A Dynamic Game Model of Crisis Communication on Social Media

Completed Research Paper

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Abstract

When faced with the proliferation of negative information on social media, companies must decide whether to react in a positive way by responding in a timely manner, disclosing the facts, offering apology or compensation, etc., or by reacting negatively with a denial, threat of legal actions, etc. The optimal choice of strategy for the company depends on the costs of the strategy incurred by the company and the propensity of netizens to publicly condemn and shame the company on social media. In this paper, we employ evolutionary game theory in order to propose a model of social media crisis communication. We conduct numeric simulations under different parameters in order to find evolutionary equilibria, which may serve as guidelines for companies deciding on the right social media strategy.

Keywords: Social media strategy, evolutionary game theory, simulation

Introduction

In recent years, crisis communication has increasingly become an interest of management research, especially in relation to political elections (Arjen et al. 2009), anti-terrorism (Falkheimer 2014), and disasters (Choi and Lee 2017). With the rise of social media on the internet, crisis communication on social media has garnered much attention from industry. Due to the characteristics of social media and the speed of dissemination of information, a crisis in the real-world causes a secondary crisis in the realm of social media (Schultz et al. 2011). The proliferation of negative information among netizens and the different strategies of the organization brought different levels of reputation loss (Coombs 2007; Zheng et al. 2018), which affects corporate governance structure (Dyck et al. 2008) and the economic performance of the enterprise as a whole (Fang and Peress 2009). In practice, however, many enterprises do not have a clear strategy – a master plan – for how to respond to negative information on social media. Therefore, when dealing with negative information on social media, enterprises often adopt an opportunistic approach, trying to limit the negative media coverage (Nijkrake et al. 2015), e.g., by simply deleting posts. A negative response by the company may entail even more negative comments on social media along with a further loss in reputation. For companies, the question remains what strategy should be employed to cope with social media fallout in the aftermath of a negative event.

In this paper, we propose an evolutionary game theory model for the analysis of social media strategies employed by both netizens and the enterprise facing a crisis. The publication of negative information may either be ignored by netizens, silently acknowledged, or entail negative posts. The response of the company influences the subsequent loss. A negative reaction, where the company tries to hold back the proliferation of negative information by deleting posts, possibly even pursuing legal actions, may come with a huge loss of reputation for the company, which subsequently translates into a financial loss for the company. Consider the case of the United Express Flight 3411 incident (Bang

2019; Selk 2017), where the airline was faced with a considerable number of negative posts by netizens following the release of a video showing rude treatment of a passenger. In its initial statement, the airline failed to apologize for its mistakes, even claiming that the passenger was "disruptive and belligerent." A positive reaction, however, where the company embraces the negative situation by disclosing the full facts, possibly even offering compensation, comes with its own costs: promotional activities, investments into customer service, recalling a product, etc. The presented model aims to represent the evolution of the players' strategies under different situations. Starting from a real-world use case, numeric simulations serve to find the equilibrium of strategies given different parameter values. Those equilibria may serve practitioners to determine a company's optimal strategy when faced with a crisis on social media, which depends on the costs of the respective positive or negative response as well as the netizens' propensity to vent their frustration online.

The remainder of this paper is organized as follows. We first review related work. We then present an evolutionary game theory model for crisis communication on social media. Finally, we present simulation results for various situations before concluding the paper with a summary of our findings and an outlook on future work.

Related Work

Crisis is defined as an unpredictable event that threatens important expectations of stakeholders and can seriously impact an organization's performance as well as generate negative outcomes. Due to the uncertainty of the crisis and the huge losses, crisis communication has become a major issue for organizations (Coombs and Holladay 2011). An organization hopes to use information required to address a crisis situation (Coombs 2014) in order to minimize losses. Related theoretical research investigates the repair of damage caused by a crisis, e.g., Image Repair Theory (Benoit 1997) and Situational Crisis Communication Theory (SCCT) (Coombs 2007). These theoretical models analyze the organization's crisis public relations strategy through qualitative analysis.

Traditionally, crisis communication is mainly aimed at stakeholders. With the development of social networks, crisis communication now requires the company to face the secondary spread of information on social media (Schultz et al. 2011).

Social media has the characteristics of fast information dissemination, convenient sharing and dialog (Fuchs 2017). The individual person on social media may be a recipient of information as well as a publisher of information. These characteristics make social media an important platform for media crisis public relations (Veil et al. 2011). Social media influence is composed of four factors: output, reactive outtake, proactive outtake, and network positioning (Zhao et al. 2018). Topics such as the dissemination of negative information on the internet (Liu et al. 2013), the use of big data to monitor information on social media (Avery 2017; Teodorescu 2015), the use of social media to interact with the public (Spence et al. 2016)c, and public sentiment analysis on social media (Zhang et al. 2018) have received attention from academia and industry alike.

Previous qualitative research (Jin et al. 2018; Roshan et al. 2016), through case studies or interviews, have investigated organizational social media use for crisis communication. Other work (Smith et al. 2018) has employed semantic network and content analysis to investigate public opinion. Among the critical factors for effective crisis management that have been identified in related work are resilience and agenda-setting, the role of hybrid reputations and the nature of crises (Lee et al. 2018) as well as enhancing a discourse of renewal through dialogic content (Du Plessis 2018).

The traditional game model is based on perfect rationality of the participants (Weibull 1997). The extension of the traditional game model to account for the participants' heterogeneous beliefs is more aligned with reality of the nature of human beings, in which participants are not perfect rational beings. The subjects have *bounded rationality*, i.e., the individuals' cognitive abilities influence the choice of the strategy to maximize their interests (Hofbauer and Sigmund 2003). Therefore, in this paper, we use the evolutionary game model to study crisis events and to analyze the evolution of social media incidents.

