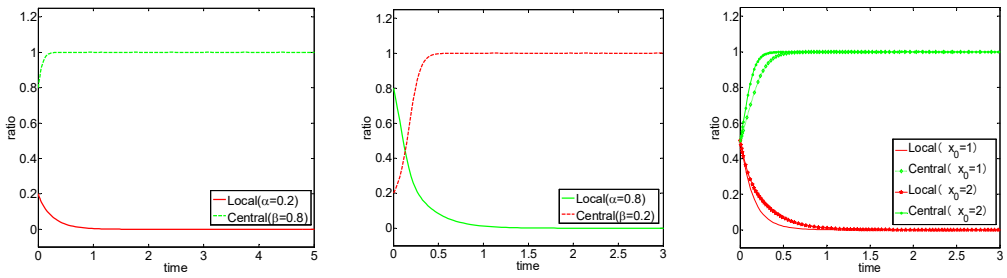

Figure 2 simulation process of information game between the central and local government under scenario 2

Next, we choose the related parameters in the information disclosure evolutionary game model, which satisfies the conditions of **situation 2**: $C_1=3; C_2=4; R_2=8; R_3=20; p=0.6; F=5; C_s=8; x_0=2; C_f=5; \varepsilon=5$, and the initial strategy ratios (α_0, β_0) of the two stakeholders are set as {0.8, 0.2} and {0.2,0.8} respectively. Besides, social media's influence(x_0) is set to range from 1 to 2. As is shown in the left and middle image of **Figure 2**, the strategy ratio of limited disclosure of local governments decrease with the ratio increase of the supervision strategy of the central government. Ultimately, all central governments tend to select to supervise local governments and their officials' malpractice in the progress of environmental incidents, but all local governments and their officials still choose limited disclosure as their optimal strategy, thus reaching the equilibrium point $E_2=(0,1)$. In this case, the infor -mation disclosure during environmental incidents is still less effective, though the central government adopts various methods to supervise and investigate local officials' malpractice. One important reason might be that local governments and their officials can obtain a positive net benefit $\mathrm{R}_3-(p+(1-p)x_0)F-(R_2-C_2+\varepsilon)$ by adopting limited disclosure under the supervision of the central government. On one hand, the potential benefits, including regional interests or benefits from corruption, may be great. For example, the majority of local governments fear that social conflict occurs caused by the rumor, thus they often tend to control information source for maintaining social stability. On the other hand, the central government might only discover few malpractice of local officials under a low probability of discovery(p), and most of malpractice, such as limited disclosure during the environmental incidents, is largely unrecognized. Meanwhile, at the right of **Figure 2**, we find that social media has a dramatic impact on the strategy of local governments and the central government. Namely, the greater influence of social media during environmental incidents, the faster convergence to the strategy ratios of local governments and the central government, which means that social media can inhibit local officials' limited disclosure during environmental incidents, and also promote the central government to adopt supervision strategy. For example, in the case of illegal pollution discharge in Tengger Desert, local officials have been adopting a negative attitude to response to the demand of the public's information disclosure. Specifically, the earlier official statement informed the public that there is no illegal pollution discharge in Tengger Desert. Followed by another official statement, which declares that the authorities haven't checked the issue of desert pollution. And finally, local governments admitted the regulation may be not in place under the intense social media exposure, which aroused the concern of the central, and the central government dispatches the supervision group to investigate and punish local officials' malpractice. It can be seen, the change of official statement actually shows that the change progress of regional governments' strategy such environmental pollution incidents. In this case, we can find that local officials still tend to select the limited disclosure as their optimal strategy for avoiding the loss of the great desert pollution governance and revenue under the exposure of social media.

