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The contagion mechanism and governance strategy of corporate social irresponsibility of Chinese food companies

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ABSTRACT

From a global perspective, the incidents of food fraud are still increasing in recent years, which shows that the food safety issue has not been well addressed. As a major world food exporter and importer, egregious incidents of corporate social irresponsibility (CSI) for domestic food companies were discovered in China. Although the Chinese government has been strengthening the supervision on food companies, the governance effect is not obvious. This research focuses on the governance of the CSI behavior of food companies. As opposed to the existing literature based on Neoclassical economics, this article analyzes food companies' CSI by applying a behavioral economic framework. The system dynamics method is used to analyze the implementation effect of the corresponding governance strategy. Researchers discovered that the short-sighted cognitive bias of food companies is the primary reason for CSI, which results in the self-reinforcing effect and interactive contagion effect. Under the current imperfect institutional environment, these effects will be further amplified to present a crisis of collective irresponsibility. This study provides timely evidence and significant regulatory implications for the ongoing food safety crisis in China. In order to control the contagion of CSI in the food industry, the government should increase its sanctions on irresponsible food companies from the short-term perspective. The government should also establish a fair and standardized market competition order and improve the information disclosure mechanisms and third-party governance mechanisms in the long term. These actions will contribute to a more comprehensive research perspective on food safety governance and, additionally, and to develop more targeted strategic tools for the government to regulate the food market. Our insights can also provide a reference for other countries and industries facing similar challenges.

1. Introduction

Safety of food has always been a global concern. According to the IFS (International Featured Standard), the total number of food fraud incidents worldwide in 2021 increased by 34 % compared with 2020; these incidents involved 44 countries and regions, an increase of 10 countries and regions compared with 2020 (IFS, 2022). Gharehgozli et al. (2017) noted that American food suppliers' corporate social irresponsibility (CSI), such as improper production and ignorance of quality inspections, has led to frequent food contamination and the spread of foodborne diseases. In the past few years, there have been many major food safety incidents in Japan, such as the "Morinaga arsenic milk incident". In addition, the famous Japanese pastry company "Fuyuga" was exposed for using expired milk and eggs to make cream puffs (Jean et al., 2018). Between January 2017 and March 2018, 978 cases were reported in South Africa due to consumption of food contaminated with Listeria monocytogenes, of which 30 % of those affected died (Boatemaa et al., 2019). Food safety issues are the subject of global government regulations and academic research, and there is no exception for China (Kang, 2019). As shown in Fig. 1, the world national food safety ranking, published by the Think-tank of the British Economist magazine, showed the obvious gap between China and major developed countries in 2012–2017. Even among emerging economies, the food safety score of China is not the highest.

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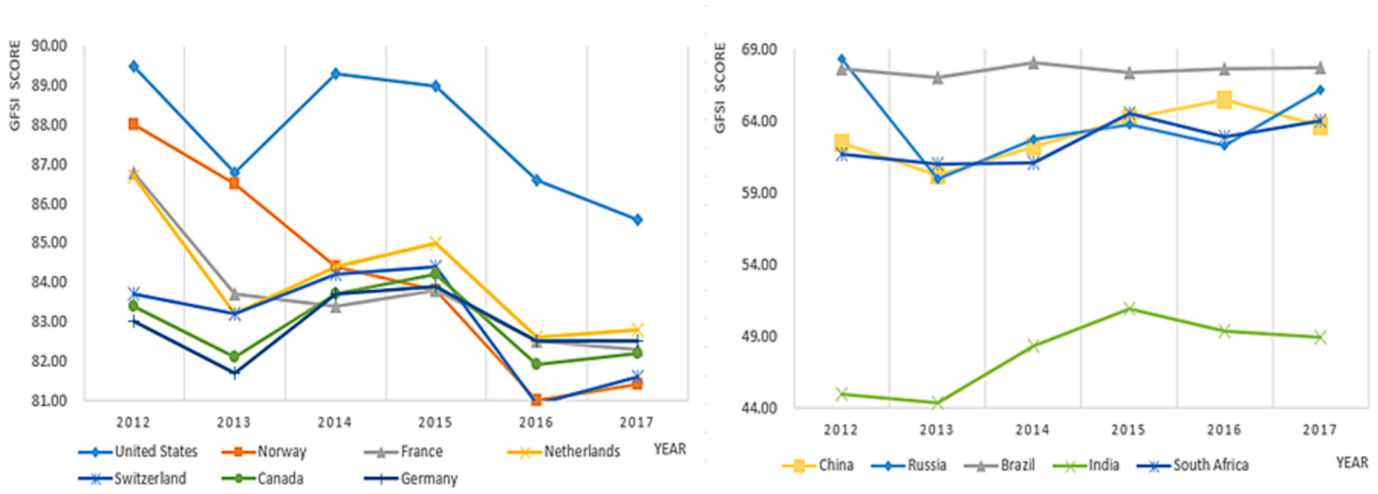

Fig. 1. The food safety scores of the world's leading countries and the emerging economies (Source: The Economist Intelligence Unit, 2021).

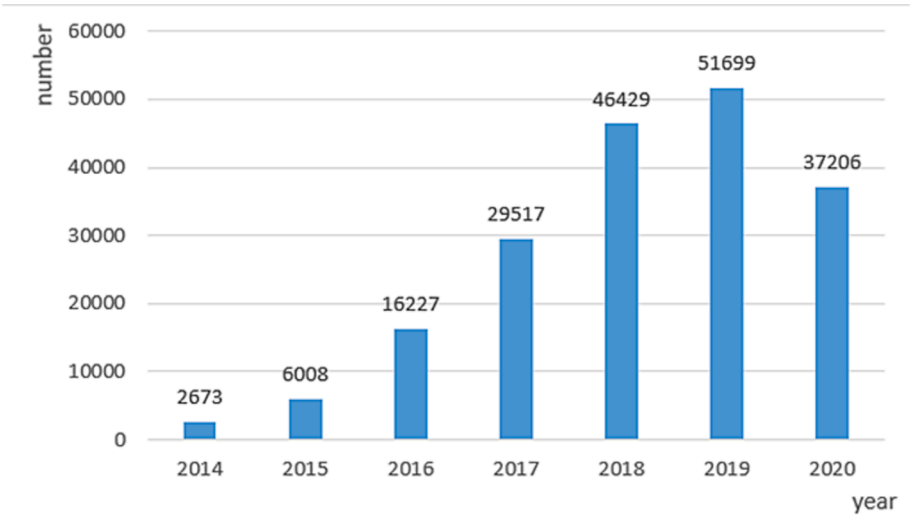

Fig. 2. Cases of food safety administrative penalties in China from 2014 to 2020 (Source: Qichacha, 2021).

The continuous occurrence of food safety issues in China reflects the inadequacy of food safety supervision, and the serious CSI of food companies (Zhang et al., 2015). In addition, once the CSI behavior appears, it will quickly spread to many food companies in the industry, resulting in the group characteristic of food safety incidents (Saak, 2012; Wang et al., 2014; Yin et al., 2019). *Mengniu*, a manufacturer of dairy products in China, was repeatedly condemned for its excessive use of additives, from 2009 to 2011. Similar problems have also been identified in other dairy companies (Zhang, 2015). There was an incident of adulteration of frozen food products at the Chinese frozen food company, *Haibawang*, in 2016, which was not uncommon for frozen food companies (Han, 2016). The Chinese liquor industry has also practiced the illegal addition of sweeteners in order to enhance the taste of liquor (Liao, 2020). As can be seen from the examples above, the CSI behavior in Chinese food companies exists not only in individual enterprises, but also in groups. In China, there is a contagious effect of CSI behavior throughout the food industry, and food safety is still a thorny issue. Frequent exposure of food safety incidents has seriously affected the public's trust in the food industry, thus posing a huge challenge to the sustainable development of China's food industry (Liu et al., 2017).

Due to severe food safety concerns, the Chinese government promulgated the most stringent *Food Safety Law of the People's Republic of China* in 2015. As can be seen from Fig. 2, the cases of punishment on Chinese food enterprises increased from 2014 to 2020. Especially, the number of cases after 2016 is much higher than that in 2014 and 2015, indicating that more potential food safety problems are exposed after the most stringent food safety law was implemented in China and the problems had not been alleviated.

China's food safety laws are based on neoclassical economic theory, which assumes that people are perfectly rational when making decisions. In this assumption, individuals assign the same discount factor to short-term revenue and long-term revenue (Barro, 1999; Leahey, 2003). If a food company commits CSI behaviors, it is likely that it will be found out and punished severely in the future. Therefore, as long as companies remain perfectly rational in their behavior, they should not pursue short-term revenue through CSI behavior, while ignoring the long-term penalty costs. Therefore, perfectly rational decision makers tend to avoid their CSI behaviors in the face of increasingly restrictive laws. However, the rising trend of food safety incidents in China shows that the decision making of food enterprises is not completely rational. Therefore, the neoclassical economic theory cannot explain the behaviors of Chinese food companies effectively. And the regulations based on the perfectly rational assumption have obvious limitations in effective governance on food safety problems.

In recent years, behavioral economics has been widely applied to a variety of subjects, including family choice (Adams et al., 2014),

environmental issues (Strulik, 2021), optimal consumption and investment (Yong and Roh, 2019), and management compensation (Niu et al., 2021). In the assumptions of behavioral economics, decision makers are bounded rational, and they always pay more attentional to short-term revenue (Laibson, 1997; Gruber and Koszegi, 2004). Therefore, bounded rational decision makers may be willing to pursue short-term revenue through CSI behaviors, by bearing the risks of being punished in the long term. As the bounded rational assumptions are closer to the actual situation in the real world, the behavioral economics may be able to provide theoretical bases for the contagion mechanism of food companies' CSI behaviors. Accordingly, this research raises the following questions: What are the root causes of the occurrence and contagion of CSI behaviors in food companies? Given that there are many food companies in China and that government regulatory resources are limited, how to effectively the CSI behaviors of food companies?

Based on behavioral economics, we developed an analytical framework to answer the above research questions. CSI behavior contagion was subsequently explained by identifying the mechanisms behind its occurrence. Our governance strategies are further developed through comparative static analysis. Finally, we determine optimal governance strategies by relying on system dynamics (SD) simulations. According to our study, behavioral economics based on bounded rationality can accurately describe food companies' "short-sighted cognitive bias." Our framework can explain why food companies engage in CSI behavior continuously and, thus, can make up for the shortcomings of existing economic theories based on perfect rational assumptions. Short-sighted cognitive bias causes food companies to value short-term interests and engage in CSI behaviors, which have self-reinforcing and contagious effects on CSI behavior. Due to the current state of incompleteness in the regulatory framework, these effects are likely to be exacerbated, resulting in a crisis of collective irresponsibility. Governance of CSI behavior in food companies requires the correction of "short-sighted cognitive bias," which requires focused regulation, a combination of strategies (long- and short-term governance strategies), and a collaborative governance approach. In particular, the government is urged to intensify the supervision on CSI behavior, especially for organizations that partake in CSI behavior frequently. Further, such behaviors should be penalized in a strict and punitive manner. Then, the self-reinforcing nature of food companies' CSI could be effectively inhibited. Moreover, a fair and uniformly regulated market order, as well as improved information disclosure mechanisms and third-party regulation mechanisms, are also necessary over the long term. Thus, combining short-term and long-term strategies and bringing together multiple parties can effectively compensate for the shortcomings of a single governance model with limited government resources, as well as effectively minimize the occurrence and spread of CSI behaviors within food companies.

The research makes significant contributions in the following areas. First, the existing literature generally focuses on the response of consumers and capital markets to the CSI behaviors of food companies. In contrast to these publications, this paper contributes to the literature on food safety governance and focus on the prevention of food safety incidents through controlling CSI contagion. Second, this paper provides an analytical framework based on behavioral economics and concludes that food companies' short-sighted cognitive bias is the root cause of the spread of CSI behavior, which has a "self-reinforcing effect" and an "interactive contagion effect" that results in a crisis within the industry. This finding is significant given that the Chinese government has adopted several stringent policies to combat CSI behavior in the food industry. However, despite the fact that these policies have been implemented, they have not had any substantial impact. Our study clarifies the underlying causes of the food safety governance dilemma, which sheds lights on the direction of future efforts in food safety governance. Last, this paper develops a framework for the governance of CSI contagion in food companies based on the SD model. It simulates and analyzes the impact of the governance strategies on their implementation, as well as determining the most effective governance strategy. The practical insights in this paper can be incorporated by the Chinese government as the bases for governing food safety. In addition, it may also serve as a reference for other countries and regions that are facing similar problems.

The rest of this paper is arranged as follows: The second section conducts the literature review. The third section introduces the hyperbolic discount model and analyzes the mechanism of CSI contagion in food companies. The fourth section derives the governance strategies based on a comparative static analysis. Then, the SD model is employed to determine the optimal governance strategy by simulating and analyzing the governance effects of the strategies. The fifth section offers the policy implications. This paper ends with a conclusion in the last section.

2. Literature review

Food safety issues were first studied in the 1950s, and research on food safety issues in developed countries has advanced rapidly since the 1990s. The studies primarily focus on the food safety system (Henson and Caswel, 1999; Karaman et al., 2012), government supervision and regulation (Antle, 1995; Thomsen, 2001), the food safety management model (Hanf and Pieniadz, 2006; Pouliot and Sumner, 2008), and the food supply chain perspective (Beulens et al., 2005). Food safety issues in China are becoming increasingly serious which have generated research interests worldwide.

Researchers typically attribute Chinese food safety issues to the macro-system level of supervision as a result of the lack of coordination among regulatory agencies (Li et al., 2010), low costs of illegality (Qi, 2012), inadequate government supervision, and an ineffective food safety system (Unnevehr and Hoffmann, 2015). In conjunction with the development of complementary studies, a number of scholars have addressed the underlying causes in the game theory and supply chain context. Rouvière and Caswell (2012) stated that food safety is determined by the interactions between stakeholders from a game theory perspective. Wang et al. (2014) suggested the problem of Chinese food safety lies in the inefficient transmission of information throughout the food supply chain. Asymmetry of information in the management of food safety leads to a loss of consumer confidence (Zhou et al., 2016). As long as consumers are not able to rely on the authenticity of food quality information, the opportunistic tendency of food producers will result in low-quality food and a low-quality market equilibrium (Anania et al., 2004).