Research Model

In this section, we present the research model based on dynamic game theory. We first introduce basic definitions and assumptions before explaining the model parameters. We then analyze the evolution process of strategies of the involved players.

Basic Definitions and Assumptions

In the following, we postulate the four underlying assumptions of the presented research model.

Assumption 1. There are two players in this model – *netizens* and *enterprise* – who are bounded rational, i.e., the players' rationality is limited by different factors. In general, we assume netizens take action on social media first, which the company observes before deciding to adopt a positive (*P*) or negative (*N*) response strategy.

Assumption 2. As a player, the netizens group, which is referred to as i, have an action set $\{I,S,T\}$. The *I* strategy refers to the netizens not paying attention to or ignoring negative information about an enterprise. The *S* strategy refers to netizens caring about the negative information but not expressing opinions on social media; netizens are still in "quiet mode". The *T* strategy refers to netizens paying attention to negative information and, in addition, investing more time and energy to further transmit and/or comment on negative information.

Assumption 3. The enterprise as the other player, which is referred to as j, is the main target of negative information and has an action set $\{P,N\}$. According to the classification of crisis response strategies of organizations based on SCCT theory (Coombs 2007), we distinguish between positive and negative strategies. The *P* strategy refers to the enterprise adopting a positive strategy when dealing with negative information, meaning timely response, disclosure of facts, apologies or sympathy, corrective actions, improvements, etc. The *N* strategy, on the other hand, refers to the enterprise adopting "tough and rude attitudes", attacking the accuser, denying the truth or refusing to publish it, presenting a scapegoat (Coombs 2007). For example, in the case of the United Express Flight 3411 incident (Bang 2019; Selk 2017), the airline, facing condemnation by netizens following the release of a video showing rude treatment of a passenger, in its initial statement failed to apologize for its mistakes, even claiming that the passenger was "disruptive and belligerent."

Assumption 4. Emotional cognition affects crisis public relations (Lu and Huang 2018). Different coping strategies by the enterprise lead to different public sentiments, which affect the company's losses to varying degrees. When netizens choose the *T* strategy, different strategic choices by the enterprise will result in different reputation and economic losses. The loss of the enterprise in case the netizens adopt the *T* strategy is mainly reflected in the condemnation by the public, which can lead to other stakeholders' condemnation, stock price changes, legal actions and legislative responses, etc.

Model Parameters

In case of an online dispute on social media between netizens and a company that ensues following the publication of negative information about the company, both players incur different costs depending on the adopted strategies. For the netizens, these costs consist mainly of emotional costs as well as an investment of time. For the enterprise, costs may be financial, e.g., the costs of additional promotional activities or offered compensation. The costs, however, may also consist of a reputation loss, which depends on the company's adopted strategy as well as on the behavior of netizens. Table 1 lists the model parameters and provides an explanation for each parameter.

Table 1. Description of model parameters

v	The total value that the enterprise faces, e.g., the company's revenue.
c_1	The cost of the *P* strategy for the enterprise – including apology and explanation – in case the netizens choose the *I* or *S* strategy.
c_2	The cost of the *P* strategy for the enterprise – including apology and explanation – in case the netizens choose the *T* strategy.
d_1	The cost of the *S* strategy for the netizens – including time and emotional costs.
d_2	The cost of the *T* strategy for the netizens – including time and emotional costs. We assume that $d_2 > d_1$.
r_1	The loss of the enterprise – including the reputation loss – in case the netizens choose the *S* strategy and the enterprise chooses the *N* strategy.
r_2	The loss of the enterprise – including the reputation loss – in case the netizens choose the *T* strategy and the enterprise chooses the *P* strategy. We assume that $r_2 > r_1$.
r_3	The loss of the enterprise – including the reputation loss – in case the netizens choose the *T* strategy and the enterprise chooses the *N* strategy. We assume that $r_3 > r_2$.
θ_I	The proportion of netizens who choose the *I* strategy in the face of negative being confronted with information on social media. $\theta_I \in [0,1]$
θ_S	The proportion of netizens who choose the *S* strategy in the face of negative being confronted with information on social media. $\theta_S \in [0,1]$
θ_T	The proportion of netizens who choose the *T* strategy in the face of negative being confronted with information on social media. $\theta_T \in [0,1], \theta_I + \theta_S + \theta_T = 1$

Figure 1 illustrates the costs for netizens and enterprise given the netizens' adopted strategy and the company's response. For netizens ignoring the negative information, there are zero costs regardless of the following response by the company. For the enterprise, when netizens ignore the negative information, a negative response does not incur any costs for the company but a positive response diminishes the total value v faced by the company, e.g., its revenue, by the amount c_1. For netizens paying attention to the negative information without taking to social media to blame and shame the company, the costs d_1 of the S strategy in case of a positive response by the company are diminished by the incurred costs c_1 for the company, assuming the value spent by the company translates into direct or indirect benefit for the netizens, e.g., promotional activities or an increase in netizens' emotional well-being knowing that justice has been served. The company's faced value is diminished by the costs of the positive response. In case of a negative response, the netizens do not have their costs diminished and the value faced by the company diminishes by r_1, mainly in the form of reputation loss. For netizens noticing the negative information and choosing to further transmit it, the emotional and time costs d_2 are diminished by the value c_2 in case of a positive response by the company. The company then has its benefit diminished by the costs c_2 of the *P* strategy as well as the reputation loss r_2. In case the company adopts a negative strategy, there is a reputation loss r_3 that diminishes the company's benefit.