Scenario 3: when the system satisfies $R_2-C_2+\varepsilon>\mathrm{R}_3-(p+(1-p)x_0)F$, the equilibrium point $E_4=(1,1)$ is the ESS. The practical significance of **scenario 3** can be shown as follows: when the benefits of local governments obtained by adopting full disclosure are greater than that from the strategy of limited disclosure, then both the central government and local governments would select "positive" strategy during environmental incidents. Namely, local governments and their officials tend to adopt full disclo-sure as their optimal strategy, and the central government would select to supervise local officials' mal-practice during environmental incidents.

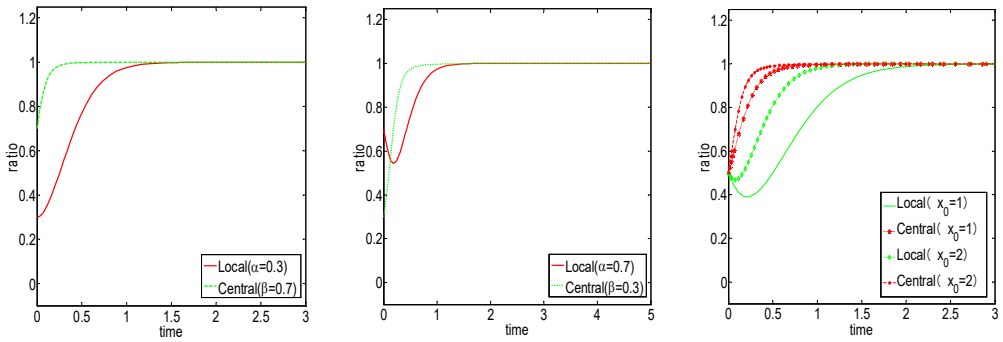

Figure 3 simulation process of information game between the central and local government under scenario 3

Next, we choose the related parameters in the information disclosure evolutionary game model, which satisfies the conditions of **situation 3**: $C_1=3; C_2=4; R_2=12; R_3=20; p=0.6; F=5; C_s=8; x_0=2; C_f=5; \varepsilon=10$, and the initial strategy ratios (α_0, β_0) of the two stakeholders are set as {0.3, 0.7} and {0.7,0.3} respectively. Besides, social media's influence(x_0) is set to range from 1 to 2. The left and mi -ddle of **Figure 3** shows, the strategy ratio of full disclosure of local governments increase with the ratio increase of the supervision strategy of the central government. Ultimately, all central governments tend to choose the strategy of supervision as their optimal strategy, and all local governments and their officials tend to choose full disclosure during environmental incidents, thus reaching the equilibrium point $E_4=(1,1)$. In this case, information disclosure during environmental incidents is most effective. One important reason might be that local governments can obtain a positive net benefit $R_2-C_2+\varepsilon-(R_3-(p+(1-p)x_0)F)$ by adopting the full disclosure. On one hand, with more social media's act to regional officials' malpractice, it is easy for the central government to supervise local officials, which decreases its supervision cost(C_1) to some extent, and also squeeze local officials' margins by increasing the costs of limited disclosure($(p+(1-p)x_0)F$). On the other hand, in the exemplary role of other regional governments who achieve the praise(ε) for taking the initiative to disclose crisis information to the public during environmental incidents, the net benefit of full disclosure increase. Besides, as the right image of **Figure 2** shows, it will be benefit to accelerate the strategy ratios of local governments and the central government to the equilibrium point $E_4=(1,1)$, which means that social media can promote local officials to adopt full disclosure during environmental incidents, and also promote the central government to adopt supervision strategy. Specifically, social media, on the one hand, provides a timely and widespread information channel for the central government to supervise local officials, which can shares the supervision cost of the central government to a certain extent, and improves its supervision efficiency. On the other hand, it also squeezes local officials' margins to some extent by reporting news about incidents timely and accurately, which make them lose their information advantage, thus tend to select the full disclosure as their optimal strategy. For example, in the case of water pollution caused by diesel oil discharge in the Weinan city, the superior governments, including the joint working group of the State Council, the Henan Province government etc, take various measures, including social media's exposure and survey on the spot, to supervise local officials' malfeasance during water pollution case, which promote the incident information to be published. Moreover, local officials also release incidents information in a timely and rapid manner to calm the public's panic. Finally, this incident is controlled with the cooperation between the central and local governments. Therefore, we can deduced that both the central and local government actually tend to choose the "positive" strategy in the context of social media.