As scholars discuss how food safety issues arise, they also attempt to alleviate the dilemma associated with Chinese food safety. Broughton and Walker (2010) analyzed the policies and practices for aquatic product quality and safety in China and argued that, to ensure maximum effectiveness, multiple departments and the Chinese government should coordinate and supervise aquatic product quality and safety supervision. Kong et al. (2019) suggested the adoption of the American punitive damages system into the Chinese legal system. Balzano (2012) advocated that Chinese food laws and regulations should be aligned with international standards by studying food safety governance in other countries. Unnevehr and Hoffmann (2015) believed that Chinese food safety issues should be addressed from two perspectives: it is crucial that public resources are devoted to the most significant risks by developing risk analysis capabilities; market incentives can be leveraged with limited public resources to implement regulatory standards. In addition, Liu et al. (2013) examined the effectiveness of the food safety risk assessment system for food safety supervision in China.

Although the current research provides an insightful guideline for Chinese food safety governance, it is evident that the existing research is concentrated on the macro-institutional level. Macro social systems and social environments play substantial roles in shaping individual behavior by influencing preferences and goals. However, the current research is limited in its exploration of the preferences and behaviors of micro-production subjects, particularly food producers' choices in

production behavior.

CSI was originally proposed as the antithesis of CSR, as presented in the form of negative corporate social responsibility (CSR) messages (Alniacik et al., 2011). Riera and Iborra (2017) contended that CSI is a deliberate strategy that is not only an accidental outcome of inadequate socially responsible behavior but also harms stakeholders' interests. Price and Sun (2017) stated that CSI behavior can have a significant negative impact on society. Guo et al. (2019) demonstrated that CSI is one of the root causes of food safety problems in manufacturing companies. CSI can be viewed as unethical behavior from the perspective of moral corruption, which leads to the phenomenon of adverse selection in the market (Scott, 2008). In most cases, the behavior of a single company is affected by that of other companies on the market. When the profits of formal companies are far less than that of companies with CSI, these formal companies will also choose CSI, which may result in a collective breach of responsibility. A review of the CSI incidents revealed by the Chinese media indicates that the CSI of food companies involves not only one company, but spans the entire industry, and also demonstrates collective misbehavior. During the 2008 melamine incident in China, 491 batches of infant milk powder from 109 product manufacturers were inspected. A total of 69 batches from 22 companies were found to contain varying levels of melamine, and the problematic milk powder had more than 50 % of the powdered milk market share (Kong, 2012). In the case of the "poison capsule incident" in 2012, 13 batches of capsules from nine pharmaceutical companies contained excessive levels of the heavy metal chromium, with most exceeding the standard by more than 90 times (Mao, 2013). CSI incidents occurring widely in the food industry are indicative of the prevalence of "short-termism". Companies will continue to engage in CSI if the process is difficult to supervise in a timely manner during the production process. By engaging in CSI, companies gain improper excess profits, which will also serve to motivate others to imitate, resulting in the widespread occurrence of collective CSI.

A significant number of CSI incidents in food organizations has already raised awareness in the government and among the general public. It is imperative that attention be paid to the governance of CSI from the perspective of industrial safety. Although the existing literature is largely concerned with consumers' and capital markets' reactions to CSI of food companies, it does not address the contagion mechanism of CSI of food companies (Gao et al., 2013; Seo et al., 2014). Dahlen and Lange (2006) demonstrated that brand crises alter consumers' perceptions and the rules of the game for entire categories of products. When a brand experiences a crisis, the impact it has on competing brands will be determined by how similar they are to the crisis brand. As a consequence of a brand reputation crisis, consumers are less likely to purchase new products from the brand, given that a contagion effect occurs in similarly positioned brands as well. Conversely, brands that possess distinctive positioning tend to be more appealing to consumers. Ma et al. (2010) indicated that *Nestlé* milk powder suffered a significant loss of market share and penetration as a result of its product hazard crisis. *Nestlé*'s product hazard crisis caused some consumers to switch to other brands, and larger brands gained more market share while smaller brands lost market share. The study by Sweetin et al. (2013) determined that CSI causes moral outrage among consumers which, in turn, triggers boycotts of the products that they consume. Both pro-boycott communication and news media coverage draw consumers' attention and can further enhance consumers' willingness to boycott CSI. It has been suggested by Paruchur and Misangyi (2015) that, when a negative event is revealed in an company, investors will categorize the company, and that company will then be seen as contagious, which will hurt its credibility.

In summary, the existing literature provides a more comprehensive theoretical and empirical basis for food safety issues. In these articles, the focus is primarily on macro systems such as regulatory systems (Zhou et al., 2015), legal systems (Geng et al., 2015; Roberts and Lin, 2016) and regulators (Balzano, 2012; Wu et al., 2017; Ma et al., 2021), and they do not address the behavioral contagion of CSI in food companies under the current conditions in China. In spite of this, the CSI of food companies is an influencing factor that contributes to food safety issues (Guo et al., 2019). While a few scholars have examined the CSI of food companies (Kong, 2012; Saak, 2012; Dai et al., 2013; Wang et al., 2014; Guo et al., 2019), such studies focus primarily on the consumer and capital markets' reaction to CSI after being exposed by the media and fail to reveal the mechanism by which CSI spreads in the food industry. Moreover, these studies are all based on Neoclassical economic theory with the perfect rational assumption, which neglects the framework with the bounded rationality assumption based on the companies' reality. In this regard, the existing literature on the CSI of food companies has research gaps regarding the inclusion of micro-subject behaviors and the impact of specific governance strategies on the control of CSI contagion among food companies.

3. Occurrence mechanism and contagion mechanism of CSI among food companies

3.1. Occurrence mechanism of CSI among food companies

The emergence of collective CSI in food companies indicates that, from a behavioral economics perspective, corporate managers are prone to short-sighted cognitive biases (Laverty, 2004; Ridge et al., 2014). Behavioral economics proposes that the behavior of food companies involves intertemporal decision making, which is a cost-benefit trade-off over time. This study characterized the short-sighted cognitive bias of food companies based on the framework of behavioral economics to reveal the occurrence mechanism of CSI contagion in the food industry.

Samuelson (1937) intended that the exponential discounting model would provide a general model of intertemporal choice. However, numerous empirical studies have found that the exponential discounting model cannot explain the reality of people's inconsistent time preferences in intertemporal decisions because it assumes that the discount rate remains constant over time (Frederick et al., 2002). Keren and Peter (1995) found that people prefer the former between $100 today and $110 tomorrow, and the latter between $100 in 30 days and $110 in 31 days. Short-termism is common in Chinese food enterprises' intertemporal decision making. For example, the Chinese frozen food company *Haibawang* has been repeatedly exposed for adulterating frozen products (Han, 2016). Many small liquor companies in China have been exposed for the illegal addition of sweeteners, which can enhance the taste of liquor but are harmful for consumers (Liao, 2020). Tea brand *Honey Snow Ice City* repeatedly tampered with the shelf life labels of ingredients in order to save costs (Hou, 2021). In the long run, companies are likely to be punished and suffer reputational damage as a result of their CSI behavior being discovered. However, the widespread existence of CSI behavior in Chinese food enterprises indicates that enterprises attach more importance to short-term interests.

When evaluating future returns, people tend to use a higher discount rate in the near term and a lower discount rate in the long term (Hoch and Loewenstein, 1991). Laibson (1997) pointed out that people's perceived utility of rewards tends to decline over time, and the trend basically conforms to the hyperbolic function. As can be seen, the hyperbolic discounting model can well explain the fact that food enterprises place more emphasis on short-term benefits and costs rather than on long-term consequences. Therefore, we use the hyperbolic discounting model to describe the "short-sighted cognitive bias".

In our model, we assume that there are N companies in the food industry producing the same products, and each company i may fulfill or violate corporate social responsibility. When fulfilling corporate social responsibility, the unit cost of a product is c_{iH} ; When violating corporate social responsibility—that is, engaging in CSI behavior—the unit cost of a product is c_{iL} . The sales price of a product is P . Under two circumstances, the production quantities of the company i are x_{iH} and x_{iL} , respectively. Based on the hyperbolic discount model, the intertemporal utility of food companies is represented by the following equation:

$$U(t,s) = u_t + \beta \sum_{s=t+1}^{\infty} \delta^{s-t} u_s \quad (1)$$

In the above equation, δ is the discount factor, which indicates the effect of the time factor on cognitive utility. β is used to characterize the degree of "short-sighted cognitive bias" of the companies. $0 < \beta < 1$; the smaller the value of β, the higher the degree of "short-sighted cognitive bias" of the company. By referring to Laibson (1997), we adopt $\{1, \beta\delta, \beta\delta^2, \ldots\ldots \beta\delta^t\}$ as the discount factor structure of food companies in our model. This indicates that food companies use a short-term discount factor for the near term, which is $\beta\delta$ from stage 1 to stage 0. The discount factor of the long term (from stage t + 1 to stage t) used by food companies is δ. As our model only includes two stages, we regard the period from stage 2 to stage 1 as long term (i.e., the discount factor from stage 2 to stage 1 is δ). Thus, the discount factor from stage 2 to stage 0 is $\beta\delta^2 (= \delta^* \beta\delta)$. In addition, $0 < \delta < 1$. Thus, companies with small short-term discount factors ($\beta\delta$) have high short-term discount rates and large long-term discount factors (δ) have low long-term discount rates. This is consistent with the results of empirical studies. $\beta = 1$ denotes that the company is perfect rational, and also denotes the case of the exponential discounting model. Thus, the exponential discounting model is actually a special case of the hyperbolic model, which has stronger explanatory power than the exponential discounting model.

We assume three stages of food production in our model ($T = 0,1,2$), representing pre-production stage, production stage, and post-production stage, respectively. Stage 0 refers to the planning and investment selection period of food companies, with only activity planning but no actual action. Stage 1 refers to the production period of food companies. Stage 2 refers to the period when food companies complete production and may be punished for CSI behaviors. During stage 1, if a food company i chooses to fulfill their corporate social responsibility, the immediate profit is $R_1 = (p - c_{iH})x_{iH}$. If the food company i chooses to violate its corporate social responsibility, the immediate profit is $R_2 = (p - c_{iL})x_{iL}$. Obviously, CSI behaviors persist among food companies only when $(p - c_{iH}) < (p - c_{iL})$, so the immediate net profit of the irresponsible food company is $R = x_{iL}(p - c_{iL})$ - $x_{iH}(p - c_{iH})$.

Once the public discovers that the food company i violates its corporate social responsibility in stage 1, the company may be punished in stage 2, resulting in hidden cost $c = \frac{\alpha}{2}x_{iL}^2$. α represents the penalty possibility of CSI when discovered by the public. The hidden cost is specifically manifested in the transaction loss caused by the corruption of reputation, and the fines imposed by the government as punishment, or even the shutdown of companies.

According to the hyperbolic discount model, the discount factor structure of food companies in stage 0 is $\{1, \beta\delta, \beta\delta^2\}$, where $\beta\delta$ is the short-term discount factor of stage 1 on stage 0, and δ is the long-term discount factor of stage 2 on stage 1.

Considering the optimization problem of the food company's production plan in stage 0, the expected utility of the company is:

$$U_1 = \beta\delta[x_{iL}(p - c_{iL}) - x_{iH}(p - c_{iH})] - \beta\delta^2\frac{\alpha}{2}x_{iL}^2 \quad (2)$$

Food companies always aim to maximize their own utilities. In stage 0, the derivative of U_1 with respect to x_{iL} is obtained according to the utilities' maximization condition, which is:

$$\beta\delta(p - c_{iL}) - \beta\delta^2\alpha x_{iL} = 0 \quad (3)$$

$$Further,\ we\ can\ obtain: x_{iL}^* = \frac{p - c_{iL}}{\delta\alpha} \quad (4)$$

In stage 1, the discount factor structure is $\{1, \beta\delta\}$. Therefore, the expected utility of food companies is:

$$U_2 = [x_{iL}(p - c_{iL}) - x_{iH}(p - c_{iH})] - \beta\delta\frac{\alpha}{2}x_{iL}^2 \quad (5)$$

In stage 1, according to the utilities' maximization condition, the derivative of U_1 with respect to x_{iL} is obtained as:

$$(p - c_{iL}) - \beta\delta\alpha x_{iL} = 0 \quad (6)$$

$$Further,\ we\ can\ obtain: x_{iL}^{**} = \frac{p - c_{iL}}{\beta\delta\alpha} \quad (7)$$

If the company has a "short-sighted cognitive bias", i.e., $0 < \beta < 1$, then there is $x_{iL}^{**} - x_{iL}^* > 0$. That is, when there is a "short-sighted cognitive bias", food companies will produce more shoddy products due to their CSI behaviors.

By defining $\Delta x_{iL} = x_{iL}^{**} - x_{iL}^*$ as the deviation number of shoddy products manufactured by food companies due to "short-sighted cognitive bias", we can get:

$$\Delta x_{iL} = \frac{(p - c_{iL})(1 - \beta)}{\beta\delta\alpha} \quad (8)$$

This variable can indicate the severity of CSI behavior of food companies due to "short-sighted cognitive bias".

Calculating the partial derivatives of the deviation amount on β and α, respectively, we have:

$$\frac{\partial\Delta x_{iL}}{\partial\beta} = -\frac{(p - c_{iL})}{\beta^2\delta\alpha} < 0; \frac{\partial\Delta x_{iL}}{\partial\alpha} = -\frac{(p - c_{iL})(1 - \beta)}{\beta^2\delta\alpha} < 0 \quad (9)$$

Therefore, we can obtain Proposition 1 as follows.

Proposition 1. *Short-sighted cognitive bias leads food companies to produce shoddy products based on CSI. The deviation number of shoddy products decreases as the short-sighted cognitive bias β coefficient and penalty coefficient α increase.*

When the managers make the production plan (stage 0), they do not fully understand the huge benefits brought about by CSI and believe that the discount factor of production costs should be consistent in the short term and long term. Once it comes to the production (stage 1), due to the existence of "short-sighted cognitive bias", the discount factor of the food company's CSI behavior becomes $\beta\delta$. As $0 < \beta < 1$, then we have $\beta\delta < \delta$. Therefore, food companies underestimate future costs, so they will attempt to maximize profits by taking advantage of CSI behavior. In the absence of timely discovery of the CSI behavior of companies, this behavior will self-reinforce, leading to the multiplicity of CSI behaviors.

3.2. Contagion mechanism of CSI among food companies

In China's famous melamine scandal in 2008, the National Bureau of Quality Inspection found melamine in milk powder produced by 22 well-known food companies, including *Sanlu, Yili, Mengniu*, and *Yashili*. Moreover, melamine was found in milk powder produced by a large number of small- and medium-sized enterprises (SMEs) during subsequent inspections. Adding melamine to milk powder has been an unspoken rule of the industry for many years. Owing to imperfect regulation, the incident did not receive public attention until it was reported in the media in 2008, resulting in a loss of trust in the whole dairy industry.