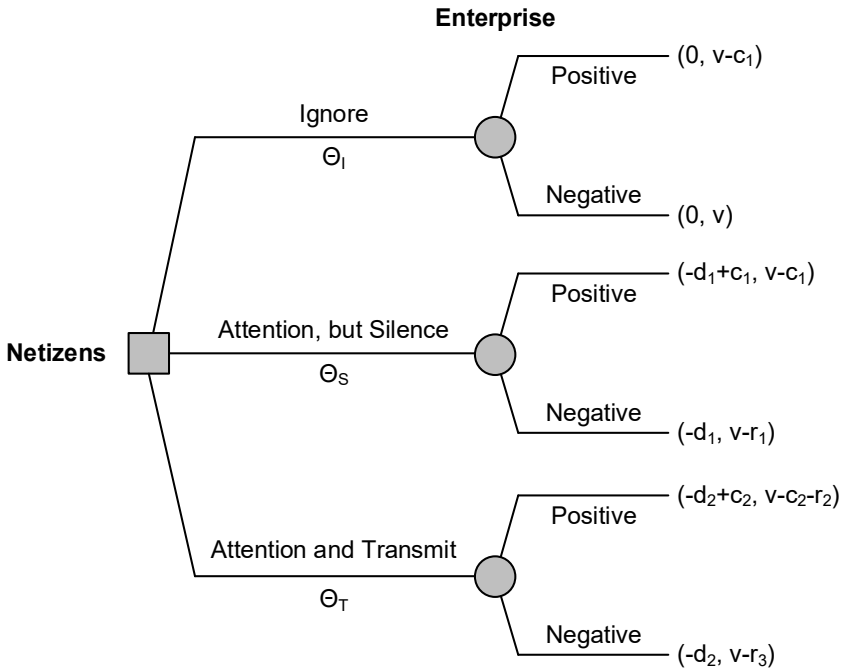


Figure 1. Dynamic game model of crisis communication on social media

Generalized Replicator Dynamics Equations

We analyze the evolution process of imitative behavior of netizens on social media based on replicator dynamic equations from evolutionary game theory (Sethi 1998).

$$\partial\theta(f)/\partial t=\theta_f[u_t(s_i)-\bar{u}] \tag{1}$$

The function $u_t(s_i)$ represents the payoff of one strategy of the netizens, and $\bar{u}$ is the average payoff of all the strategies.

We take the presented dynamic game model for crisis communication on social media and put the elemental game revenue function into the generalized replicator dynamics function. We then calculate the proportional distribution of various strategies of the citizen according to Equation 1. To this end, we distinguish different situations.

Situation 1： Only the I and S strategies exist

When $\theta_T=0$, the netizens are not publicly criticizing the enterprise and the proportional distribution of the *I, S,* and *T* strategies is $(\theta_I,\theta_S,0)$.

When the enterprise adopts the *P* strategy, the expected revenue is U_P, and the following condition holds.

$$U_P=\theta_I(v-c_1)+\theta_S(v-c_1)+\theta_T(v-c_2) \tag{2}$$

When the Enterprise adopts the *N* Strategy, the expected revenue is U_N, and the following condition holds.

$$U_N=\theta_I v+\theta_S(v-r_1)+\theta_T(v-r_3) \tag{3}$$

We now compare the values of U_P and U_N.

$$\begin{cases} U_P > U_N & \text{if } c_1 < r_1 \text{ and } \theta_S > c_1/r_1 \\ U_N > U_P & \text{if } c_1 > r_1, or, c_1 < r_1 \text{ and } \theta_S < c_1/r_1 \end{cases} \quad (4)$$

We determine the netizens' strategy equilibrium based on the comparison of the revenue of the company's two strategy choices.

When $c_1 < r_1$, and $\theta_S > c_1/r_1$, the enterprise adopts the *P* strategy and we determine the strategic equilibrium for netizens as follows.

$$\bar{u} = \theta_I * 0 + \theta_S(-d_1 + c_1) + \theta_T(-d_2 + c_2) \quad (5)$$

$$\partial\theta_I / \partial t = \theta_I(u_I - \bar{u}) = -\theta_I\theta_S(-d_1 + c_1) < 0, \quad \theta_I \to 0 \quad (6)$$

The proportion of netizens adopting the *I* strategy approaches 0. Similarly, $\theta_S \to 1$, i.e., the proportion of netizens adopting the *S* strategy approaches 1.

Inference 1: When the netizens choose the *S* strategy, if the cost of the *P* strategy for the enterprise is less than the loss of the *N* strategy, the enterprise will finally adopt the *P* strategy. At this time, the netizens' *S* strategy distribution approaches 1. The proportion of the final strategy of the netizens will be affected by the proportion of each strategy in the initial state. The resulting strategy equilibrium is the *S* strategy for the netizens and the *P* strategy for the enterprise, i.e., the equilibrium is (*S, P*).

When $c_1 < r_1$, and $\theta_S < c_1/r_1$, the enterprise adopts the *N* strategy and we determine the strategic equilibrium for netizens as follows.

$$\bar{u} = \theta_I * 0 + \theta_S(-d_1) + \theta_T(-d_2) \quad (7)$$

$$\partial\theta_I / \partial t = \theta_I(u_I - \bar{u}) = \theta_I\theta_S d_1 > 0, \quad \theta_I \to 1 \quad (8)$$

The proportion of netizens adopting the *I* strategy approaches 1. Similarly, $\theta_S \to 0$, i.e., the proportion of netizens adopting the *S* strategy is close to 0.

