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Ming Liu
Shandong University

yemei li (✉ 161611173@csu.edu.cn)
Shandong University https://orcid.org/0000-0001-7577-5001

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Study on the Effect of Income Perception on Cleaner-Production Fraud

Ming Liu, Yemei Li

1 School of Economic Research, Shandong University, Shandong 250000, China; liumingcn@foxmail.com
1* School of Economic Research, Shandong University, Shandong 250000, China; 161611173@csu.edu.cn

* Correspondence: 161611173@csu.edu.cn; Tel.: +86 18390921943

Abstract: We investigate a single-cycle product supply chain with one retailer and one supplier in a game model, where the supplier is the leader and the retailer is the follower. By innovatively introducing cleaner production fraudulent income perception factor into the game model, we studied the mechanism of the effect of enterprise social responsibility and environmental awareness on cleaner production fraud. The results showed that the value of cleaner production fraudulent income perception factor will affect the enterprise's choice of differentiation strategy. When the enterprise's sense of social responsibility is weak, i.e., the fraudulent income perception factor is correspondingly large, it more likely to choose cleaner production fraud. Conversely, under the constraints of high social responsibility, it more likely avoids production fraud. Regarding government supervision, a reasonable punishment for cleaner production fraud can reduce such violations to some extent. However, after the punishment reaches a level, the efficiency of supervision beginning to decline. In views of that, improving enterprise social responsibility through institutional reform is a more effective way to reduce cleaner production fraud. To contribute to a healthy competitive market environment, government supervision should establish a feedback mechanism, and make timely adjustments.

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1 Introduction

There are a few conditions when a behavior called production fraud. Firstly, the fraudster has the defraud intention; secondly, the fraudster has fraudulent behavior, such as fabricating false information, distorts the true situation, etc.; the civil act committed by the defrauded party is the result of the fraud (Duffield et al., 2001; Dodd, 2018; Fisher, 2015). For about cleaner production fraud, the focus of which is the uncontrollable damage to the environment compared with normal production fraud. Cleaner production fraud exists because it generates illegal excess incomes. Under this situation, a number of suppliers break the laws and regulations on cleaner production, which seriously causes serious uncontrollable environmental pollution (Spink and Moyer, 2011; Spink et al., 2015). Besides that, there are following forms of expression in reality. Forging certificates of cleaner production and evading supervision. For example, some enterprises involving in cleaner production fraud always prepare two sets of production equipment, one of which is cleaner production devices and the other is general production equipment. The general production equipment doesn't meet the government's environmental standards but it has a relatively lower variable cost. For about cleaner production devices, because of the higher cost, it operates only when they are under government supervision. Furthermore, counterfeiting other's registered trademark, forging or fraudulently using environmental certification marks, false claims and representations of the production process and passing off unqualified polluting products as qualified products are also called cleaner production fraud. The second type of cleaner production fraud is more common. Besides, given the large differences between the second category of products involving cleaner production fraud and environmentally friendly products, which is easier to model and analyze in the
supply chain, the modeling in our study is mainly related to the second category of cleaner production fraud. Nowadays, there are usually several third-party touch-points in the consumption market, such as vendors, suppliers, transporters, packers, third-party manufacturers or subcontractors, distributors, stockiest, or service providers and so on. The participation of multiple subjects can conspicuously increase the risk of collusive cost-based frauds, and it is harder to detect. At the same time, e-commerce is becoming a burgeoning distribution channel for relative consumer products companies, especially for the FMCG Enterprise. The supply chain has become an important source of new fraud risks (Muwodzi, 2019; Van Wilsem, 2013; Norris et al., 2019). For example, some online products to sale by third-party sellers at highly discounted prices, without authorized brand protection, usually obtain from the supply chain leakage. The relevant products are likely to come from highly polluting enterprises that have not been approved by the Ministry of Environmental Protection.