In addition, if companies involved in CSI incidents are not punished, it will be difficult for other companies in the same industry to resist the temptation of interest and adopt CSI practices. Also, consumers are unable to identify most of the counterfeit products since information asymmetry exists, giving rise to the dilemma of "bad money drives out good money," which leads food companies that perform well to relinquish their resistance to CSI. As a result, more companies will engage in CSI behavior, leading to industry-wide CSI contagion.

The previous analysis shows that "short-sighted cognitive bias" is an effective internal cause of food companies' CSI behaviors and, in the case of an imperfect institutional environment, "short-sighted cognitive bias" may be magnified, resulting in collective CSI behaviors across the

entire food industry. Consequently, in order to better understand the characteristics of this industry crisis and formulate corresponding governance strategies, this paper examines the following.

We assume that[1]

$$\beta = f(G, K, n, I) = \frac{GK}{nI} \tag{10}$$

Where $f'(G) > 0, f'(K) > 0, f'(n) < 0, f'(I) < 0$.$n$ represents the number of times that food companies violate corporate social responsibility to produce shoddy products[2]; $I = \sum_{j=1, j\neq i}^{N} x_{jL}$represents the acceptance of CSI behavior in the food industry[3]; G $(0 < G < 1)$ represents the completeness of the company's own governance structure; and K $(0 < K < 1)$ represents the degree of perfection of market competition order.

The parameter α means the penalty possibility of CSI when discovered by the public. From the perspective of direct impact, it is related to the penalty degree of CSI by the government, the degree of perfection of CSI information disclosure mechanism of food companies, and the degree of supervision of the third-party regulators. Logically, α is positively correlated with these parameters. However, for the convenience of analysis, we constructed the formula of α as the following.

$$\alpha = F(L, D, P_g) = \frac{L + D}{P_g} \tag{11}$$

Where $0 < L < 1$, $0 < D < 1$, $0 < P_g < 1$, and $F'(L) > 0$, $F'(D) > 0$, $F'(P_g) < 0$. L represents penalty degree of CSI by the government. D represents the degree of perfection of CSI information disclosure mechanism of food companies. P_g refers to the degree of government intervention on the third-party regulators. $P_g$can be used as a negative indicator of the degree of supervision by third-party regulators.[4] The lower the degree of the government intervention, depicted by smaller P_g, the more effective the third-party regulators' supervision. Substituting $\beta = f(G, K, n, I)$, $I = \sum_{j=1, j\neq i}^{N} x_{jL}$, and $\alpha = F(L, D, P_g)$ into Δx_{iL} , we have:

$$\Delta x_{iL} = \frac{P_g(p - c_{iL})(nI - GK)}{\delta GK(L + D)} \tag{12}$$

The partial derivative of Δx_{iL} to n can be obtained as follows:

$$\frac{\partial \Delta x_{iL}}{\partial n} = \frac{IP_g(p - c_{iL})}{\delta GK(L + D)} > 0 \tag{13}$$

The above formula indicates that the greater the number of CSIs taken by the food company, the greater the degree of cognitive deviation. Thus, the company is more likely to violate corporate social responsibility during the production process, which means that the company's CSI behavior has a self-reinforcing effect. This effect also explains why companies frequently engage in CSI behavior. The more CSI behaviors that companies engage in and are not found out, the greater the benefits they will receive. Therefore, companies will experience "path dependence", meaning that they will increasingly rely on CSI behaviors to gain market advantages and become the target of imitation by their peers, thus becoming a significant "source of contagion".

The partial derivative of Δx_{iL} to Δx_{jL} can be obtained as follows:

$$\frac{\partial \Delta x_{iL}}{\partial x_{jL}} = \frac{nP_g(p - c_{iL})}{\delta GK(L + D)} > 0 \tag{14}$$

The above formula shows that, in the food industry, the more shoddy products that a certain company produces, the easier it is for other companies to imitate its CSI behavior; moreover, the more peer companies that have CSI behaviors, the more CSI behaviors will occur in this company. This shows that there is an "interactive contagion effect" in the CSI behaviors of food companies.

Further analysis reveals that:

$$\frac{\partial^2 \Delta x_{iL}}{\partial n \partial x_{jL}} = \frac{P_g(p - c_{iL})}{\delta GK(L + D)} > 0 \tag{15}$$

Food companies will mutually reinforce each other through their self-reinforcing effect and interactive contagion effect. When a company violates its corporate social responsibility on a regular basis, the company's sense of shame as a result of its CSI behavior will decrease and it will be easier for the company to resume its CSI behavior in the future. Enticed by the extra high profits, companies that perform well within the industry have reduced their resistance to CSI, or simply give up resisting and engage in CSI behaviors. If the food industry's institutional environment is inadequate, it is likely that CSI will lead to collective misbehavior, and the food industry will then face a CSI crisis.

Proposition 2. *The CSI of food companies has a self-reinforcing effect and an interactive contagion effect. The two effects can mutually reinforce each other.*

4. Governance strategies of CSI contagion in Chinese food companies

Section 3 explores the contagion mechanism of CSI in food companies from the perspective of behavioral economics, which suggests that short-sighted cognitive biases can increase companies' CSI impulse. A self-reinforcing and an interactive contagion effect are associated with CSI in food companies. CSI behavior will spread in the industry through the mutual reinforcement of the two effects, resulting in a phenomenon of collective moral corruption. Conversely, such collective CSI behavior will amplify the short-sighted cognitive biases of each company, creating a vicious cycle. It is, therefore, imperative that we take strict and effective measures to curb the vicious cycle of CSI in the food industry.

According to Laibson (1997), lock-in policies have been the most effective means of regulating short-sighted cognitive biases. The process of internal lock-in is based on individual norms among the actors and

[1] The factors that directly affect β are considered here, including the degree of perfection of the company's own governance structure, the frequency of the company's CSI behaviors, the industry's acceptance of CSI behaviors, and the standard degree of competition order. In Equation (1), we assume that, the smaller the value of β, the higher the degree of "short-sighted cognitive bias" of the company. Logically, β is positively correlated with the degree of perfection of the company's own governance structure and the standard degree of competition order, while it is negatively correlated with the frequency of a company's CSI behaviors and the industry's acceptance of CSI behaviors. Thus, we put them into formula (10). In addition, for the convenience of calculation, we consider the current functional form.

[2] The "path dependence" of companies is primarily captured in this setting. In a research study by Sydow et al. (2009), they found that there will be "path dependence" in an organization, and organization fraud will also show path dependence. In this case, it is assumed that the number of CSI occurrences will exacerbate short-sighted cognitive bias in the company. The intuition of economics also supports this conclusion. As a company has CSI more frequently, the marginal loss of reputation will be lower, and as a company cares more about short-term interests, the less weight it places on long-term interests. This is just in line with the characteristic that β becomes smaller.

[3] Company herd behavior is primarily captured in this setting. Scharfstein and Stein (1990) found that company behavior exhibits a herd effect. Due to this, the behavior of other companies in the industry will influence the decisions of the company, causing it to adopt herd behavior. Furthermore, the CSI behavior of other companies in the industry will enhance the short-sighted cognitive bias of the company, resulting in a preference for short-term returns.

[4] Due to the strong intervention power of the Chinese government, whether the supervision of third-party institutions can be realized is largely influenced by the government. If the government interferes too much, it is difficult for third-party institutions to achieve effective supervision. Therefore, the degree of government intervention is negatively correlated with the degree of regulation by third-party regulators, and is also negatively correlated with α.

emphasizes the self-discipline of the individual organizations. External lock-in refers to the implementation of restraint through regulations and laws. Due to the fact that external locking applies to companies with or without self-restraint, it is more conducive to China's current requirement for food safety governance. In this section, by using comparative static analysis methods, this research examines the effects of various external institutional strategies on the CSI contagion caused by corporate cognitive biases. Moreover, this research also simulates and compares the effects of various governance strategies.

4.1. Proposal of governance strategies

(1) Establish a fair and standardized market competition regime. In practice, market competition is an influential constraint on the short-sightedness of companies. By establishing a fair and standardized market competition order, companies will be guided to operate in compliance with regulations and engage in fair competition among themselves. Additionally, the order of market competition will exert external pressure on irresponsible companies so that they will evaluate their governance structure and, if necessary, change their governance structure and refrain from engaging in short-sighted behavior.

The partial derivative of Δx_{iL} to K can be obtained as follows:

$$\frac{\partial \Delta x_{iL}}{\partial K} = -\frac{nIP_g(p-c_{iL})}{\delta GK^2(L+D)} < 0; \frac{\partial^2 \Delta x_{iL}}{\partial K \partial n} = -\frac{IP_g(p-c_{iL})}{\delta GK^2(L+D)} < 0; \frac{\partial^2 \Delta x_{iL}}{\partial K \partial x_{jL}} = -\frac{nP_g(p-c_{iL})}{\delta GK^2(L+D)} < 0 \tag{16}$$

Equation (16) means that the larger K is, the smaller Δx_{iL} is; that is, the better the market competition order, the smaller the probability of occurrence of CSI in food companies. Furthermore, the short-sighted cognitive bias of food companies will be suppressed and the interactive contagion effect will be weakened.

Strategy 1: In food safety governance, full attention should be paid to guiding the order of industry competition to reduce the contagion of CSI.

(2) Increase the penalties associated with CSI behavior. Mendelhoff and Gray (2005) argued that corporate compliance behavior will be improved through stricter deterrence measures such as punishment and enforcement actions. In addition to having a substantial impact on the company that is punished for noncompliance, the punishment has a significant impact on the surrounding companies (Shimshack and Michael, 2005). Thus, the government with limited resources has the ability to impose more severe penalties on companies that repeatedly neglect their corporate social responsibility. Despite the fact that counterfeiting companies can be penalized, this can also serve as a deterrent to potential violators.

The partial derivative of Δx_{iL} to L can be obtained as follows:

$$\frac{\partial \Delta x_{iL}}{\partial L} = -\frac{P_g(p-c_{iL})(nI-GK)}{\delta GK(L+D)^2} < 0; \frac{\partial^2 \Delta x_{iL}}{\partial L \partial n} = -\frac{IP_g(p-c_{iL})}{\delta GK(L+D)^2} < 0; \frac{\partial^2 \Delta x_{iL}}{\partial L \partial x_{jL}} = -\frac{nP_g(p-c_{iL})}{\delta GK(L+D)^2} < 0 \tag{17}$$

The greater the value of L and the closer the value of β is to 1, the more rational the food company will be. Under external pressure, companies will become stronger in their self-discipline ability, which will increase the consistency of companies' compliance with corporate social responsibility.

Strategy 2: In the process of food supervision, the government should strengthen the punishment of companies that frequently engage in CSI behaviors. Increasing penalties can not only allow illegal companies to receive due sanctions, but can also make government supervision an invisible deterrent, effectively reducing the impulse of other companies to engage in CSI behaviors.

(3) Enhance the mechanism for third-party governance. The role of third-party regulatory agencies, such as the media and industry associations, is crucial to the supervision of food companies. The extent to which third-party regulatory agencies can actively participate in the supervision of public opinion is strongly dependent upon the environment in which they operate (Miller, 2006). Media market entry regulations imposed by the government will significantly hinder competition between media companies, reducing the chance of the public being able to access accurate information (Gentzkow and Shapiro, 2006).

The partial derivative of Δx_{iL} to P_g can be obtained as follows:

$$\frac{\partial \Delta x_{iL}}{\partial P_g} = \frac{(p-c_{iL})(nI-GK)}{\delta GK(L+D)} > 0; \frac{\partial^2 \Delta x_{iL}}{\partial P_g \partial n} = -\frac{I(p-c_{iL})}{\delta GK(L+D)} > 0; \frac{\partial^2 \Delta x_{iL}}{\partial P_g \partial x_{jL}} = \frac{n(p-c_{iL})}{\delta GK(L+D)} > 0 \tag{18}$$

P_g indicates the degree to which third-party regulatory agencies such as the media have been interfered with by companies and governments. Obviously, as P_g increases, it becomes easier for food companies to violate their corporate social responsibility. By interfering with industry associations and media public opinion, the government will weaken the ability and willingness of these institutions to supervise food companies, which will further aggravate food safety concerns.

Strategy 3: In the long-term development, food safety governance depends on the improvement of the third-party governance mechanism. Improving the third-party governance mechanism can effectively restrict the occurrence of CSI behavior.

(4) Enhance the mechanism for releasing information. Consumers and investors can punish a company that has engaged in CSI behavior by voting with their feet as soon as the company's behavior is revealed. It has been observed that the reputational threat resulting from CSI activity can lead companies to abandon CSI behavior voluntarily, which can contribute to the regulatory burden placed on law enforcement agencies (Liu, 2010). The key to the reputation–punishment mechanism for the market lies in the efficient flow and credibility of information. In spite of this, the current lack of information regarding food safety on the market provides companies with the opportunity to engage in CSI activities.

The partial derivative of Δx_{iL} to D can be obtained as follows:

$$\frac{\partial \Delta x_{iL}}{\partial D} = -\frac{P_g(p-c_{iL})(nI-GK)}{\delta GK(L+D)^2} < 0; \frac{\partial^2 \Delta x_{iL}}{\partial D \partial n} = -\frac{IP_g(p-c_{iL})}{\delta GK(L+D)^2} < 0; \frac{\partial^2 \Delta x_{iL}}{\partial D \partial x_{jL}} = -\frac{nP_g(p-c_{iL})}{\delta GK(L+D)^2} < 0 \tag{19}$$

Equation (19) indicates that the more complete the information disclosure mechanism, the greater the likelihood that the company's CSI behaviors will be disclosed. Consequently, the market's reputation mechanism can correct a company's short-sighted cognitive bias, allowing it to better fulfill its role in food safety governance.