Inference 2: Under the condition that $c_1 < r_1$ and $\theta_S < c_1/r_1$, the enterprise adopts the *N* strategy and the netizens tend to choose the *I* strategy. When the proportion of the S strategy is small in the initial state, the netizens will tend to choose the *I* strategy. The resulting equilibrium strategy is (*I, N*).

When $c_1 \geq r_1$, the enterprise adopts the *N* strategy. At this time, the *N* strategy is the dominant strategy of the enterprise. This case is analogous to Inference 2.

Situation 2: The I, S, and T strategies coexist

When $\theta_T \neq 0$, part of the netizens publicly condemn the company in negative comments and by reposting negative content on social media. In this case, the distribution of strategies adopted by the netizens is $(\theta_I, \theta_S, \theta_T)$.

If the loss r_3 for the enterprise is small, i.e., $r_3 < (c_1 - r_1\theta_S)/\theta_T + r_2 + c_2 - c_1$, then the loss caused by the *N* strategy is manageable for the enterprise, meaning that the condemnation of netizens has little impact on the reputation of the enterprise. In this situation, the enterprise adopts the *N* Strategy, and we determine the equilibrium strategy of netizens based on the comparison of the benefit of the three strategies for the netizens.

$$\partial\theta_I / \partial t = \theta_I[-\theta_S(-d_1) - \theta_T(-d_2)] > 0, \theta_I \to 1 \quad (9)$$

The proportion of netizens adopting the *I* strategy will be close to 1.

$$\partial\theta_S / \partial t = \theta_S[(1 - \theta_S)(-d_1) - \theta_T(-d_2)] \quad (10)$$

Assuming the following condition holds

$$\theta_S < 1 - d_2 / (d_2 - d_1)\theta_I, \partial\theta_S / \partial t > 0, \tag{11}$$

then $\theta_I \to \theta_I^*, \theta_S \to \theta_S^*$, depending on the original distribution of strategies.

$$\text{When } \theta_S > 1 - d_2 / (d_2 - d_1)\theta_I, \ \partial\theta_S / \partial t < 0, \theta_S \to 0 \tag{12}$$

$$\partial\theta_T / \partial t = \theta_T[-\theta_S(-d_1) + (1 - \theta_T)(-d_2)] < 0, \theta_T \to 0 \tag{13}$$

Inference 3: When the netizens adopt the *T* strategy and the loss of the enterprise adopting the *N* strategy is small, in the course of evolution, the enterprise will finally choose the *N* strategy and the netizens will gradually adopt a non-condemnation (*I* or *S*) strategy. If the enterprise always chooses a strong/negative strategy, the netizens strategy will gradually shift to an attitude of non-condemnation strategy, and the final equilibrium state depends on the initial distribution of the *I* and *S* strategies. In this situation, the resulting strategy equilibrium is (*I* or *S*, *N*).

If the value of r_3 is large, the dominant strategy for the enterprise is the *P* strategy, i.e., the company makes a positive response by apologizing and promising improvements. We analyze the strategy equilibrium results of both participants in that case.

According to the general replication equation, the proportional distribution of the netizens taking the *I* strategy is

$$\partial\theta_I / \partial t = \theta_I(u_I - \bar{u}) = -\theta_I[\theta_S(-d_1 + c_1) + \theta_T(-d_2 + c_2)] < 0, \theta_I \to 0 \tag{14}$$

The proportional distribution of the netizens taking the *S* strategy is

$$\partial\theta_S / \partial t = \theta_S(u_S - \bar{u}) = \theta_S[(1 - \theta_S)(-d_1 + c_1) - \theta_T(-d_2 + c_2)] \tag{15}$$

The proportional distribution of the netizens taking the *T* strategy is

$$\partial\theta_T / \partial t = \theta_T(u_T - \bar{u} = \theta_T[(1 - \theta_T)(-d_2 + c_2) - \theta_S(-d_1 + c_1)] \tag{16}$$

$$\text{When } -d_1 + c_1 > -d_2 + c_2 > 0, \text{ then } \partial\theta_S / \partial t > 0, \theta_S \to 1, \theta_T \to 0, \tag{17}$$

meaning that when the company adopts the *P* strategy and the revenue of the netizens adopting the *S* strategy is greater than that of the netizens adopting the *T* strategy, the netizens will tend to take the *S* strategy. In that case, the strategic equilibrium result is (*S, P*).

$$\text{When } -d_2 + c_2 > -d_1 + c_1 > 0, \text{ then } \partial\theta_T / \partial t > 0, \theta_T \to 1, \theta_S \to 0, \tag{18}$$

meaning that when the company adopts the *P* strategy and the revenue of the netizens adopting the *T* strategy is greater than that of the netizens adopting the *S* strategy, the netizens will tend to adopt the *T* strategy. In that case, the strategic equilibrium result is (*T, P*).

$$\text{When } -d_1 + c_1 = -d_2 + c_2 > 0, \text{ then } \partial\theta_S / \partial t > 0, \partial\theta_T / \partial t > 0, \theta_T \to \theta_T^*, \theta_S \to \theta_S^* \tag{19}$$

meaning that when the company adopts the *P* strategy and the benefit of the netizens adopting the *T* strategy is equal to that of the netizens adopting the S strategy then the strategic equilibrium result is (*S* or *T, P)*, depending on the original distribution of *S* and *T* strategies.

Inference 4: When the company faces a crisis of negative information appearing on the internet and the netizens have already shown large-scale activity on social media, it will bring great loss for the enterprise to adopt the *N* strategy. Consequently, in that case, the dominant strategy that the enterprise should adopt is the *P* strategy. At the same time, when the cost of the *P* strategy for the enterprise meets certain conditions, resistance by the netizens can lead to greater benefits, i.e., adopting the *S* strategy. The netizens will then be more inclined to actively express their opinions and protest to seek a positive response from the enterprise.