3 Discussion

Previous literatures have investigated the role of social media in the public sector from the public management perspective[17-19], but most of the studies used qualitative analysis and lack a framework to simulate the role of social media on government's information disclosure during environmental incidents. Thus, this article models information disclosure during environmental incidents as a game process between the central and local government in social media context, and examines the internal mechanism that how social media influence regional governments and their officials' information disclosure progress. The major research findings can be summarized as follows, social media plays an

active constructive role in central-local government game relations. On one hand, social media can provides an efficient information channel for the superior and central government to supervise local governments and their officials, which shares the supervision costs of the central government to some extent, thus strengthen the central government's supervision on local officials' limited disclosure. On the other hand, it also acts an important role of social supervision by reporting the government officials' activities, especially at the local level, which, to some extent, weaken the information asymmetry, and reduce the probability of limited disclosure during environmental incidents.

3.1 the role of social media as information channel for the central government

According to principal-agent theory, both the central and local government are risk averse under the current China system, which means that environmental incidents' information is difficult to open essentially lies in the dilemma caused by the conflict of interests between the central government and local governments. For the central government, information disclosure is an effective tool to investigate local governance, and corruption levels, which in turn helps the central government avoid the ruling risk by holding local officials accountable for accidents. But in fact, the central control over local officials is not as effective as it is designed to be. One important reason might be summarized as follows: the main information sources about environmental accidents are collected and processed by regional officials, and are then reported through administrative channels level by level all the way to the central government. The central government uses the reported information to evaluate local governments' job performance on environmental governance, which leads to its poor supervision.

To deal with the dilemma, this increase in social-media driven transparency paves the way for the superior and central government to control local officials' malfeasance and departure from their political, legal, and ethical duties in a broader sense[20-22]. On one hand, the state allows and even actively stimulates social media, such as microblogs and blogs etc, to expose local officials' malpractice from incompetence to corruption before relevant officials are investigated or convicted, often with the idea to build countervailing power against the distortion of information between the central and local authorities[23] .In fact, it can help explain why the central authority tolerates negative news about local levels of government, though local authorities strive to suppress such news[24]. On the other hand, the central government may also use social media to monitor local officials and ensure local governments and their officials act responsibly[25-26]. For instance, some authors argued that media criticism of the local governments would help the central government ensure local compliance and create favorable public opinion by disclosing local recalcitrance before relevant officials are investigated or convicted [27-28]. In summary, despite the formal institutional relations between central and local governments, informal measures such as using social media have the potential to expand the information channels for the central government to supervise local governments and their officials' activities as soon as possible, and thus alleviating the information asymmetry between the central and local government.

Of course, the role of social media is not unlimited. Indeed, the main information institutions, such as television, newspapers, the radio and news agencies have been kept in state hands for a long time, and the techniques of information control have been largely effective, and thus the central government still effectively monitors local governments and local officials' malpractice[29-31].

3.2 the role of social media as social supervision tool for local government

In recent years, frequent environmental incidents and limited disclosure on the incidents have become an increasing concern in China, and have also attracted international attention. And fortunately, most of the cases have successfully attracted the attention of the public with the help of social media, and finally made local governments that intended to block or hide information had to make information accessible to the public[14]. It can be seen, social media, as a new tool of communication, has great promise to inspired people to exchange information and express their views in the internet space, which can increase the efficiency of social supervision by reporting the government officials' activities, especially at the local level[32], and thus promoting regional governments' transparency during environmental incidents. Empirical results also show that the level of government transparency is higher under the strong media pressure, which means that social media can be seen as a powerful tool to push regional governments to act responsibly[19]. This tool is even more necessary when regulation on access to information is low; media enables citizens to access the decisions taken by the government and to observe the strategies, activities and results of public policies[33]. One important reason might be that social media have the advantage of good "input-output" effect in supervising government officials. In other word, it would take a low cost to seek relevant information of government activities, and find government officials' malpractice with it's strong intellectual support and professional advantage[34],