Strategy 4: Improving the information disclosure mechanism can ensure the efficient flow and accuracy of food safety information in the market. The market reputation penalty mechanism is conducive to building a safe

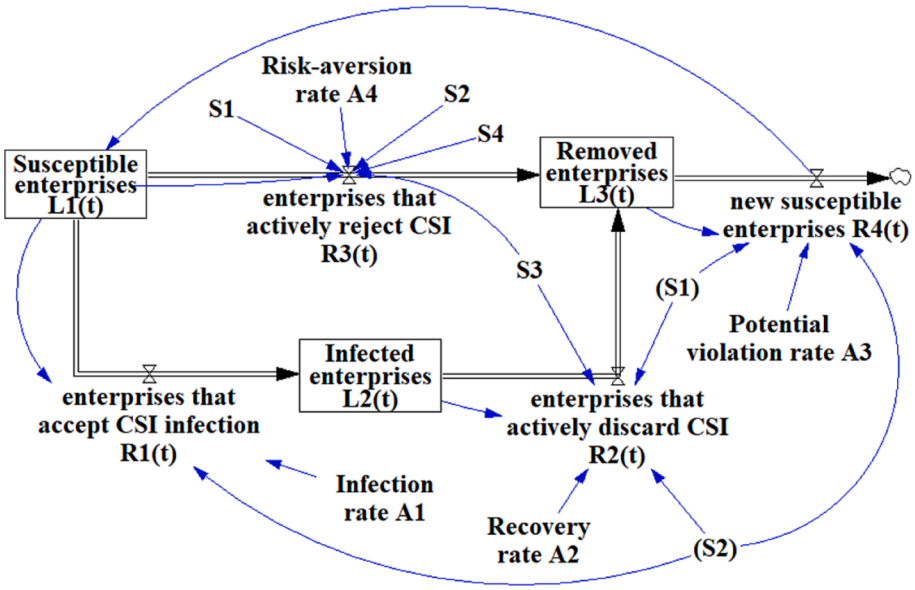

Fig. 3. SD model of CSI behavioral contagion governance in food companies.

food system and weakening the interactive contagion of CSI behavior in the food industry.

To summarize the results of Section 3 and Subsection 4.1, we provide a table that links the propositions and strategies to the parameters in Appendix A.

4.2. Simulation analysis on the governance strategies of CSI contagion in food companies

The previous section of the comparative static analysis proposed governance strategies, but the effect of implementing these strategies remains to be determined. For example, we still know little about the most effective strategy and the differences between the strategy combination and a single strategy. When making decisions to improve governance performance, decision makers (particularly government officials) may refer to detailed schemes of strategy implementation, which needs further exploration. In order to demonstrate the dynamic implementation effect of governance policies, we utilize the system dynamics model to simulate and analyze these strategies as the following.

4.2.1. System dynamics model of CSI behavior governance in food companies

In order to determine the effectiveness of the governance strategy for CSI behavior contagion, it is necessary to study the process of CSI behavior contagion in food companies. There have been significant advancements in the use of infectious disease models in the study of micro diffusion problems, such as the spread of rumors and knowledge (Derbali and Hallara, 2016; Giorno and Spina, 2016; Rode and Weber, 2016). In terms of contagious nature and contagious directions, food companies' CSI behaviors exhibit typical characteristics of infectious diseases. In order to analyze the evolution process of CSI behavior and contagion in food companies, this paper employs an infectious disease model. According to Kuperman and Abramson (2001), the SIRS model is a modified version of the traditional infectious disease model (SIR model) that takes into account the complexity of social networks. Different from the SIR model, the SIRS model may result in a recurrence of infection for immune individuals. It has been demonstrated that food companies that give up CSI behavior may adopt CSI behavior again, which is why the SIRS model may better explain the evolution of CSI contagion in food companies. Researchers have begun to use infectious disease models to study food safety issues, and the dissemination of public opinion regarding food safety is an important area of research being currently investigated (Chen et al., 2018). However, these studies have rarely addressed the contagion mechanism of CSI behavior in food companies.

System dynamics is an approach to understanding the nonlinear behaviors of complex systems over time using stocks, flows, and internal feedback loops. Flows represent the rates at which resources such as materials, energy, or information enter or leave a system. They describe the movement or transfer of resources between different stocks in the system and the levels or amounts of resources that are stored or accumulated over time. Feedback loops refer to the interactions and feedback mechanisms among various components or stocks within a system. These loops can be positive or negative, influencing the dynamic behaviors of the system (Sterman, 2000). System dynamics provides a powerful framework for designing and evaluating policies because it allows policymakers to understand the complex interrelationships and feedback dynamics within a system. By incorporating system dynamics into policy design, policymakers can gain valuable insights into the complex dynamics of the system, anticipate the potential outcomes of policy interventions, and make more informed decisions that lead to desirable and sustainable outcomes. The purpose of this subsection is to simulate the impacts of the different governance strategies by constructing an SD model based on the subject of CSI behavior contagion in the food industry.

On the basis of the SIRS model, this paper divides food companies into three categories: infected, susceptible, and removed. The SD model of contagion of CSI behavior is then constructed, and these three types of companies will transform into each other during the contagion process. As our research focuses on the implementation effect of governance strategies, governance strategies are simulated in the SD model. The governance strategies include the establishment of a fair market competition order, the enhancement of the severity of government punishments, the improvement of the mechanisms for third-party governance, and the improvement of the information disclosure mechanism. In order to simplify the analysis, these four strategies are designated as S1, S2, S3, and S4. As shown in Fig. 3, we developed a system flow figure based on the SD model. In the rectangle, the stock variable represents the accumulation of different types of companies. In the valve, the flow variable represents the actual flow of companies accepting, rejecting, or withdrawing from CSI behaviors. This study utilizes the variation of the number of different types of firms as the basis

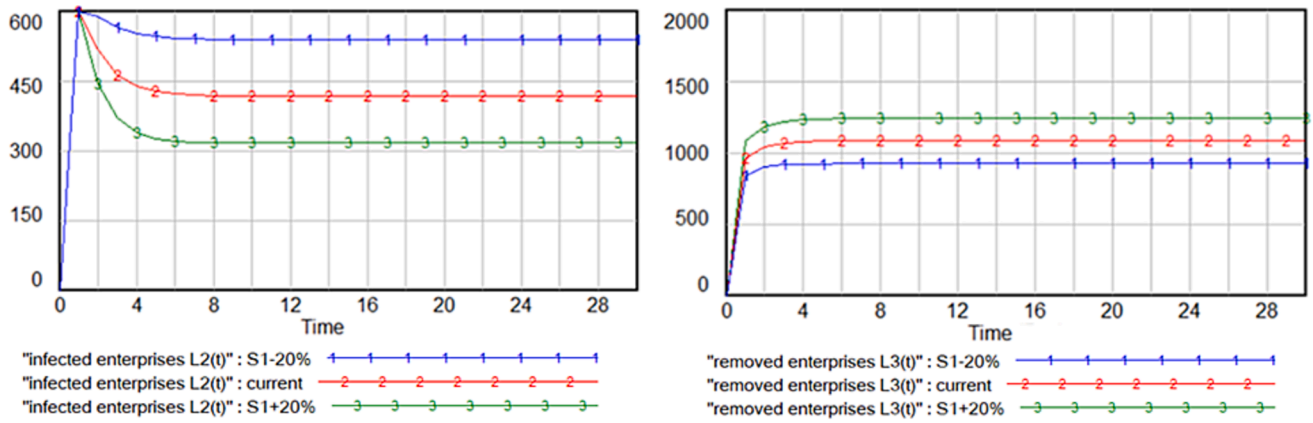

Fig. 4. The impacts of S1 on the contagion of food companies' CSI.

to judge the impact of different governance strategies. The implementation effect of a policy or combination of policies is positively correlated with the reduced number of infected firms and the increased number of removed firms. By changing the value of related strategy variables, the model can intuitively display the changing trend of the results, thus reflecting the implementation impacts of different governance strategies (Poles, 2013).

The assumptions associated with the above description are as follows:

(1) For the convenience of analysis, we assume that the initial number of susceptible companies is fixed. Because of the "short-sighted cognitive bias," when they observe CSI behavior of infected companies, they have two options — accept or reject it.
(2) When the deterrence of the governance strategy is not strong enough, due to the "short-sighted cognitive bias", a certain proportion of susceptible companies will be transformed into infected companies, and they will engage in CSI behavior. The infection rate (A1) is used to express this proportion.
(3) With diversification and the strength of governance strategies, susceptible companies will be deterred from their "short-sighted cognitive bias", and a certain proportion of susceptible companies will reject CSI behaviors. The risk-aversion rate (A4) is used to indicate this proportion.
(4) Infected companies will discard CSI behavior in a certain proportion if the impact of governance strategies is large enough, which is represented by the recovery rate (A2).
(5) Due to "short-sighted cognitive bias", a certain percentage of removed companies will become susceptible companies when their CSI behavior remains undiscovered and unpunished. This percentage is represented by the potential violation rate (A3).

Fig. 3 shows the contagion process of CSI behavior in food companies and the external governance effect based on the SD model. Among them, the single stock of susceptible companies $L_1(t)$ represents the net accumulation of gradual changes of three kinds of flows: the inflow of formatting new susceptible companies $R_4(t)$; the outflow of companies accepting CSI behavior $R_1(t)$; and the outflow of companies rejecting CSI behavior $R_3(t)$. We assume that a certain proportion (potential violation rate A3) of the removed companies are transformed into new susceptible companies, thus flowing into $L_1(t)$; a certain proportion (infection rate A1) of susceptible companies accepting CSI are transformed into infected companies, thus flowing out of $L_1(t)$; and a certain proportion (risk-aversion rate A4) of susceptible companies reject CSI and are converted into removed companies, thus flowing out of $L_1(t)$. The single stock of infected companies represents the net accumulation of gradual changes of two kinds of flows: the inflow $R_1(t)$ of companies accepting CSI behavior and the outflow of companies giving up CSI behavior $R_2(t)$. We assume that a certain proportion (infection rate A1) of susceptible companies accept CSI and are converted into infected companies, thus flowing into $L_2(t)$; and a certain proportion (recovery rate A2) of infected companies are converted into removed companies, thus flowing out of $L_2(t)$. The single stock of the removed companies $L_3(t)$ represents the net accumulation of gradual changes of three kinds of flows: the inflow of companies that give up CSI contagion, the inflow of companies that reject CSI behavior, and the outflow of companies that have potential CSI behavior. We assume that a certain proportion (recovery rate A2) of infected companies are converted into removed companies, thus flowing into $L_3(t)$, and a certain proportion (risk-aversion rate A3) of susceptible companies reject CSI behavior and are converted to removed companies, thus flowing into $L_3(t)$. In addition, there is a certain proportion (potential violation rate A4) of the removed companies that are transformed into susceptible companies, thus flowing out of $L_3(t)$.

As shown in Fig. 3, this paper presents a set of equations that describe the relationship between variables in the system in order to introduce governance strategies. The following equations describe the main variables in the overall CSI behavioral contagion governance system for food companies:

$$\textit{The number of susceptible companies } L_1(t) = R_4(t) - R_1(t) - R_3(t) \tag{20}$$

$$\textit{The number of infected companies } L_2(t) = R_1(t) - R_2(t) \tag{21}$$

$$\textit{The number of removed companies } L_3(t) = R_2(t) + R_3(t) - R_4(t) \tag{22}$$

$R_1(t)$ represents the number of companies that accept CSI, expressed as follows:

$$R_1(t) = L_1(t)*A1*(1 - a2) \tag{23}$$

$R_2(t)$ represents the number of companies that abandon CSI, expressed as follows:

$$R_2(t) = L_2(t)*A2*(a1 + a2 + a3) \tag{24}$$

$R_3(t)$ represents the number of companies that reject CSI, expressed as follows:

$$R_3(t) = L_1(t)*A4*(a1 + a2 + a3 + a4) \tag{25}$$

$R_4(t)$ represents the number of newly formed susceptible companies, expressed as follows:

$$R_4(t) = L_3(t)*A3*[(1 - a1) + (1 - a2)] \tag{26}$$

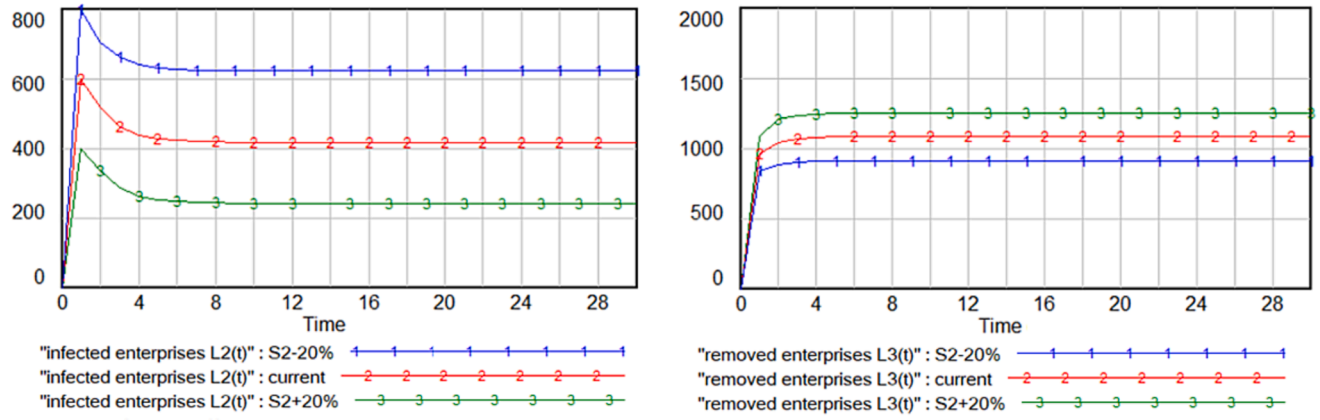

Fig. 5. The impacts of S2 on the contagion of food companies' CSI.

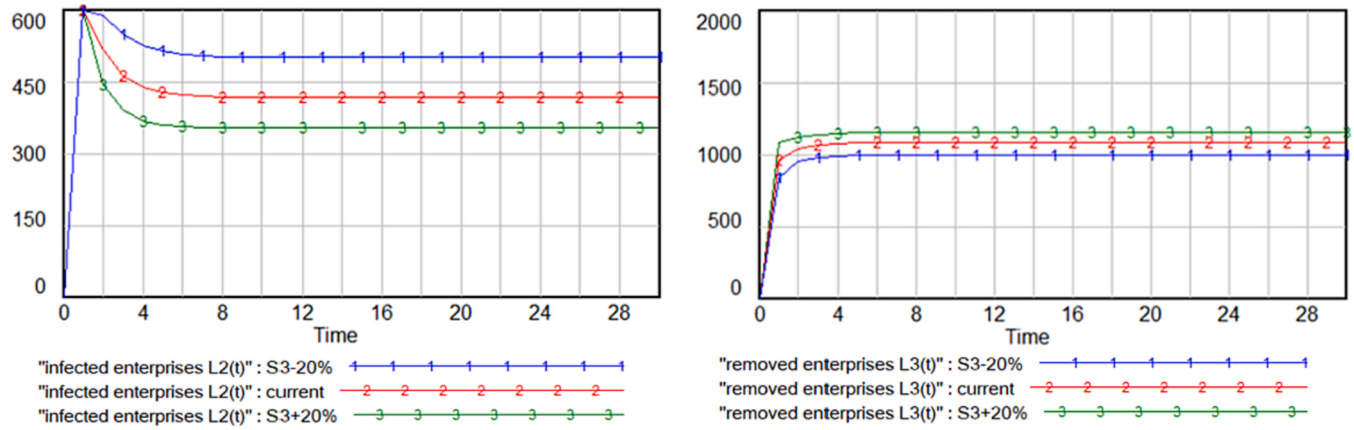

Fig. 6. The impacts of S3 on the contagion of food companies' CSI.