Case Study and Simulation

In this section, we employ numeric simulation to investigate the strategy equilibrium for different situations given certain parameter values. We estimate the parameter values based on a real-world social media incident faced by the company Jingdong in China.

Case Overview

Jingdong (JD) is an electronic commerce platform in China, which runs its own online trading business while also offering a third-party marketplace where external sellers offer their products. On 13 March, 2018, Chinese writer Liu Liu (六六) published a blog post, which she later advertised in a tweet on the Chinese microblogging service Weibo, complaining about JD following a friend's purchase of a product via a third-party shop on the JD platform. Liu Liu's friend received allegedly fake goods from the external seller, which JD initially denied, refusing to compensate; Liu Liu's friend and JD did not reach a settlement. After tweeting a link to her blog, Liu Liu received the attention of netizens on social media, followed by a negative first response by JD causing, which accused Liu Liu and her friend of foul play, even threatening Liu Liu with legal actions. JD's negative reaction caused uproar among netizens as evidenced by a vast increase in forwards of Liu Liu's original blog post (see Figure 2). Finally, JD had to publicly apologize to Liu Liu and her friend.

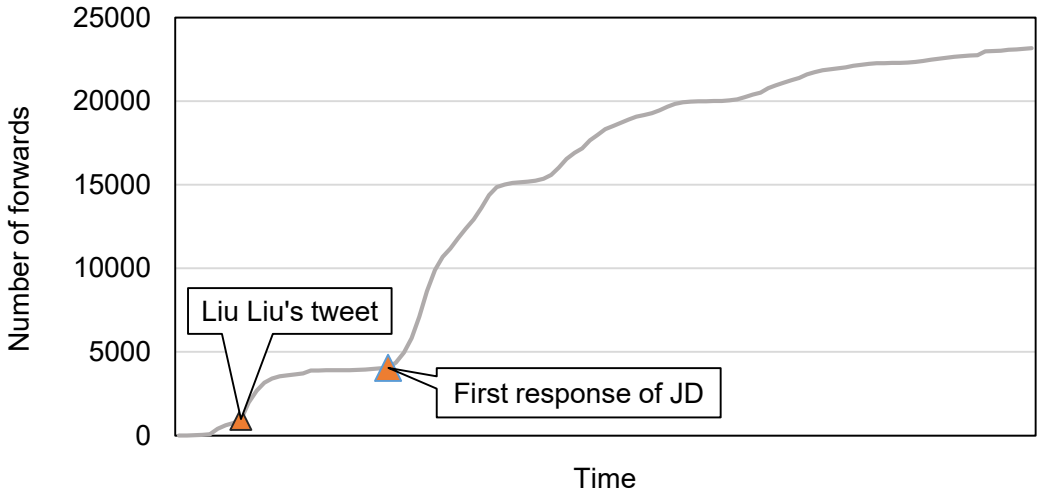


Figure 2. Cumulative number of forwards on Weibo of Liu Liu's original blog post over time

Parameter Values

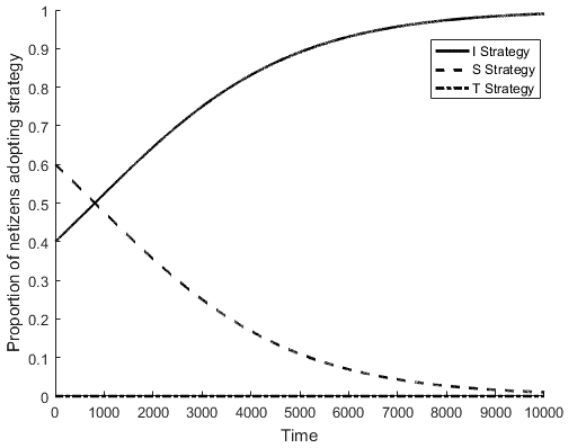
We employ Matlab to conduct different simulations with varying values for the model parameters. In each simulation, we observe the evolution of strategies adopted by netizens and the enterprise. Specifically, we study the evolution over time of the values for θ_I, θ_S, and θ_T, which represent the proportion of netizens adopting the *I, S,* and *T* strategies, respectively. We also study the evolutionary equilibrium, which serves as an indicator of the optimal response strategy that the enterprise should adopt given its current situation. We use the case of Liu Liu vs. JD for illustration purposes as well as for the estimation of initial parameter values.

Table 2. Initial parameter values for the simulation (in hundreds of millions)