In recent years, the world economy has been developing at a high speed, but environmental problems are becoming increasingly serious (Beeson, 2010; Hens et al., 2018). Under the context of environmental problems, researches on cleaner production are emerging. According to an expert report published in The Lancet in 2018, environmental pollution has become a serious threat to human survival, with at least 9 million people dying each year worldwide because of air, water, soil and workplace pollution (Das and Horton, 2018). The report points out that while some of the traditional pollution problems have been significantly improved under the active treatment of governments, modern pollution problems such as air and chemical pollution caused by fossil fuels are rapidly increasing and the situation is worrisome (Das and Horton, 2018). This shows that cleaner production has become an important choice for global sustainable development. Until now, existing research on cleaner production focuses on the analysis of the relationship between environmental pollution and production (Lu et al., 2017), cleaner production efficiency measurement (Zulfiqar et al., 2017; Liu et al., 2020), cleaner production improvement (Zulfiqar et al., 2017) and related policy evaluation (Leroy and Crabb, 2012). That is, existing studies mainly focus on the causes of pollution under policy control and provide policy recommendations. Few studies have been conducted on hidden sources of pollution that is not under government control, such as cleaner production fraud. In the case of developing countries, they haven’t undergone the long-term development process as developed countries. Some of the backward production capacity is not completely eliminated from the market. As a result, drove by economic interests, the problem of fraudulent clean production does not meet government norms abound. Some manufacturers illegally discharge waste gas and wastewater, and some areas are full of small workshops that produce serious pollution, which has caused incalculable damage to the local environment. Since it is not in the scope of the government's corporate management, the government's environmental strategy is difficult to implement accurately. Besides, the cost of dealing with relevant pollution is huge, so such behavior is like a cancer that is deeply damaging the development achievements of developing countries in recent years. However, given the role of the market, it is difficult to eliminate such phenomena in the short term. Based on this, our study attempts to analyze the causes of such cleaner production fraud, and then tries to propose corresponding policy recommendations.

Although there are more articles on production fraud, product fraud, there are fewer articles on cleaner production fraud. Therefore, the following is a review of the relevant literature on production fraud and product fraud. Production fraud and product fraud are harmful to both the society and the citizens (Wheatley and Spink, 2013). For consumer products industry, fraud can be a pressing
challenge for it with the potential to impact finances (Wang and Winton, 2014), erode customer trust (Kendall et al., 2018) and impact brand value (Johnson et al., 2014). For enterprises whose patent rights are infringed, production fraud affects their innovation effort, reduces their innovation performance, and then affects the overall innovation environment of society. Besides that, when it comes to food fraud, the effect of which to citizens' health and social stability is incalculable (Spink and Moyer, 2011; Breitenbach et al., 2018). Shears (2010) found that thousands of consumers suffer from the injury of food production fraud in the United Kingdom every year. In recent years, the "melamine event" (Zhang et al., 2009; Douglas et al., 2017), "Clenbuterol event" (Spiller et al., 2013; Zhou, 2015), "Horsemeat event" (Lopez et al., 2014; Reisch, 2014; Ellis et al., 2015) and "fraudulent wines event" (Moore et al., 2012) have been come to light. Especially for the scandal of melamine, it rocked global food and beverage industry (Morehouse and Cardoso, 2011). It demonstrated that although our detective technology and modern safeguards become more and more advanced, the food supply chain is still vulnerable to disruption or contamination. Furthermore, it is shocked that a single instance of fraud resulting from economic gain can have global consequences. It significantly affects enterprise's brands, industry's performance, peoples' lives and even the entire countries' reputation. Bouzembrak and Marvin (2015) found that fraud in food production mainly for food sanitation certificate, incorrect date, misleading and fraudulent use of labels and so on. These vicious food production frauds are not only harmful to human health, but also have a great threat to the social stability. Moreover, it makes food enterprises suffering from an unprecedented crisis of confidence (Gong et al., 2013; Falkheimer and Heide, 2015; Vallee and Charlebois, 2015). There are a number of production fraud cases in other industries (Button et al., 2009). Such as financial fraud (Li et al., 2018; Liao et al., 2019), retail forest products fraud (Wiedenhoeft et al., 2019), car production fraud (Braithwaite and John, 1979) and so on. However, because of the atypical nature of such cases, we will not go into detail.