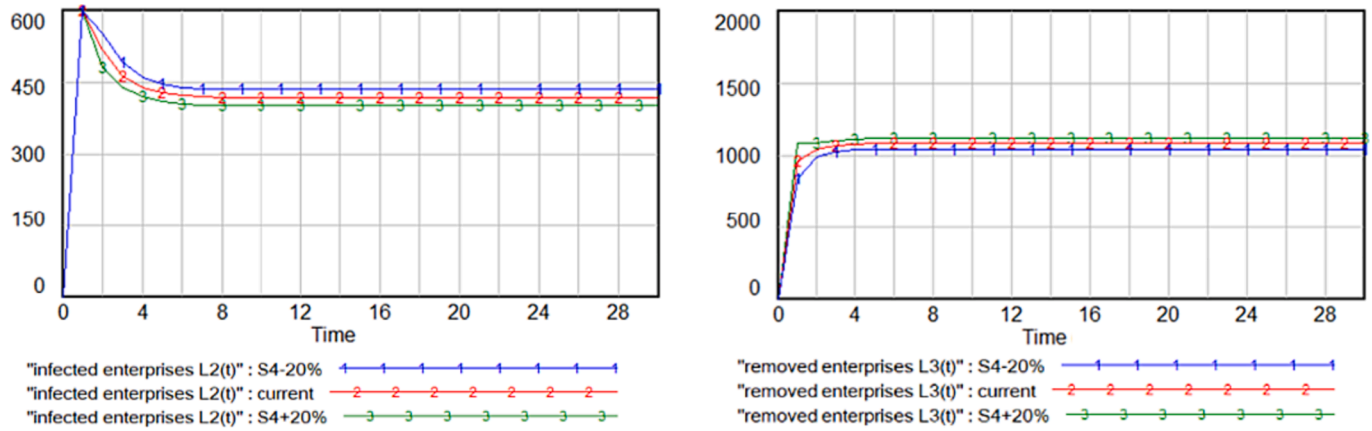

Fig. 7. The impacts of S4 on the contagion of food companies' CSI.

4.2.2. Analysis of simulation results

This section simulates the established model using the governance strategies obtained in subsection 4.1. The initial number of susceptible companies is 2000, and the initial number of infected and removed companies is zero. Based on the fact that the governance strategies have been initially implemented in China, the initial value of each governance strategy is set to 0.4. By reducing or increasing the value of the strategy, we then observe the changes in the number of various types of companies in the system after the strategy is implemented. Specifically, we assign different initial values to the intensity of the governance policy in each experiment, which is reflected in the lines 1–3 in Figs. 4–7. Line 2 indicates that the initial value of each governance strategy is set to 0.4, depicted by "current". Lines 1 and 3 indicate that the initial value of the governance policy has decreased and increased by 20 % from the current strength, respectively. By comparing the implementation effect of the strategy, we analyze the necessity of weakening or strengthening the current governance intensity. The simulation analysis is intended to show the change trend of the dependent variable in relation to the governance strategy. If the parameters are set when the premise is satisfied, and the different values of the parameters do not affect the

Table 1
Numerical results of strategy simulation.

	Infected companies L2				Removed companies L3			
Strategy	Original value	Peak value	Stabilized value	Periods for stabilization	Original value	Peak value	Stabilized value	Periods for stabilization
current	0	600	417	18	0	1083	1083	13
S1-20 %	0	600	538	18	0	923	923	18
S1 + 20 %	0	600	316	16	0	1240	1240	15
S2-20 %	0	800	622	17	0	911	911	15
S2 + 20 %	0	400	242	18	0	1251	1251	15
S3-20 %	0	600	500	21	0	1000	1000	19
S3 + 20 %	0	600	353	16	0	1153	1153	14
S4-20 %	0	600	435	17	0	1043	1043	14
S4 + 20 %	0	600	400	19	0	1120	1120	15
Scheme1	0	300	108	16	0	1526	1526	13
Scheme2	0	500	253	16	0	1291	1291	13
Scheme3	0	700	432	16	0	1200	1088	14

	S1	S2	S3	S4
Scheme 1	0.7	0.7	0.3	0.3
Scheme 2	0.5	0.5	0.5	0.5
Scheme 3	0.3	0.3	0.7	0.7

Fig. 8. The Schemes of different strategy combinations.

evolution trend but only the amplitude of the curve, then the model is robust and the results are reliable.

The data of the number of Chinese food companies involved in CSI used in this paper are highly sensitive, such as the number of susceptible and removed companies. Officials did not report the corresponding data for these companies. The majority of companies are theoretically located in the middle state. Accordingly, the number of infected and removed companies should be less than the number of susceptible companies. Consequently, the number of initial susceptible companies that we set is greater than the number of initial infected companies and the number of initial removed companies. In order to facilitate our analysis, we set the number of initially infected and removed companies to zero.

To verify the robustness of the model results, we have adopted different assignment Schemes. If the initial susceptible companies are 2000, the numbers of infected companies and removed companies are set to be 500, 1000, and 1500, respectively, for simulation (see the Appendix B for more details). The results of our study indicate that the

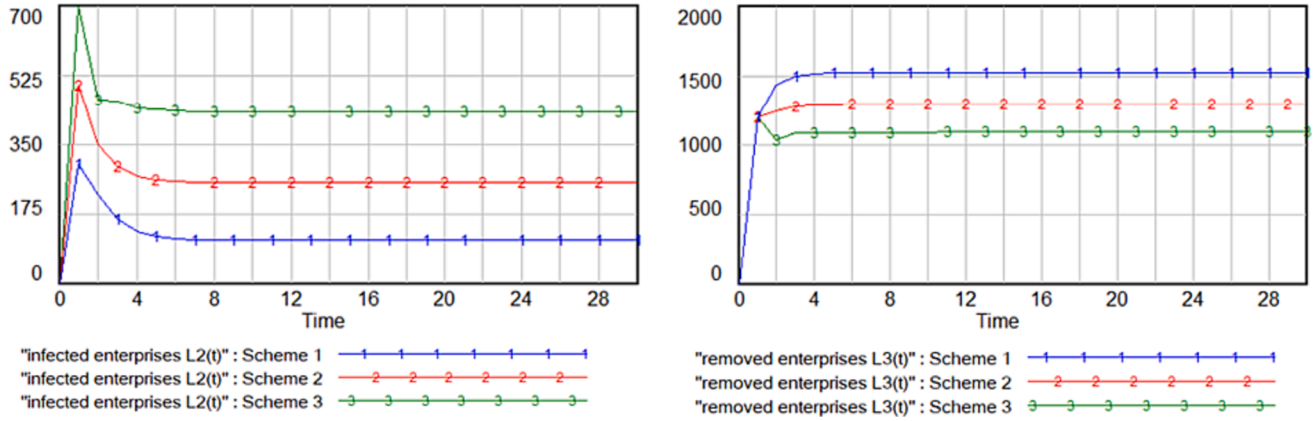

Fig. 9. The impacts of different strategy combinations on the contagion of food companies' CSI.

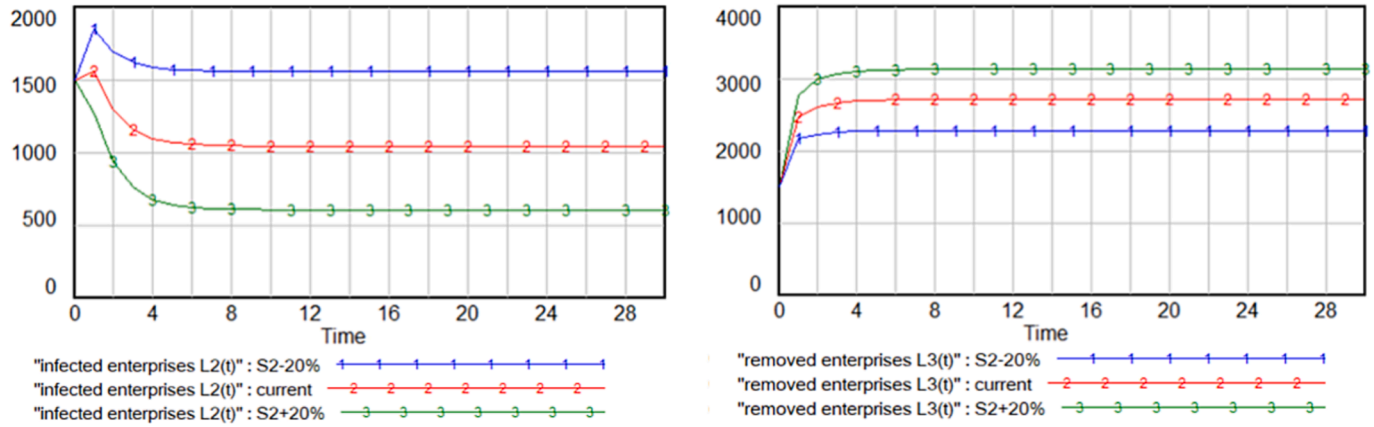

Fig. A1. Impacts of S1 on the contagion of CSI among food companies.

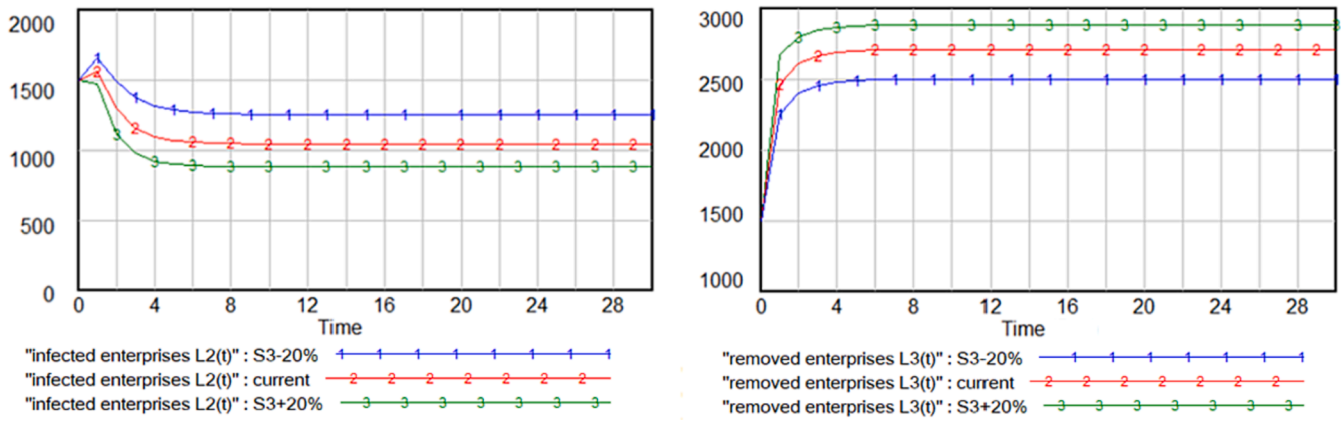

Fig. A2. Impacts of S2 on the contagion of CSI among food companies.

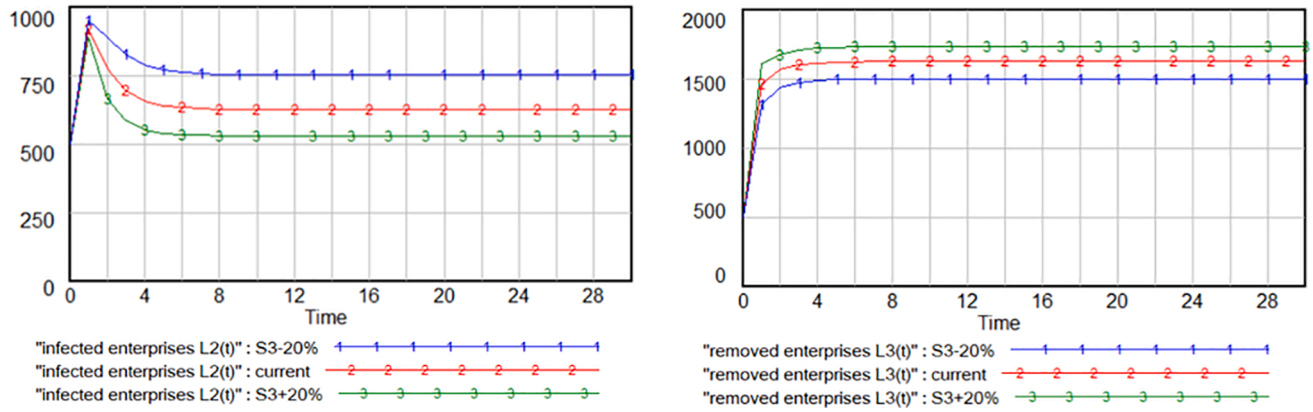

Fig. A3. Impacts of S3 on the contagion of CSI among food companies.

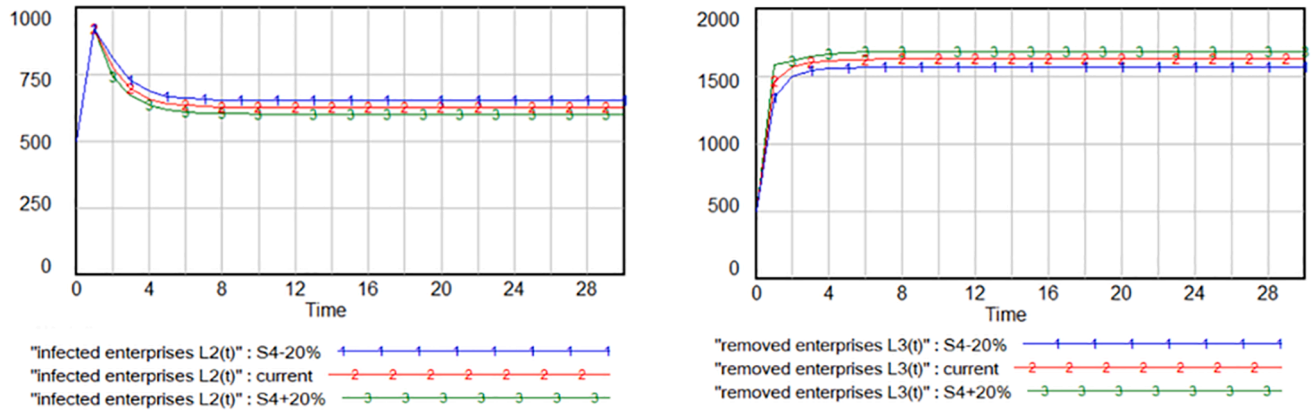

Fig. A4. Impacts of S4 on the contagion of CSI among food companies.

different assignment Schemes exhibit the same trend.