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which make it more difficult for politicians and public servants to cover up their malpractice, such as limited disclosure and corrupt behavior[26]. So we can conclude that social media provides an important means for internet mobilization and further online-offline interaction in environmental incidents, which would help form strong public voice by encouraging the public exchange information and express their views, and thus effectively promote local officials to take the initiative to disclose information.

Significantly, social media also act as a rumors carrier in the discussion process of environmental incidents. For instance, in the "8.12 Tianjin explosion incident", there were rumors spreading like "the actual number of deaths over 1000", "nobody alive within one kilometer of the explosion scene",and "most markets in Tianjin being rubbed" as Tianjin municipality had not publicize incident information in time, which in fact leads to a great disposal cost caused by rumors propagation. Therefore, it has also shows that local governments need to actively publicize incident information for avoiding secondary social risk.

4 Conclusion and Suggestion

The purpose of this study is to investigate the role of social media in the information disclosure of local government during environmental incident. The research findings show that social media plays an active constructive role in the positive interaction among the central, local and public under the current Chinese system. Specifically, social media, who act as the role of social supervision, can dramatically change the strategy choices of the central government and local governments in the progress of the information game. On one hand, social media can provides an efficient information channels for the superior and central government supervise local officials in environmental incidents, which can shares the central government's supervision cost to some extent, and thus improves its supervision efficiency. On the other hand, it also provides an important means for internet mobilization and further online-offline interaction during environmental incidents by encouraging the public exchange information and express their views, which increases information controlling cost, and in turn forces local governments and their officials tend to disclosure ahead. In summary, both stakeholders would tend to change their strategy from maximizing their profits to improve the overall welfare of the society under the social media pressure.

The research findings shed new light on how to actualize social media potential as a tool for promoting regional governments and their officials to take the initiative to disclose information during environmental incidents, and thus contribute to extending the scope of research on the relationship between social media use and government actions. As noted previously, government's information disclosure in the stage of accident investigation, handing, response and disposal, to a large extent, determines the quality and result of the emergency disposal, however few literatures investigate the role of social media in the information disclosure of local government during environmental incident. Considering this fact, this study adopts evolutionary game theory to explore the interaction mechanism that how social media influence local government's information disclosure. Also, this study elaborates that how to improve the degree of government's information disclosure in the era of social media. Specifically, on the one hand, the performance methods of "judge a hero by GDP" should be changed, while we can further refine the performance assessment mechanism, for instance, taking the collection and publication of local government information as one of the measurement indicators, which would contribute to promoting local governments to collect and disclose information positively. On the other hand, social media should play a positive role in supervising the government officials. In fact, the progress of crisis response in environmental incidents has changed into the information game among the public, government, enterprise and so on in the social media context. In summary, an efficient information channel should be constructed to supervise local governments and their officials for the superior and central government, and thereby the central government can take effective accountability to promote local government’s information disclosure during environmental incidents.

This study is not without limitations and there is a need for follow-up studies. Importantly, these research findings raise the question that the role of social media in supervising government action in the situation of public crisis. In fact, the public opinion environment constructed by social media is a double-edged sword, and has many defects, such as information distortion, false reports. Therefore, the future research agenda is as follows. Consider the possibility of information distortion, future research can investigate on how can the central government distinguish the authenticity of media exposure and how to prevent a conspiracy between local governments and social media? In addition, the disclosure of government crisis information is a typical complex dynamic system, involving various elements,

such as information disclosure regulation system, public pressure and so on, therefore, these questions are required to discuss in the future study.

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