To explore the inherent causes of its generation is a prerequisite for combating production fraud (Donaldson, 2014; Mu et al., 2014; Manning and Soon, 2016; Michael and Georgios, 2016). Gallagher and Thomas (2010) found that the primary motive behind production fraudulent is economic greed or excessive profit seek. With the explorer of milk production fraud issues, Handford et al. (2016) found that the information asymmetry, the lack of strict supervision and the seek for supplier profit are the main reasons for production fraud. Darby and Karni (1973) also mentioned the importance of information asymmetry in production fraud. Overall, the existing studies show that the lack of effective regulation and excessive profits is the major causes of production fraud. To build a healthy and orderly market, enterprises, as major participants, are supposed to not only stay focus on economic interests, but also pay attention to their own social responsibility (Jiang and Zhu, 2013).

From the above analysis, we learned that economic interests are the main driving factor of cleaner production fraud. And generally speaking, the enterprise seeks for cleaner production fraud economic interests are an important manifestation of lack of social responsibility (Dove, 2020). Shnayder et al. (2016) suggested that in the era of information, compared with the economic efficiency, social responsibility is becoming more important for the development of enterprise. However, although the existing studies found that there is relationship between social responsibility and production fraud (Harjoto, 2017; Rodgers, 2015; Liao et al., 2019), but the effect of social responsibility on cleaner production fraud mechanism has not been effectively studied yet. Therefore, as an inherent factor of enterprise fraud decision-making, social responsibility is worthy
of further study.

Based on the above research, we use a game model to study a single-period product supply chain with a retailer and a supplier. The enterprise social responsibility and environmental awareness perception variables were introduced in our paper innovatively. It explored enterprise social responsibility benefit perception, government supervision and punishment, fraudulent behavior and other variables, which affect on their decision-making behavior. Our results show that, the higher the enterprise social responsibility, the more sensitive to production fraud. When an enterprise has a high social responsibility, since fraudulent behavior is contrary to the social responsibility, the perception of the enterprise's fraud benefits is negative, so the total income of the fraud is negative. From the perspective of overall social welfare improvement, the government's appropriate punishment can decrease enterprise fraud effectively. In views of that, our paper innovatively introduced the enterprise's income perception variables, and explored the influence of the enterprise's income perception and government supervision on their behaviors.

There are several contributions. First of all, we innovatively use cleaner production fraudulent income factor as an agent variable for enterprise social responsibility. In this way, enterprise social responsibility is involved into the mechanism analysis of cleaner production fraud decisions theoretically and practically. Secondly, we use social responsibility agent variables as an income affecting factor, which is different with the current research that dividing the two. Finally, based on the above setting, we received the optimal government penalty amount under different social responsibility level, which is significant for improving cleaner production fraud regulation.

The rest of our paper is organized as following. Section 2 is methodology, which contains theoretical framing analysis and game model. Section 3 is numerical analysis. The effect factors of enterprise’s fraud decision-making is explored in this part. In section 4, the discussion is described in detail. Conclusions and corresponding implications are provided in Section 5.

2 Methodology

2.1 The model description and assumptions

Our research model involves two subjects, the supplier and the retailer. Suppliers can provide differentiated products for retailers in the downstream of the supply chain. As the leader in the supply chain, the supplier determines the supply price, and whether to choose high-cost cleaner production. If a retailer chooses to provide false information to the consumer, the supplier will give the retailer some price discount, etc. As for the retailer, as a follower, it decides whether to provide false information to the consumer who purchases its product. If it chooses to provide false information about the product, such as emphasizing that all the products they sell are legal green products which has certificate of qualification, there will be a level of effort to provide false information about the product, which will directly affect the difficulty of the government supervision, as well as the probability of discovering production fraud. Specifically, when a retailer chooses to provide false information about the product and production process, it can only dictate that its product is genuine and legal or make efforts to provide false purchase records. Obviously, the latter is more difficult to identify as fraud. The decision tree diagram of the two is shown below.
Fig. 1 behaviors of suppliers and retailers in product supply chain