(1) The governance effect of fair and standard market competition orders on the contagion of food companies' CSI.

As the degree of fairness and standardization of market competition order is altered, we observe a change in the contagiousness of CSI among food companies. Fig. 4 shows that when the fairness of the market competition order increased by 20 % from the initial value, the infected companies will suffer public boycotts if the competition order in the food industry is sufficiently advanced. They will be eliminated by the market or transformed into removed companies. For simplicity, we will use enhanced Strategy 1 and weakened Strategy 1 to represent the fairness of the market competition order increased and decreased by 20 % from the initial value, respectively.

The Table 1 presents all the specific numerical results, including the results of the four single strategies and the results of strategy combinations. It can be seen from Table 1 that the number of infected firms, affected by enhanced Strategy 1 (row 3), stabilized at 316 in the 16th periods, which is a significant decrease compared to the number of stabilized infected firms, 417, before intervention. Also, the number of removed firms, affected by the enhanced Strategy 1, stabilized at 1240

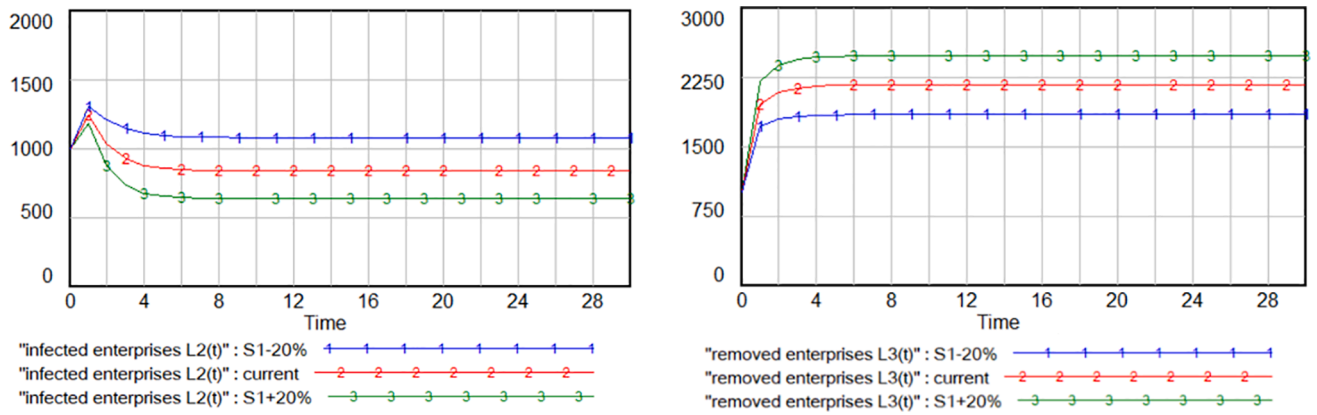

Fig. A5. Impacts of S1 on the contagion of CSI among food companies.

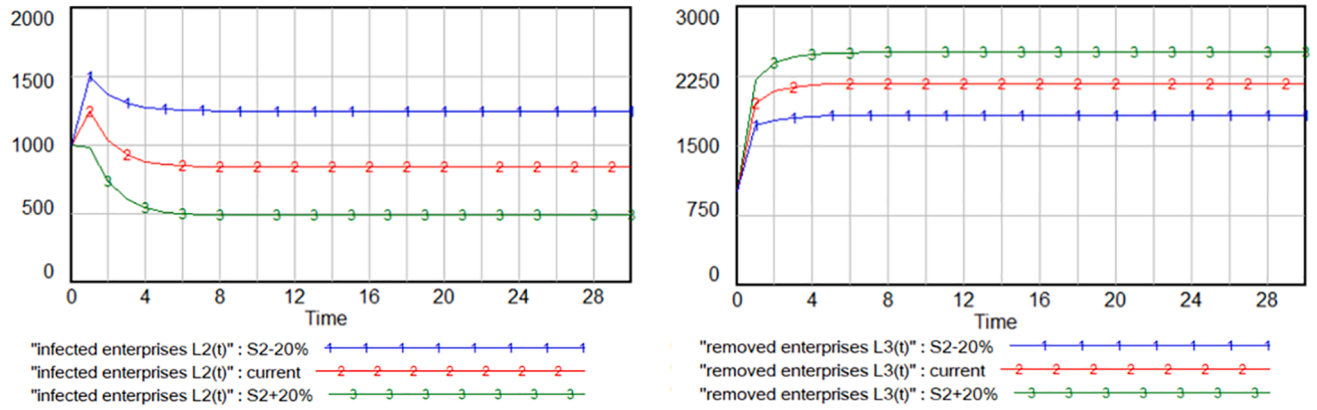

Fig. A6. Impacts of S2 on the contagion of CSI among food companies.

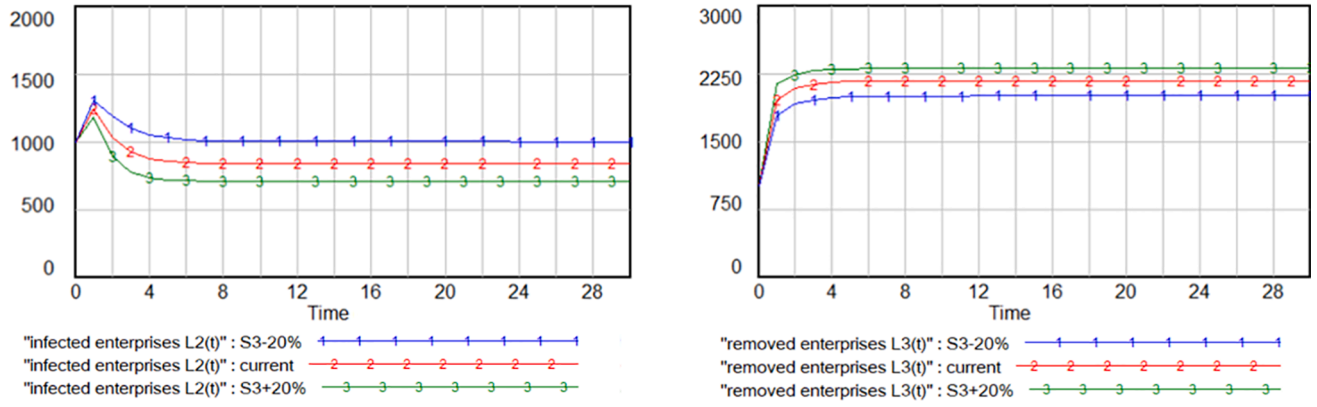

Fig. A7. Impacts of S3 on the contagion of CSI among food companies.

in the 15th periods, which is a significant increase compared to the number of stabilized removed firms, 1083, before intervention. As a result, the phenomenon of "bad money driving out good money" will no longer exist in the food market. Furthermore, companies tend to produce products with better quality to gain a greater competitive advantage, and the entire food industry is more stable and healthier.

(2) The governance effect of government penalty intensity on the contagion of food companies' CSI.

By changing the value of penalty intensity, we observe its impacts on the contagion of food companies' CSI. The simulation results are shown in Fig. 5:

It can be seen from Fig. 5 that when the government penalty intensity increased by 20 % from the initial value, the peak value of infected companies drops significantly. In addition, the number of infected companies is limited to a small range. When the government penalty intensity decreased by 20 % from the initial value, the proportion of infected companies increases rapidly. It can be seen from Table 1 that the number of infected firms, affected by enhanced Strategy 2 (row 5), stabilized at 242 in the 18th periods, which is a significant decrease compared to the number of stabilized infected firms, 417, before intervention. Also, the number of removed firms, affected by enhanced Strategy 2, stabilized at 1251 in the 15th periods, which is a significant

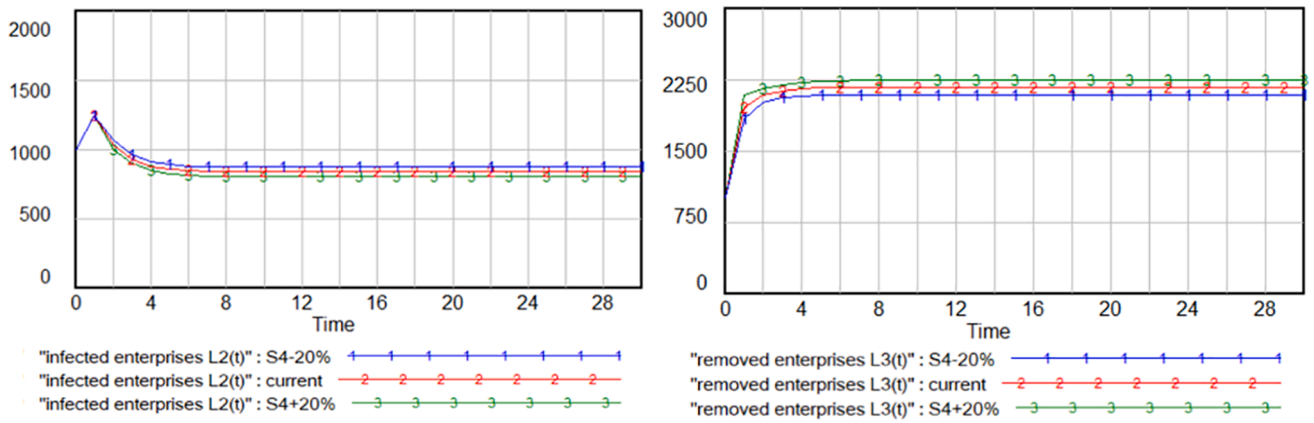

Fig. A8. Impacts of S4 on the contagion of CSI among food companies.

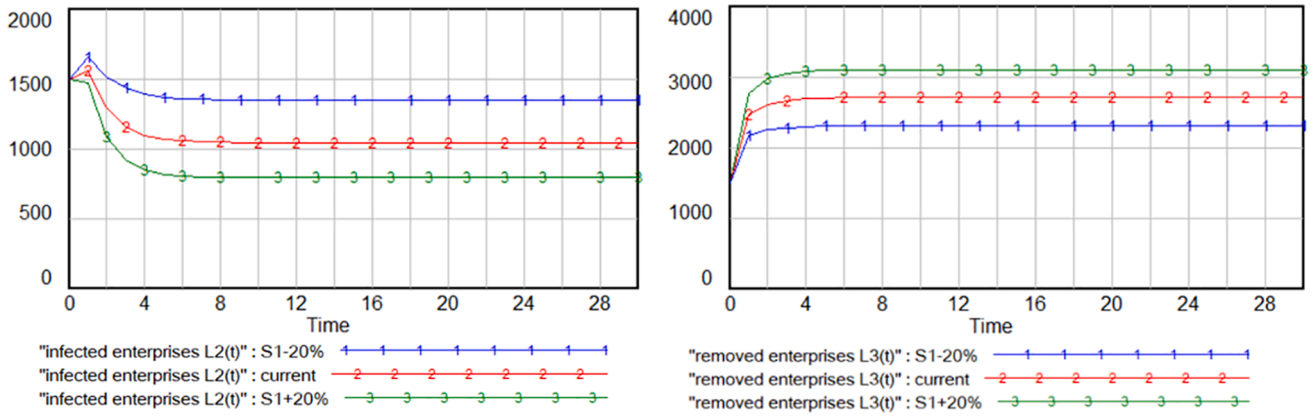

Fig. A9. Impacts of S1 on the contagion of CSI among food companies.

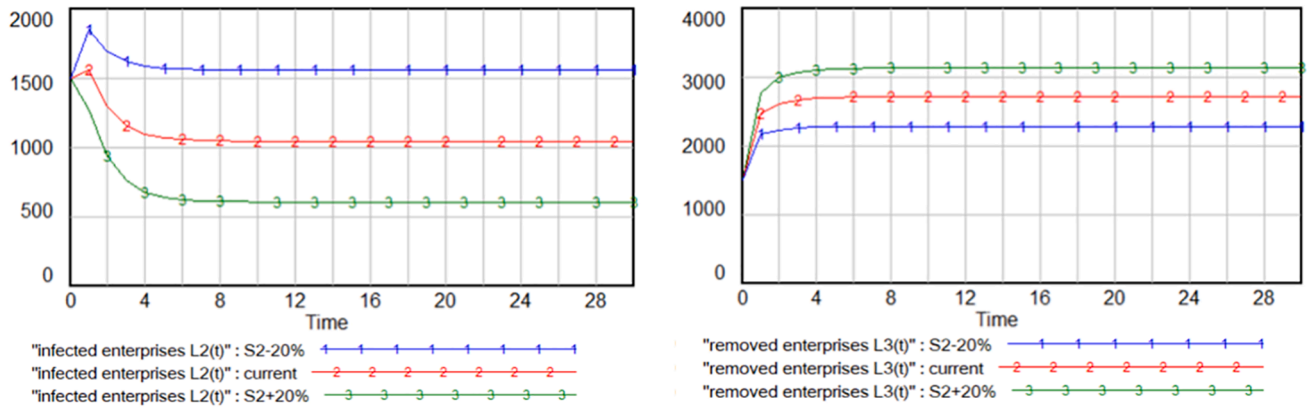

Fig. A10. Impacts of S2 on the contagion of CSI among food companies.

increase compared to the number of stabilized removed firms, 1083, before intervention. When the government's penalty amount is strong enough, infected companies give up their CSIs or are expelled from the market; on the other hand, the punishment acts as a deterrent for susceptible companies that fear the government's regulatory system. Therefore, the number of removed companies will also increase to a greater extent.

(3) The governance effect of third-party governance mechanism on the contagion of food companies' CSI.