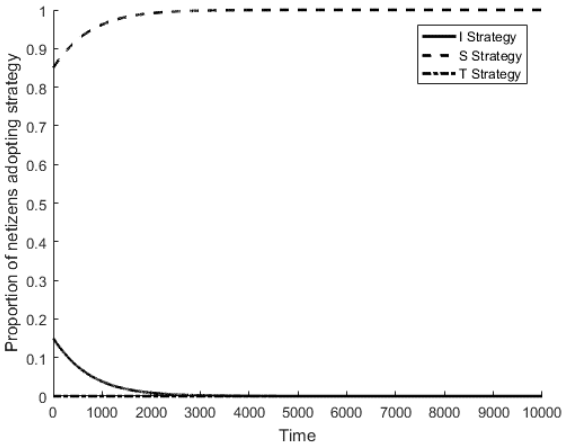
Parameter	Value	Rationale
v	20	The revenue generated by third-party merchants to JD is mainly derived from platform usage fees and sales. JD receives an average platform fee of 1 000 Yuan per merchant (Jingdong 2019). As of 30 September 2018, there were approximately 200 000 contracted merchants on JD's third-party platform, and the revenue from the platform fee was 2 billion Yuan.
r_3	100	Following Liu Liu's complaint about JD, the company gave a negative response. We use the changes in the market value of JD's stock, listed on NASDAQ, for the next two days (13 and 14 March 2018) as JD's loss r_3. Comparing the JD stock price volatility (-4.1522%) with average market volatility (-1.7137%) in the same period, we estimate JD's loss at 1.6 billion USD, which is equal to around 10 billion Yuan.
r_2	15	When netizens condemned the company, the cost of the company's positive response r_2 is estimated to be 1.5 billion Yuan, mainly referring to the decline in the reputation of the company brought by netizens. This value is obtained by taking the average stock price change of JD on March 13, before JD's negative response.
r_1	2.4	We use the value of fans to measure r_1. Liu Liu has about 12 million fans. We estimate the value of each fan at 20 Yuan. The value of r_1 is then expected to be 240 million Yuan. The value of an individual fan is derived from public figures in relation to Yuye Co.'s intended acquisition of Shenzhen Quantum Cloud Technology Co., which was announced on 27 April 2018, along with its 981 WeChat public accounts. The purchase price would have been 3.8 billion Yuan. According to the data of the proposed acquisition, the value of each fan is estimated to be 20 Yuan.
c_1	5	The cost c_1 refers to the cost for the enterprise adopting the *P* strategy. We base c_1 on the volume of the contract between JD and Blue Focus – a public relations company – in the 2017 financial report of Blue Focus.
c_2	7	We take an arbitrary initial value and vary this parameter over the course of the simulation analysis.
d_1	0.5	We take an arbitrary initial value and vary this parameter over the course of the simulation analysis.
d_2	2	We believe that the revenue of Sina Weibo's advertising and marketing business can represent the cost of netizens' attention and condemnation. According to the revenue of advertising and marketing business in the first three quarters of Sina Weibo, the number of monthly active users (446 million), and the average attention time of users on the event (one week), we calculated the cost of the netizens' T strategy is about 200 million.

Simulation Results

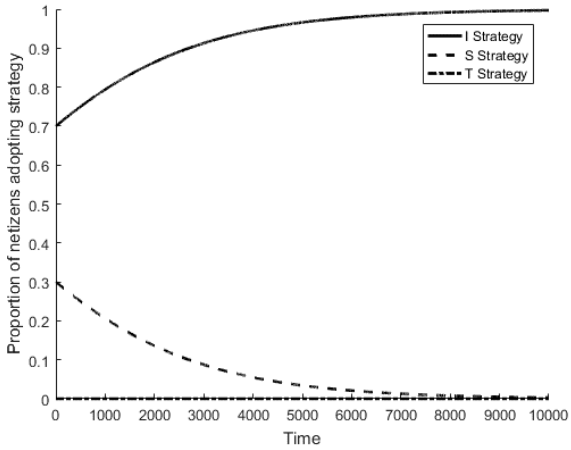
In the following, we show the results of numeric simulations using the presented model with varying parameter values. We aim to find out the evolutionary equilibrium of strategies under different circumstances. For a company facing a social media incident, the equilibrium indicates the ideal strategy given a certain situation.