During the decision-making period, when suppliers choose to produce goods using environmentally unfriendly production methods, if the retailer not to provide false information to consumers, and then cleaner production fraud is discovered because of supervision. The supplier shall bear the main punishment. For the retailer, it has a concerted violation of the law of knowing but not reporting, so it also needs to pay a certain amount of fine, but the amount is relatively small. Conversely, if the retailer chooses to provide false information to consumers, the supplier and retailer should jointly bear the corresponding punishment. For example, if a supplier A produce leather goods and has not installed environmental protection equipment. It will produce serious air pollution, water pollution and solid waste pollution. Supplier A sells its products under counterfeit brands. Retailer B has not provided false promises or information to consumers. Once the consumer finds that the product is "Three without" unqualified product or residents near the leather factory found illegal emissions. The consumer or the relevant will reports to government. Retailer B will cooperate with the investigation and provide truthful sources of supply channels. At this time, because retailer B did not provide false information, if the government pursues accountability, supplier A shall bear the main penalty. In another situation, if retailer B conducts false product marketing, fabricates supply channels, or even falsifies purchase vouchers in exchange for consumer trust. At this time, if product fraud is found to be held accountable, both the retailer and the supplier shall bear corresponding legal liabilities.

To simplify our research, we assume that if the product supply is fraudulent, the detection time for fraud to be found obeys an exponential distribution with the parameter. Let the probability density function be \( f(\cdot) \). The probability distribution function is \( F(\cdot) \). Therefore, \( f(\cdot)/F(\cdot) \) is a monotonously decreasing function. If the retailer is involved in fraud, we assumed that its effort level is \( e \), and \( e \in [0,1] \); let \( \lambda = a + e \) and \( a \) is a constant and \( a > 0 \), that is, in a fraud, the higher the fraud effort paid by the retailer, the lower the probability of being discovered, which is consistent with reality.

During the decision-making period, supplier’s cleaner production fraudulent income is composed of two parts, the general income without fraud, and the excess income from cleaner production fraud. Specifically, if the product supplier does not commit cleaner production fraud, it can only obtain a basic income roughly equivalent to the value of the product. However, if it chooses to engage in cleaner production fraud, such as illegal discharge of waste or counterfeiting a brand, in addition to obtaining a basic income roughly equivalent to the value of the product, it can also obtain a bonus income from production cost reduction.

In our study, the total income is expressed as \( \alpha + t\theta \), where \( \alpha \) is the basic income of the supplier who did not engage in cleaner production fraud. \( t \) is the excess income of involving
cleaner production fraud, and $\theta_s$ is the income perception of production fraud. Similarly, unit income of a retailer’s product sales also consists of two parts. One is the basic price differential income of selling products, and the other is the excess income formed by the discounted price given by the supplier to reward its behavior when it chooses to provide false information. The retailer’s unit income is specifically expressed as $\beta + \gamma \theta_r$, where $\beta$ is the unit income of product retail, $\gamma$ is the proportion of false information provided by the overall false information, and $\theta_r$ is the perception of the retailer’s sales of the product involved in fraud.

The intensity of enterprise social responsibility and environmental protection perception directly affects the magnitude of income perception. When $\theta_i < 0$, the enterprise provides products involved in cleaner production fraud with a non-positive perception of income. At this time, its fraudulent behavior negatively affects the enterprise’s overall income, and the enterprise will refuse to participate in fraudulent cleaner-production behavior. Conversely, when $\theta_i \geq 0$, the enterprise has a certain possibility to participate in fraudulent cleaner-production activities driven by monetary interests. However, whether to participate depends on the enterprise's analysis of expected benefits. If the expected loss caused by the punishment is too high, it is clear that the enterprise will give up participating in fraud. To be specific, if $0 < \theta_i < 1$, the enterprise has a strong sense of social responsibility, and its fraudulent acts will produce a certain sense of guilt, but its desire to chase money makes it still willing to involve in cleaner production fraud. If $\theta_i = 1$ (where $i = s, r$), if $a=1$, the enterprise's income perception of fraudulent products is neutral. At this time, the sense of social responsibility will not affect the enterprise’s income from fraudulent behavior. Finally, if $\theta_i > 1$, the enterprise’s sense of social responsibility is extremely weak and the desire to chase interests is extremely strong. Fraudulent behavior positively affects the overall income of the enterprise. Based on the above assumptions, the main variables in our paper follow as the table below.