By changing the degree of third-party governance, we observe its impacts on the contagion of food companies' CSI. The simulation results are shown in Fig. 6:

As shown in Fig. 6, improving third-party governance has limited regulatory effects on the contagion of food companies' CSI. As the degree of improvement increased by 20 % from the initial value, the peak value of infected companies decreased slightly, while the peak value of removed companies increased accordingly. By exposing the CSI behaviors of food companies through third-party regulatory agencies like the media and industry associations, the information asymmetry between the market and food companies is mitigated and the contagion of CSI

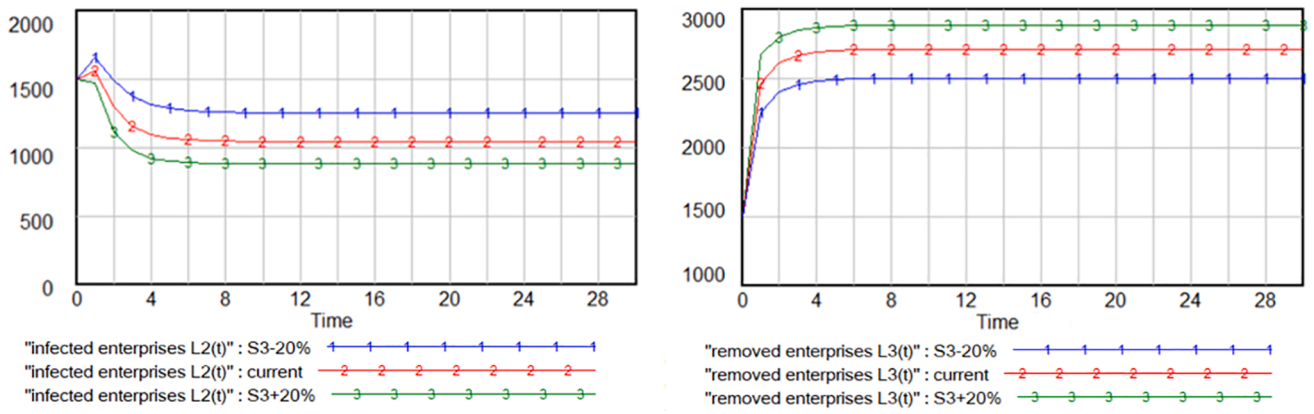

Fig. A11. Impacts of S3 on the contagion of CSI among food companies.

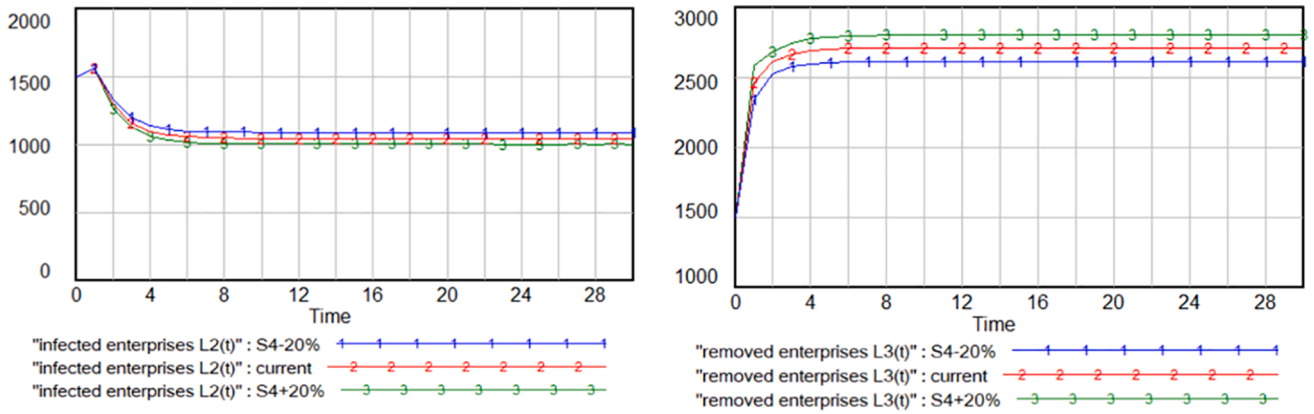

Fig. A12. Impacts of S4 on the contagion of CSI among food companies.

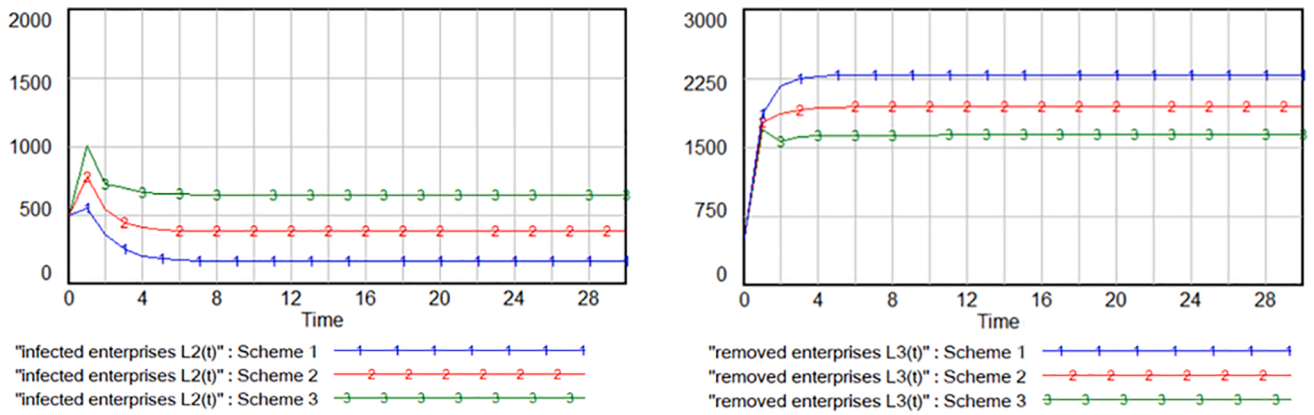

Fig. A13. The impact of strategy combination on the contagion of CSI among food companies.

behaviors in the food industry is effectively curtailed.

It can be seen from Table 1 that the number of infected firms, affected by the enhanced Strategy 3 (row 7), stabilized at 353 in the 16th periods, which is a slight decline compared to the number of stabilized infected firms, 417, before intervention. Also, the number of removed firms, affected by the enhanced Strategy 3, stabilized at 1153 in the 14th periods, which is a slight increase compared to the number of stabilized removed firms, 1083, before intervention. Furthermore, with the same enhanced intervention degree, the decreased number of infected companies in Strategies 1 and 2 are 316 and 242, respectively, both lower than 353 in Strategy 3. Also, the increased number of removed companies in Strategies 1 and 2 are 1240 and 1251, respectively, both higher than 1153 in Strategy 3. Therefore, Strategies 1 and 2 outperform Strategy 3.

(4) The governance effect of information disclosure mechanism on the contagion of food companies' CSI.

By changing the degree of information disclosure, we observe its impacts on the contagion of food companies' CSI. The simulation results are shown in Fig. 7:

From Fig. 7, it is apparent that improving the current information disclosure mechanism facilitates inhibiting the growth of infected companies, while the number of removed companies increased slightly.

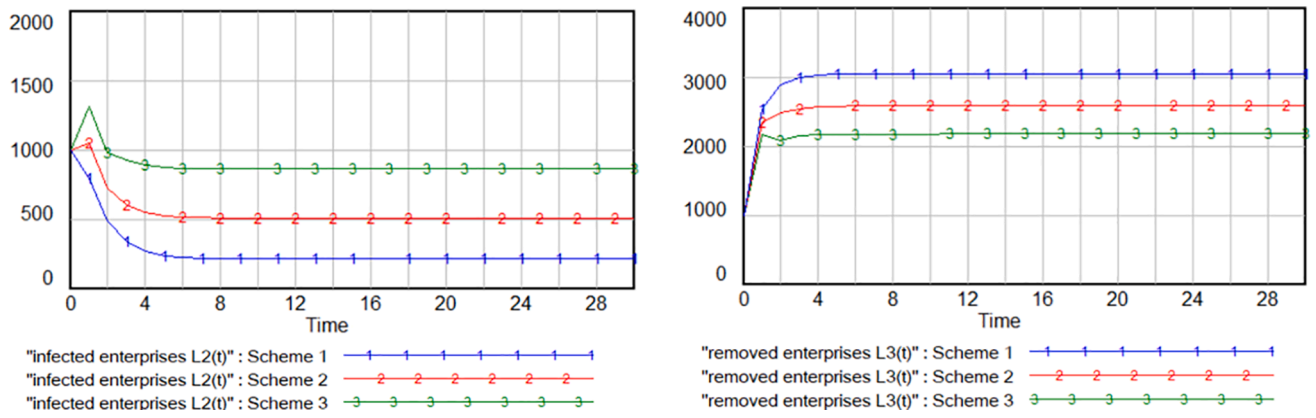

Fig. A14. The impact of strategy combination on the contagion of CSI among food companies.

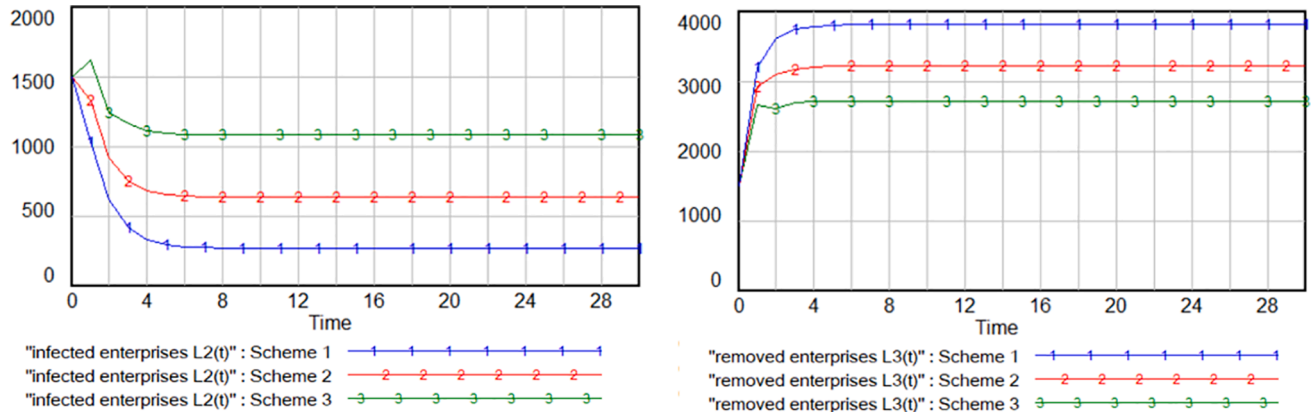

Fig. A15. The impact of strategy combination on the contagion of CSI among food companies.

It can be seen from Table 1 that the number of infected firms, affected by the enhanced Strategy 4 (row 9), stabilized at 400 in the 19th periods, which is a slight decline compared to the number of stabilized infected firms, 417, before intervention. Also, the number of removed firms, affected by the enhanced Strategy 4, stabilized at 1120 in the 15th periods, which is a slight increase compared to the number of stabilized removed firms, 1083, before intervention.

Furthermore, with the same enhanced intervention degree, the decreased number of infected companies in Strategies 1 and 2 are 316 and 242, respectively, both lower than 400 in Strategy 4. Also, the increased number of removed companies in Strategies 1 and 2 are 1240 and 1251, respectively, both higher than 1120 in Strategy 4. Therefore, Strategies 1 and 2 outperform Strategy 4.

(5) The governance effect of combined strategies on the contagion of food companies' CSI.

Due to the complex nature of the food industry, a number of strategies are needed to effectively control the contagion of CSI behaviors. In light of the complete experimental method, there are a large number of strategy combinations that must be simulated, and it is not possible to present them all in this paper. Out of the four strategies we propose, Strategy 1, Strategy 3, and Strategy 4 are long-term strategies, whereas strategy 2 is a short-term strategy. Therefore, this study proposes three representative Schemes in accordance with the different emphasis that has been placed on each of these strategies (Fig. 8).

Throughout Scheme 1, the weights are given to strategies S1 and S2, which are a combination of short- and long-term ideas. In Scheme 3, the weights are given to Strategies 3 and 4, which reflect a long-term perspective. In Scheme 2, each strategy is given equal weight, which represents an "average force" approach that is untargeted. The simulation results are as shown in Fig. 9.

According to Fig. 9, Scheme 1 is the most effective, followed by Scheme 2, and Scheme 3 is the least effective. As a result of Scheme 1, both long-term and short-term strategies are strengthened, particularly Strategies 1 and 2. These strategies have the potential to significantly reduce the spread of the contagion of food companies' CSI behavior. Because they can exert a strong deterrent effect on susceptible companies in a short amount of time by increasing the government's penalties for infected companies, resulting in more companies being removed. It is a long-term project to regulate the competitive order of the market, but it also provides companies with the opportunity to make changes to their governance structure and treat their own CSI behaviors in an impartial manner. Thus, regulating the order of market competition can play an instrumental role in managing the spread of CSI throughout the food industry. Scheme 2 involves conferring equal importance to each strategy, which is actually an untargeted "average force" approach, which will result in weaker impacts. It is apparent that Scheme 3 puts a great deal of emphasis on some long-term strategies while ignoring some short-term strategies, and that the implementation effect of long-term strategies will take a long time to appear. Therefore, the implementation effect of this solution may not be apparent. Thus, in order to obtain effective governance of CSI contagion behavior in food companies, it is necessary to combine long-term and short-term strategies, and more emphasis should be put on establishing a fair market order and increasing punishment for CSI behavior rather than avoiding 'average force'.

It can also be seen from Table 1 that the number of infected firms, affected by Scheme 1, stabilized at 108 in the 16th periods, while the number of removed firms, affected by Scheme 1, stabilized at 1526 in

the 13th periods. Furthermore, the number of infected firms, affected by the best single strategy, enhanced Strategy 2, stabilized at 242 in the 18th periods, while the number of removed firms, affected by the enhanced Strategy 2, stabilized at 1251 in the 15th periods. The results indicate that the governance effect of the Scheme 1 is obviously better than the best single strategy, Strategy 2, revealing that the strategy combination outperforms the single strategy.

5. Policy implications

The traditional governance strategy is mainly to increase the intensity of punishment on the irresponsible enterprises. But, in fact, after the Chinese government implemented strict laws and regulations, the CSI behavior of Chinese food enterprises still persists. Based on the analytical framework of behavioral economics, this study reveals the infectious mechanism of CSI behavior in food enterprises. Through static analysis, this study puts forward the corresponding governance strategies, the implementation effect of which are simulated and analyzed through the system dynamics model. This study has significant policy implications, including the following aspects.

First, this study finds that the "short-sighted cognitive bias" of food companies is the root cause of their CSI behavior. China's existing strategies for the governance of food companies' CSI behavior focus on government punishment (Kong et al., 2019). Due to information asymmetry, it is difficult for the government to discover the CSI behavior of enterprises in time. Due to the short-sighted cognitive bias, some food companies obtain market advantages by producing shoddy products through CSI behavior, and this unfair market advantage will bring competitive pressure to formal companies and force these companies to passively engage in CSI behaviors. On the other hand, the unjust enrichment brought about by CSI will also induce companies to actively imitate CSI behavior. Compared with post-event control, by correcting the short-sighted cognitive bias of food companies, it is helpful to avoid the occurrence and contagion of CSI behaviors in food companies from the source. The policy implications of our results are that correcting the "short-sighted cognitive bias" of food companies is the key to effectively regulate their CSI behaviors. Specifically, the government can help food companies to establish reasonable expectations and correct their short-termism behavior through guidance and regulation, which can fundamentally prevent the occurrence of CSI in food companies.