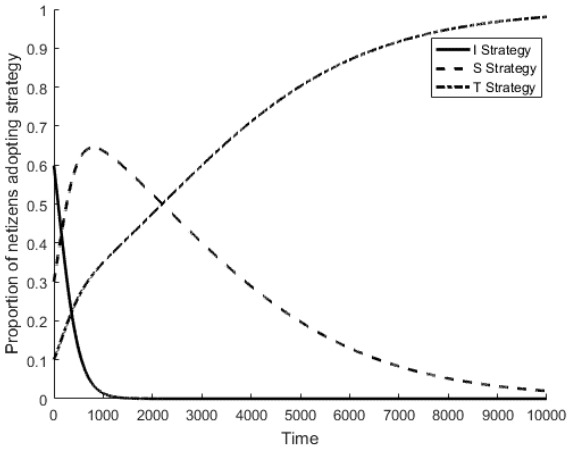
(a) Simulation 1



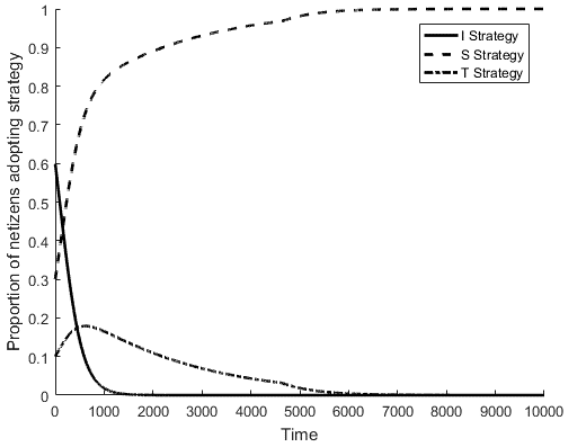
(b) Simulation 2



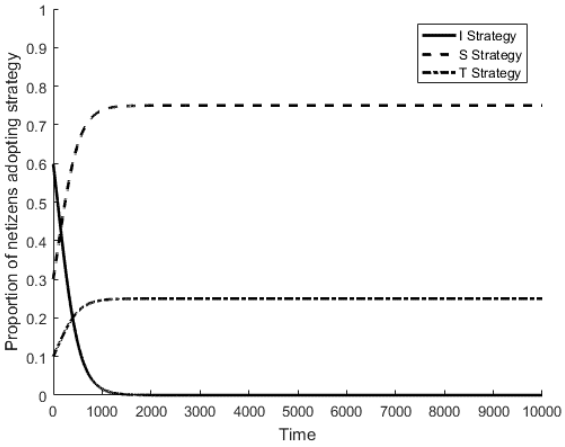
(c) Simulation 3



(d) Simulation 4

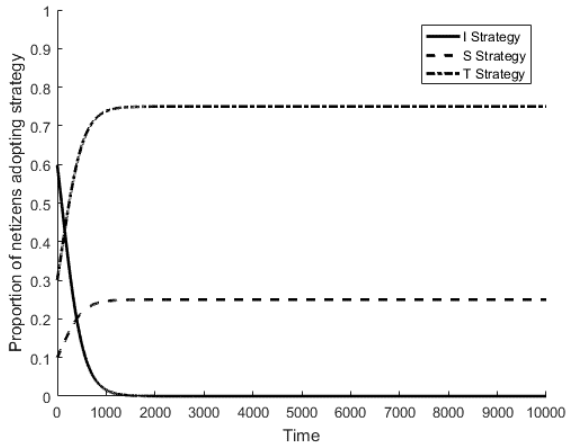


(e) Simulation 5

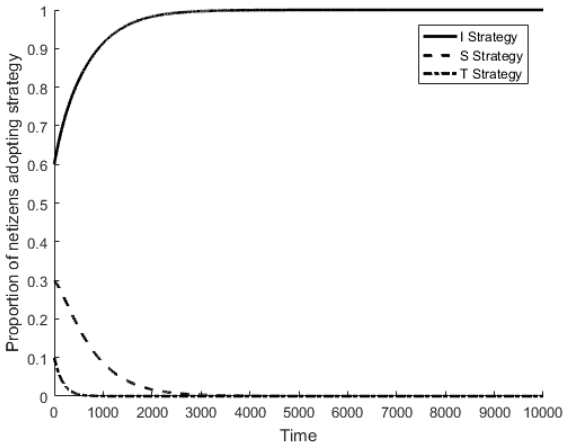


(f) Simulation 6

Figure 3. Simulated evolution of distribution of netizen strategies (*continues on next page*)



(g) Simulation 7



(h) Simulation 8

Figure 3 (continued). Simulated evolution of distribution of netizen strategies

Simulation 1. We assume that netizens adopt only the *I* and *S* strategies (Situation 1) and the cost of the enterprise adopting the *N* strategy is less than the cost of adopting the *P* strategy. We set $c_1 = 5,\ r_1 = 2.4$, thus $c_1 \geq r_1$, and we assume that the initial distribution of the adoption of *I, S,* and *T* strategies is 40%, 60%, and 0%, i.e., the majority of netizens notices the negative information while a minority of netizens ignores the incident but nobody takes action. Under these conditions, companies should adopt the *N* strategy and, consequently, the proportion of netizens choosing the *I* strategy will eventually approach 100% (Figure 3a). Once the company adopts the *N* strategy, the company's choice will lead netizens to eventually adopt the *I* strategy.

Simulation 2. We assume again that netizens adopt only the *I* and *S* strategies but this time the cost for the enterprise adopting the *N* strategy is more than the cost of adopting the *P* strategy. We vary the model parameters and set $c_1 = 2, r_1 = 2.4$, thus $c_1 < r_1$, and we assume the initial distribution of the adoption of *I, S,* and *T* strategies is 15%, 85%, and 0%, which satisfies the condition that $\theta_S > c_1/r_1$. When the proportion of the netizens choosing the *S* strategy is high and the benefit for the enterprise adopting the *P* strategy is greater than the benefit of choosing the *N* strategy, the enterprise should adopt the *P* Strategy. The netizens then will eventually adopt the *S* strategy (Figure 3b).

Simulation 3. We assume that netizens choose only the *I* and *S* strategies and the cost of the enterprise adopting the *N* strategy is more than the cost of adopting the *P* strategy. We set $c_1 = 2, r_1 = 2.4$, thus $c_1 < r_1$, and we assume the initial distribution of the adoption of *I, S,* and *T* strategies is 70%, 30%, and 0%, which satisfies the condition that $\theta_S < c_1/r_1$. In this situation, the proportion of netizens adopting the *S* strategy and noticing the negative information in the beginning is relatively small and most netizens do not to pay attention and ignore relevant negative information. Eventually, the proportion of netizens choosing the *I* strategy approaches 100% (Figure 3c). Despite the cost r_1, the enterprise will continue to adopt the *N* strategy to control the evolution of events, reflecting the reality that some enterprises hastily aim to limit the further proliferation of negative information through deterrence and deletion of posts in the immediate aftermath of the appearance of negative information on social media, hoping the netizens strategic choice evolves into the *I* strategy.

Simulation 4. We now assume that netizens choose the *I, S,* and *T* strategies (Situation 2) and the loss for the enterprise choosing the *N* strategy (r_3) is large, and for the netizens choosing the *T* strategy is more profitable than choosing the *S* strategy, i.e., $-d_2 + c_2 > -d_1 + c_1 > 0$. This situation corresponds to the use case. When r_3 is large, the enterprise should choose the *P* strategy. In this case, since the

benefit of choosing the *T* Strategy is greater than that of the *S* strategy, the proportion of netizens choosing the *T* strategy approaches 100% (Figure 3d). The company needs to adopt a positive strategy to ensure its loss is minimal. When the company adopts the *P* strategy, due to the fact that the benefits of the *S* strategy are greater than the benefits of the *I* strategy, the netizens who originally adopted the *I* strategy begin to pay attention to the negative information and gradually turn to the *T* strategy. This is the reason why, in the course of evolution, the proportion of netizens adopting the S strategy first increases slightly and then approaches 0%. Thus, in the situation $-d_2 + c_2 > -d_1 + c_1 > 0$ the netizens turn to the T strategy. The evolutionary equilibrium of strategies is *(T, P)*.