| Variables | Definition |
|-----------|------------|
| $R_s$     | Unit income of supplier |
| $R_r$     | Unit income of retailer |
| $e$       | Efforts made by retailers to provide false information |
| $\phi_s$  | Government’s unit penalties received by the supplier when fraud discovered |
| $\phi_r$  | Government’s unit penalties received by the retailer when fraud discovered |
| $\alpha$  | Unit income of supply for cleaner-production products |
Additional unit income of products involved in cleaner-production frauds

Supplier’s perception of income from producing products involved in fraud

Unit income of retailer from selling cleaner-production products

Retailer’s perception of income from providing products involved in fraud

Price discount the supplier gives to the retailer when the retailer participates in fraud

Time cost for consumers to detect production fraud

2.2 payment function

There are two factors in our model, the retailer and the supplier, and their behavior selection and income matrix are as follows.

When a supplier chooses to provide a cleaner-production product, the retailer sells the product normally. Both the retailer and the supplier have basic income. At this time, the income of the supplier $R_s = \alpha$; the income of the retailer $R_r = \beta$. When a supplier provides a product involved in cleaner production fraud, the retailer has two behavioral choices, one is to collude and provide false information, and the other is not to collude. The income matrix of the two actors in this case is shown in the table below:

| Behavioral choice | Probability                  | $R_s$        | $R_r$        |
|-------------------|-----------------------------|--------------|--------------|
| Collude           | The probability of detected | $-\phi_s$    | $-\phi_r$    |
|                   | $\left(\frac{1}{a + e}\right)$ |               |              |
|                   | The probability of undetected | $\alpha + t\theta_s - y$ | $\beta + y\theta_r$ |
|                   | $\left(1 - \frac{1}{a + e}\right)$ |               |              |
| Not to Collude    | The probability of detected | $-\phi_s$    | 0            |
|                   | $\left(\frac{1}{a}\right)$ |              |              |
|                   | The probability of undetected | $\alpha + t\theta_s$ | $\beta$   |
|                   | $\left(1 - \frac{1}{a}\right)$ |               |              |

The above table lists the probabilities and benefits in different situations. It can be obtained that when the retailer chooses to provide false information. The supplier’s expected income is

$$R_s = (1 - \frac{1}{a + e})(\alpha + t\theta_s - y) - \frac{1}{a + e}\phi_s$$

and the retailer’s expected income is

$$R_r = (1 - \frac{1}{a + e})(\beta + y\theta_r) - \frac{1}{a + e}\phi_r.$$ When the retailer gives up collusion and chooses not to provide false information, the supplier’s expected income is

$$R_s = (1 - \frac{1}{a})(\alpha + t\theta_s) - \frac{1}{a}\phi_s$$

and the retailer's expected income is

$$R_r = (1 - \frac{1}{a})\beta.$$ Based on the above analysis, the game tree between suppliers and retailers is shown in the figure below.
2.3 Game process

From Figure 2 above, when a retailer chooses to commit fraud, the probability of being found is \(1/(a + e)\).

At this point, if the retailer chooses to provide false information and the degree of effort \(e = 1\), the retailer can effectively reduce the possibility of cleaner production fraud being detected. When the selected effort level \(e = 0\), obviously, the probability of cleaner production fraud being detected is not significantly affected. Based on the principle of incentive compatibility, suppliers tend to incentivize retailers to make more effort in fraud to reduce the possibility of being discovered. Therefore, in the face of the retailer’s degree of effort, the supplier usually gives a different purchase discount. The higher the retailer’s effort to commit fraud, the more discounts the supplier will give. From the above analysis, the expected return of the retailer’s choice of \(a=1\) strategy is significantly higher than the expected return of the retailer’s choice of other fraud efforts. \(a=1\) is the dominant strategy in this situation. And if the retailer chooses not to provide false information, it will not be able to obtain the price discount provided by the supplier. At this time, if cleaner production fraud is found, it will not be punished by the government department. Obviously in this case, the effort level \(e = 0\) is better than \(e = 1\). Based on the above analysis, the following lemma is obtained.