Second, the study found that CSI behavior can also lead to the development of "self-reinforcing effects" and "interactive contagion effects." The policy implication of this result is that the government needs to encourage the establishment of a collaborative governance system involving multiple parties in order to effectively curb CSI contagion in food companies. Government departments are the main body of China's safety regulatory force (Broughton and Walker, 2010; Unnevehr and Hoffmann, 2015). In view of the large number of food companies in China and the limited resources available to the government, it is unlikely that relying solely on government supervision will have a significant impact. It is necessary for the government to introduce multiple stakeholders—such as industry associations, the media, and the public—to improve the third-party supervision mechanism in order to compensate for the lack of government supervision resources and to ensure full supervision of food companies. Furthermore, it is imperative to actively promote the establishment of independent information disclosure institutions in order to improve the process of information disclosure. Disclosure of CSI information and the "blacklist" are effective methods for deterring companies from engaging in CSI practices by arousing the resistance of key stakeholders such as consumers.

Last, the simulation analysis suggests that increasing the punishment of violating companies and establishing a fair and standardized market order are more effective than other strategies. The reason for this is that direct punishment by the government has a stronger deterrent effect while, at the same time, a fair and standardized market order is more helpful for companies in establishing accurate expectations. The results also indicate the policy implication that the government must combine both long-term and short-term governance strategies in order to effectively control CSI contagion in food companies. Specifically, if food companies are repeatedly found to participate in CSI behaviors, the government can increase the supervision and punishment intensity of such enterprises. On the one hand, focusing on the supervision of food enterprises that repeatedly violate the law enables the government to narrow the scope of supervision. On the other hand, severe punishment will increase the crime cost to enterprises. In the short term, this strategy can maximize the use of limited government resources and improve governance efficiency. In the long run, we suggest that the government should establish and maintain a fair and standardized market order. A good market competition order facilitates food enterprises in forming the concept of legitimate operations and in establishing reasonable expectations, thus effectively reducing CSI behavior.

Overall, due to limited financial resources, the government's selective supervision of food companies cannot correct their CSI behavior in a timely manner. In addition, existing practices have shown that the government's harsh punishment laws on the CSI behavior of food companies has failed to achieve the expected effect. The government's establishment of a fair market competition order proposed in this paper can guide companies to establish reasonable expectations and avoid short-sighted behaviors from the source. The regulatory mechanism involving multiple stakeholders can not only reduce the pressure on the government but can also effectively govern the CSI behavior of food companies as a whole. Our policy suggestions could inform other resource-constrained countries when they tackle similar challenges.

6. Conclusion

With the rapid development of the Chinese food industry in recent years, many food safety issues have also emerged. A trend of mass outbreaks has been observed in the CSI of food companies. In the previous literature, there has been a heightened focus on the response of consumers and capital markets to the CSI of food companies. Thus, it is difficult to formulate a targeted governance strategy. In this paper, we establish an analysis framework based on bounded rational assumption of behavioral economics, investigate the contagion mechanism, and elicit a governance strategy for the CSI of the food industry. The effectiveness of the governance strategy is simulated and analyzed based on a SD model.

6.1. Research findings

(1) Due to the current imperfect supervision system of the Chinese food market, food companies are prone to CSI as a result of short-sighted bias. There is no doubt that this behavior has self-reinforcing effects as well as interactive contagion effects, which reinforce each other. In the food industry, CSI is widespread, resulting in a situation of collective moral misbehavior which, in turn, results in a crisis for the entire industry.

(2) Currently, the combination of various food safety governance strategies is capable of enhancing the control effect on CSI contagion. Despite the fact that each strategy has theoretically undeniable governance effects, the simulation results indicate that there is a difference in the implementation effect and that a specific combination of strategies achieves greater governance effects than a single strategy. To resolve the problem of collective moral misbehavior in the food industry, a coordinated governance strategy should be adopted in the process of governing food safety issues. A strong deterrent should be used by the government to curb potential CSI motives of other companies in the short term, and the government should increase penalties for CSI companies. Nonetheless, the government should also focus on establishing a fair and standardized food market competition order in the long run. Market and social forces can be integrated

into the food regulatory governance system through improved disclosure mechanisms and third-party governance mechanisms. Thus, multi-party coordinated governance can be achieved.

6.2. Theoretical contributions

The theoretical significance of this study can be summarized as follows. First, this paper extends the existing literature by examining the governance of food safety from the perspective of what leads to CSI behavior in food companies. The existing literature on China's food safety is concentrated on the macro-institutional level (Li et al., 2010, Qi, 2012; Unnevehr and Hoffmann, 2015; Kang, 2019). Macro institutions play a substantial role in shaping individual behavior by influencing preferences and goals. However, the current research is limited in its exploration of the preferences and behaviors of micro-production subjects, particularly food companies' choices in production behavior. This paper contributes to the food safety literature by providing new insights into food safety regulation from the perspective of food company CSI behavior contagion governance. Second, the existing research on the behavior of food companies is based on the assumption of perfect rationality (Kong, 2012; Saak, 2012; Dai et al., 2013; Wang et al., 2014; Guo et al., 2019). This paper presents a theoretical framework for CSI contagion in food companies based on the behavioral economics theory of bounded rationality, which is closer to the reality of business managers. Therefore, our framework contributes theoretically to the food safety governance literature by moving beyond the traditional paradigm. Furthermore, this paper illustrates the dynamics of CSI contagion in food companies using an analytical framework based on behavioral economics and develops corresponding governance strategies based on a comparative static analysis. This paper not only expands the applicability of behavioral economics to study the CSI behavior of food companies but also provides a basis for future research focused on behavioral economics. On the basis of this study, subsequent scholars may conduct empirical research. Additionally, this article differs from existing literature which focuses on suggesting strategies but does not examine the effect of implementing these strategies. This paper presents simulation-based strategies for effective governance. Specifically, this study parametrized the governance strategies based on comparative static analysis, introduced the strategies into the SD model for simulation analysis, compared the implementation effects of different strategies, and determined the optimal strategy. Therefore, this study provides a robust policy analysis tool for food safety governance.

6.3. Future research directions

This article focuses on the spread of CSI among food companies in the industry. There are also close links between food companies and upstream and downstream companies throughout the entire supply chain. Consequently, behavioral contagion caused by CSI is likely to occur. CSI contagion in heterogeneous companies could be the future research direction.

Further, since data sensitivities to CSI of food companies make it difficult to obtain relevant data, this paper does not include empirical analysis. The results will be more comprehensive and detailed if an empirical analysis can be conducted. Upon improving the data, future empirical studies can be conducted on the specific impact of CSI contagion behavior on food companies.

CRediT authorship contribution statement

Gang Tian: Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Yumeng Wang:** Writing – original draft, Writing – review & editing. **Yu Gong:** Supervision, Writing – review & editing. **Yi Tian:** Methodology, Writing – review & editing. **Xuexu Piao:** Methodology, Writing – review & editing. **Tianyu Zhang:** Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Proposition	Main parameters	Meaning	Relationship between parameters	Illustration	Strategies	Equation	Explanation
Proposition 1	$\beta 0 < \beta < 1$	Short-sighted cognitive bias coefficient	Negatively correlated with Δx_{iL}, refer to Equation (9)	The greater the β, the smaller the degree of "short sighted cognitive bias" of food companies, and the smaller the number of counterfeit products produced by food companies.	This suggests that governance strategy needs to consider weakening the degree of "short sighted cognitive bias" in food companies, i.e., increasing β		
Proposition 1	$\alpha 0 < \alpha < 1$	The probability that CSI behavior be detected by the public and punished by the government	Negatively correlated with Δx_{iL}, refer to Equation (9)	The greater the α, the greater the degree of CSI is detected and punished, and the smaller the number of counterfeit products produced by food companies.	This suggests that the governance strategy needs to consider increasing the likelihood of CSI being detected and punished, i.e., increasing the α		
Proposition 2	$G0 < G < 1$	The degree of perfection of the company's own governance structure.	Positively correlated with β, refer to Equation (10)	The greater the G, the greater the degree of perfection of the company's own governance structure, and the smaller the			This paper mainly studies the governance of the "short-sighted cognitive bias" of food companies by external forces, so internal

(continued on next page)

(*continued*)

Proposition	Main parameters	Meaning	Relationship between parameters	Illustration	Strategies	Equation	Explanation
				possibility of "short-sighted cognitive bias" is.			factors of the company are not considered.
Proposition 2	$K0 < K < 1$	The degree of perfection of the competition order in the food market	Positively correlated with β, refer to Equation (10)	The greater the K, the greater the degree of perfection of the competition order in the food market, and the smaller the possibility of 'short-sighted cognitive bias' is. (According to the definition of β, the greater the value of β, the smaller the short-sighted cognitive bias. Therefore, K is positively correlated with β, indicating that the greater the K, the smaller the short-sighted cognitive bias).	Strategy 1	Equation (16)	Increase K to increase β, so as to reduce the degree of "short-sighted cognitive bias" of food companies, and reduce CSI behavior.
Proposition 2	$nn \geqslant 0$	The number of occurrences of CSI behavior of food companies	Negatively correlated with β, refer to Equation (10)	The greater the n , the greater the possibility of "short-sighted cognitive bias", and he more times of the CSI behavior of food companies occur.			This paper mainly studies the governance of the "short-sighted cognitive bias" of food companies by external forces, so internal factors of the company are not considered
Proposition 2	$I0 < I < 1$	The acceptance of CSI behavior in the food industry	Negatively correlated with β, refer to Equation (10)	The greater I is, the more acceptable the CSI behavior in food industry, and the greater the possibility of "short-sighted cognitive bias".			This paper mainly studies the governance of the "short-sighted cognitive bias" of food companies by external forces, so internal factors of the company are not considered
Proposition 2	$L0 < L < 1$	The strength of government penalties for CSI behavior of food companies	Positively correlated with α, refer to Equation (11)	The greater L is, the more punishment the government will impose, i.e., the greater α is.	Strategy 2	Equation (17)	Increase L,to increase α, so as to promote food companies to reduce CSI behavior
Proposition 2	$P_g0 < P_g < 1$	The degree of supervision of the third-party regulators	Negatively correlated with α, refer to Equation (11)	The smaller P_g is, the more effective the third-party regulators' supervision is, namely α is greater.	Strategy 3	Equation (18)	Decrease P_g to increase α, so as to promote food companies can reduce CSI behavior
	$D0 < D < 1$	The degree of perfection of CSI information disclosure mechanism of food companies.	Positively correlated with α, refer to Equation (11)	The greater D is, the more perfect the disclosure mechanism is, the easier CSI is to be discovered, and the greater α is.	Strategy 4	Equation (19)	Increase D, to increase α, so as to promote food companies to reduce CSI behavior

Appendix B.

We adopted different assignment Schemes in order to verify the robustness of the model results. In the simulation, the number of initial susceptible companies is 2000, and both the initial values of the infected companies and the removed companies are 500, 1000, and 1500, respectively. It is evident from our results that different assignment Schemes exhibit the same trend. For example, Strategy 1 and Strategy 2 perform better than Strategy 3 and Strategy 4 in different settings. Combination strategy 1 is also the most effective in different settings, while combination strategy 3 is the least effective. The detailed results are presented as the following.

(1) Simulation results of separated strategies: both initial values of the infected companies and the removed companies are 500.

As can be seen in Figs. A1-A4, the minimum values of the infected companies in Figs. A3 and A4 are larger than those in Figs. A1 and A2, while the maximum value of the number of removed companies in Figs. A3 and A4 are smaller than those in Figs. A1 and A2.

The results also indicate that if the intensity of strategies increased by 20 % or 40 % (from Line 2 to Line 3 or from Line 1 to Line 3 in Figs. A1-A4), the decreased number of infected companies is larger in Strategies 1 and 2 than that in Strategies 3 and 4, and the increased number of removed companies is larger in Strategies 1 and 2 than that in Strategies 3 and Strategy 4.

Therefore, in these two situations, Strategies 1 and 2 outperform Strategies 3 and 4.

(2) Simulation results of separated strategies: both initial values of the infected companies and the removed companies are 1000.

As can be seen in Figs. A5-A8, the minimum values of the infected companies in Figs. A7 and A8 are larger than those in Figs. A5 and A6, while the maximum value of the number of removed companies in Figs. A7 and A8 is smaller than that in Figs. A5 and A6.

The results also indicate that if the intensity of strategies increased by 20 % or 40 % (from Line 2 to Line 3 or from Line 1 to Line 3 in Figs. A5-A8),

the decreased number of infected companies is larger in Strategies 1 and 2 than that in Strategies 3 and 4, and the increased number of removed companies is larger in Strategies 1 and 2 than that in Strategies 3 and Strategy 4.

Therefore, in these two situations, Strategies 1 and 2 outperform Strategies 3 and 4.

(3) Simulation results of separated strategies: both initial values of the infected companies and the removed companies are 1500.

As can be seen in Figs. A9-A12, the minimum values of the infected companies in Figs. A11 and A12 are larger than those in Figs. A9 and A10, while the maximum value of the number of removed companies in Figs. A11 and A12 is smaller than that in Figs. A9 and A10.

The results also indicate that if the intensity of strategies increased by 20 % or 40 % (from Line 2 to Line 3 or from Line 1 to Line 3 in Figs. A9-A12), the decreased number of infected companies is larger in Strategies 1 and 2 than that in Strategies 3 and 4, and the increased number of removed companies is larger in Strategies 1 and 2 than that in Strategies 3 and Strategy 4.

Therefore, in these two situations, Strategies 1 and 2 outperform Strategies 3 and 4.

(4) The simulation results of the strategy combination when both the initial values of the infected companies and the removed companies are 500
(5) The simulation results of the strategy combination when both the initial values of the infected companies and the removed companies are 1000.
(6) The simulation results of the strategy combination when both the initial values of the infected companies and the removed companies are 1500.

As can be seen from Figs. A13- A15, when different initial values are assigned, the trends of the three Schemes of the strategy combination are the same. The number of infected companies in Scheme 3 is the highest, while the number of infected companies in Scheme 1 is the lowest. Meanwhile, the number of removed companies in Scheme 3 is the lowest, while the number of removed companies in Scheme 1 is the highest. Scheme 1 has the best governance effect, while Scheme 3 has the worst governance effect.

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