Simulation 5. We assume that a certain proportion of netizens (10%) choose the *T* strategy and the loss for the enterprise choosing *N* strategy (r_3) is large. For the netizens, choosing the *S* strategy is more profitable than choosing the *T* strategy. We assume $c_2 = 6$, other initial value remain unchanged, satisfying $-d_2 + c_2 < -d_1 + c_1$. Figure 3e shows the ensuing distribution of netizen strategies. In the beginning, the proportion of the netizens choosing the *T* strategy is relatively high, causing significant impact on the enterprise which will adopt the *P* strategy. In the process of evolution, netizens who adopted the *S* strategy find that free-riding behavior is cost-effective and profitable, so more and more people choose to go as a free-loader. The proportion of netizens choosing the *T* strategy becomes smaller. Consequently, the risk of great loss for the company also becomes smaller. When monitoring public opinion, the enterprise may spot the change and quietly reverse its strategy, turning to a negative strategy. At this time, netizens would like to force companies to adopt the *P* strategy but find that more effort is required – which does not pay off – and they finally maintain an *S* Strategy. The costs for netizens (d_1 and d_2) may be influenced by many factors, such as the activity of netizens, different cultural backgrounds, and awareness of rights of netizens. The enterprise, however, may control to some extent the costs c_1 and c_2 to encourage the netizens to choose *S* or *T* strategy.

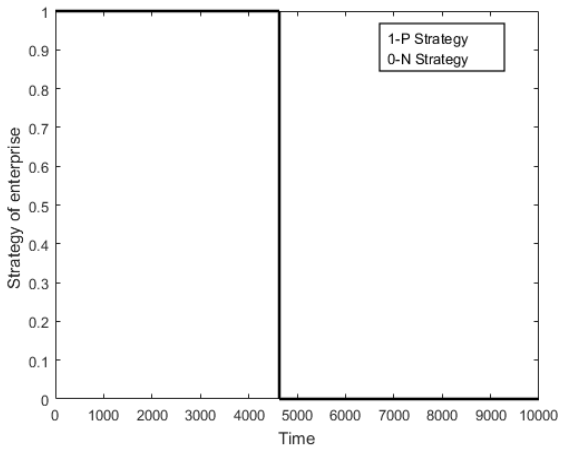


Figure 4. The evolution of the enterprise's strategy in the course of Simulation 5

Simulation 6. We now assume a larger proportion of netizens choosing the *T* strategy, the loss for the enterprise choosing the *N* strategy is large, and the payoff for the netizens choosing the *T* strategy is equal to that of the *S* strategy. We assume $c_2 = 6.5$, other initial value remain unchanged, satisfying $-d_1 + c_1 = -d_2 + c_2 > 0$. The initial distribution of the three strategies of netizens is 60% for the *I* strategy, 30% for the *S* strategy, and 10% for the *T* strategy. In such a situation, enterprises should always adopt a *P* Strategy. The proportion of netizens choosing *I* strategy approaches 0%, and the distribution of the *S* and *T* strategies depends on the initial distribution of the strategy (Figure 3f).

Simulation 7. Starting from Simulation 6, when $-d_1 + c_1 = -d_2 + c_2 > 0$, the distribution of the I, S, and T strategies depends on the initial distribution. We set the proportions of netizens choosing the *I*, *S*, and *T* strategy to $(0.6,\ 0.1,\ 0.3)$. Figure 3g shows the evolution of the strategy distribution in this scenario, confirming that the distribution of the *I* and *S* strategies depends on the initial distribution.

Simulation 8. We now look at the case when only a small proportion of netizens chooses the *T* strategy. Consequently, the loss of the enterprise choosing the *N* strategy will be smaller; we assume $r_3 = 30$. Other parameter values remain unchanged. Figure 3h then illustrates the evolution of strategic choices over time. The enterprise will always choose the *N* Strategy. The proportion of netizens choosing the T strategy will approach 0, and the distribution of the *I* and *S* strategies depends on the initial proportions as well as the values of d_1 and d_2 .

When the company has always chosen a negative strategy, the netizens' strategic choice gradually deviates from the *T* strategy in the course of evolution. When the attention of netizens incurs only a small loss for the enterprise and does not constitute a deterrent, netizens will gradually choose the *I* or *S* strategy. To explain such a behavior, consider a monopolistic company, which holds (almost) absolute control over resources and market. Such a company does not have to care about a public complaint.

Conclusion

The initial proportion of netizens adopting the *T* strategy and the value of the company's loss r_3 in case of adopting the *N* strategy are the determining factors for the company's strategy. For enterprises, it is necessary to strengthen the monitoring of public opinion, grasp the proportion of netizens taking to social media in order to vent frustration, and respond as soon as possible when negative information appears on social media.

Future work may employ sentiment analysis on social media data in order to empirically investigate social media crisis communication. Through sentiment analysis of social media data, future work can further analyze the mood or attitude changes of netizens' comments due to different response strategies of the company. Furthermore, in the presented model, the strategy of netizens is a discrete distribution. Future work may consider the netizens' attitude as a continuous function reflecting the impact of the company's strategy on the evolution of the netizen strategy.

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