**Lemma 1:** When the retailer chooses to provide false information about the product, it will choose the effort level of \(a=1\), and when it gives up product fraud, the effort level is \(a=0\).

The following will calculate and analyze the establishment conditions of the retailer’s choice of fraud when the supplier chooses cleaner production fraud.

Obviously, when a supplier provides a product involved in cleaner production fraud. Whether the retailer will choose to follow it to conduct fraud depends on the expected benefits obtained from the fraud behavior. The expected income is the difference between the additional income from fraud and the expected loss from fraud being discovered. Therefore, the expected income depends on the relative size of the two. From figure 2, when a retailer chooses to provide false information, its expected return is \(1 - \frac{1}{a+1}(\beta + y\theta_e) - \frac{1}{a+1}\phi_e\). It can be seen that \((1 - \frac{1}{a+1})(\beta + y\theta_e)\) is the excess income of fraud, and \(\frac{1}{a+1}\phi_e\) is the expected loss after cleaner production fraud is discovered. In addition, the expected benefit of the retailer not providing false information is \((1 - \frac{1}{a})\beta\).

Obviously, the retailer will choose to provide false information only when the expected income from providing fraudulent information is greater than the income from not providing fraudulent information.
information. Therefore, when \( \frac{1}{a+1} - \frac{1}{a^2} \beta \geq 0 \), the retailer chooses to provide false information. As for the retailer’s perception of fraudulent income, after simplification, it can be obtained that when \( \theta_i < \frac{a\phi_i - \beta}{a^2 y} \), the retailer’s effort to choose fraudulent behavior is \( e = 1 \), on the contrary, if \( \theta_i < \frac{a\phi_i - \beta}{a^2 y} \), the retailer tends to choose not to provide false information of products involved in cleaner production fraud, at this time, its chosen degree of effort \( e = 0 \).

Based on the above analysis, Lemma 2 is obtained.

**Lemma 2:** When the retailer's income perception meets the condition \( \theta_i \geq \frac{a\phi_i - \beta}{a^2 y} \), it chooses to provide fraudulent information and collude with the supplier of cleaner production fraud. When the retailer's income perception is \( \theta_i < \frac{a\phi_i - \beta}{a^2 y} \), it chooses to give up providing false information.

Based on the above analysis, it is obvious that when a retailer has a low sense of enterprise social responsibility and a high perception of fraudulent returns, it chooses to provide false information and colludes with the supplier to conduct cleaner production fraud, otherwise, it gives up providing false information. When \( \theta_i < 1 \), the perception of social responsibility makes the retailer's expected income less than its actual income, especially when \( \theta_i < 0 \), the enterprise's sense of social responsibility is extremely high, and engaging in activities that provide false information significantly reduces its own expected income level. When \( 0 < \theta_i < \frac{a\phi_i - \beta}{a^2 y} \), although the enterprise has a low degree of social responsibility and has a certain perception of fraud gains, the income gained from participating in cleaner production fraud is obviously less than the expected loss of punishment for cleaner production fraud been discovered. Therefore, it also will choose to give up participating in cleaner production fraud.

After analyzing the establishment conditions for retailers to engage in fraudulent activities, the following will analyze the establishment conditions for suppliers to provide products involved in cleaner production fraud.

From the above, when \( \theta_i \geq \frac{a\phi_i - \beta}{a^2 y} \), the retailer chooses to provide fraudulent information to obtain higher income. At this point, based on Lemma 1, the retailer's effort to choose fraudulent behavior is 1. Then, in this situation, the supplier’s expected income is

\[
(1 - \frac{1}{a + e})(\alpha + t\theta_i - y) - \frac{1}{a + e}\phi_i.
\]

Similar to the above analysis of the retailer’s expected income composition, \( (1 - \frac{1}{a + e})(\alpha + t\theta_i - y) \) is the income from the supplier’s production of products involved in cleaner production fraud, \( \frac{1}{a + e}\phi_i \) is the expected loss that it has to bear when it is found that the products it produces involved in cleaner production fraud. When \( \theta_i < \frac{a\phi_i - \beta}{a^2 y} \), the retailer chooses not to provide fraudulent information. Obviously, at this time \( e = 0 \), the retailer's sales activities do not change the probability of the supplier's product being seized, and the supplier's expected return is

\[
(1 - \frac{1}{a + e})(\alpha + t\theta_i - y) - \frac{1}{a + e}\phi_i.
\]

By comprehensively analyzing and calculating the expected income in the two situations where the supplier provides products involved in cleaner production fraud and not producing relevant products, the specific conditions for the supplier to produce products involved in cleaner production fraud can be obtained. That is, when \( (1 - \frac{1}{a + e})(\alpha + t\theta_i - y) - \frac{1}{a + e}\phi_i - \alpha \geq 0 \), the supplier chooses
to provide products involved in cleaner production fraud, on the contrary, when
\( (1 - \frac{1}{a + e})(\alpha + \theta_s - y) - \frac{1}{a + e} \phi_s - \alpha < 0 \), the supplier chooses not to provide products involved in
cleaner production fraud. In simplifying the calculation of the above formula, it can be obtained that
when the supplier's fraudulent income perception factor \( \theta_s \geq \frac{(a + e)y + \phi_s + \alpha - y}{(a + e - 1)t} \). The supplier
tends to choose to provide products involved in cleaner production fraud. Conversely, when
\( \theta_s < \frac{(a + e)y + \phi_s + \alpha - y}{(a + e - 1)t} \), the supplier gives up providing products involved in cleaner production
fraud and chooses to provide environmentally friendly products at this time. Based on the above
analysis, Lemma 3 is obtained.

**Lemma 3:** When the supplier's income perception meets the condition
\( \theta_s \geq \frac{(a + e)y + \phi_s + \alpha - y}{(a + e - 1)t} \), the supplier tends to provide products involved in cleaner production
fraud. Conversely, when \( \theta_s < \frac{(a + e)y + \phi_s + \alpha - y}{(a + e - 1)t} \), the supplier tends to provide environmentally
friendly products instead of products involved in cleaner production fraud. When \( \theta_s < 0 \), the
supplier's perception of the benefits of providing products involved in cleaner production fraud is
negative, and providing relevant products will produce negative benefits. Under the guilt brought
by the sense of social responsibility, the supplier enterprise will give up providing products involved
in cleaner production fraud. However, when \( 0 \leq \theta_s < \frac{(a + e)y + \phi_s + \alpha - y}{(a + e - 1)t} \), although the
enterprise’s sense of social responsibility is not strong, and there exists a high perception of the
benefits of products involved in cleaner production fraud, in view of the legal risks of providing
products involved in cleaner production fraud or the high penalty costs from the government, the
enterprise will also choose to give up producing products involved in cleaner production fraud.

2.4 Best discounts rate and best punishment

(1) The Best discounts rate

According to Lemma 3, when a supplier provides a product involved in cleaner production
fraud, the supplier’s fraudulent income perception factor meets the condition
\( \theta_s \geq \frac{(a + e)y + \phi_s + \alpha - y}{(a + e - 1)t} \). At this time, the retailer has two behavioral choices, one is to collude
with the supplier, by providing efforts such as false information to prevent products from being
detected as unqualified, the second is to give up false information and sell products honestly. Based
on the principal-agent relationship between suppliers and retailers, in order to reduce the risk of
detection of products involved in cleaner production fraud, suppliers tend to provide retailers with
certain price discounts to encourage retailers to participate in fraud. From the above analysis, when
\( (1 - \frac{1}{a + 1})(\beta + y \theta_s) - \frac{1}{a + 1} \phi_s - (1 - \frac{1}{a})\beta \geq 0 \), the retailer will participate in fraud. Through
calculation, that is \( y \geq \frac{a \phi_s - \beta}{d^2 \theta_s} \) in this case. According to Lemma 3, when the supplier’s fraudulent
income perception factor \( \theta_s \geq \frac{(a + e)y + \phi_s + \alpha - y}{(a + e - 1)t} \), he chooses to produce products involved in
cleaner production fraud, and in this case, the supplier’s optimal discount price to the retailer is
\( y^* = \frac{a \phi_s - \beta}{d^2 \theta_s} \).

From the basic manifestation of the optimal discount price, the optimal discount rate provided
by the supplier is positively related to the value of fines after product involved in cleaner production fraud is discovered. The optimal discount rate is negatively correlated with the retailer's unit income from selling environmentally friendly products, and negatively correlated with the retailer's fraudulent income. In reality, if the government imposes severe penalties on retailers for participating in fraud, suppliers can only encourage retailers to participate in fraudulent activities by offering a higher percentage of commissions. In addition, the greater the retailer's perception of the benefits of providing fraudulent information and the lower the discounted price offered by the supplier, the higher the retailer's income from participating in fraud. At this point, the supplier only needs to provide a lower price discount to encourage retailers to participate in fraud.

(2) the Best punishment

For government regulators, in order to effectively control cleaner production fraud and develop the market efficiently and orderly, it is necessary to conduct effective supervision and establish a punishment mechanism.

For retail enterprises, only when the fraud income they obtain is lower than the expected cost brought by government supervision, they will give up the provision of product fraud information. According to the above conditions for the retailer to commit fraud, the establishment conditions for waiving the fraud information can be obtained. The details are as follows, \((1 - \frac{1}{a})\beta\) is the expected income of the retailer not participating in the fraudulent behavior, and \((1 - \frac{1}{a + 1})(\beta + y\theta_s) - \frac{1}{a + 1}\phi_s\) is the expected income of the retailer participating in the fraudulent behavior. The difference between the two is the basic condition for the retailer to give up providing fraudulent information. Through calculations, the amount of fine that the government should take is

\[
(1 - \frac{1}{a})\beta - (1 - \frac{1}{a + 1})(\beta + y\theta_s) - \frac{1}{a + 1}\phi_s \geq 0, \quad \phi_s \geq ay\theta_s + \frac{\beta}{a}.
\]

Therefore, the government's minimum penalty for effectively controlling the retailer's participation in product information fraud is \(\phi_s^* = ay\theta_s + \frac{\beta}{a}\). Under the optimal conditions, government's penalty on the retailer is positively related to the supplier's discount factor for the retailer's participation in fraud. The government's penalties on retailers are positively correlated with retailers' perception of product fraud income and retailers' unit income from product sales.

As for supply enterprises, similar to retail enterprises, when the income from producing environmentally friendly products is greater than the income from producing products involved in cleaner production fraud, they will not produce products involved in cleaner production fraud. Obviously, supplier's loss of providing products involved in cleaner production fraud alone is greater than the loss of its colluding with the retailer to commit fraud. In addition, the amount of government penalties for fraudulent activities by the retailer has been set before. Therefore, when the supplier's income from providing products involved in cleaner production fraud alone is less than its income from providing environmentally friendly products, the specific conditions are as follows:

\[
\alpha - [(1 - \frac{1}{a})(\alpha + t\theta_c) - \frac{1}{a}\phi_s] \geq 0, \quad \alpha \geq (a - 1)t\theta_c - \alpha.
\]

Based on the above analysis, in order to effectively control suppliers' participation in cleaner production fraud, the government's optimal penalty for suppliers is \(\phi_s^* = (a - 1)t\theta_c - \alpha\). Under optimal conditions, the amount of government penalties is positively correlated with the excess return of fraud provided by the supplier and the perception of fraud income. And the amount of government penalties is inversely proportional to the unit income of the environmentally friendly product provided by the supplier. Under optimal conditions, the amount of government penalties is positively correlated with the supplier's excess return from products involved in cleaner production fraud and its income perception of fraud, and negatively correlated with the supplier's unit income of environmentally friendly products.

3. Numerical Analysis
In Guangdong, China, various unqualified small garment factories and printing and dyeing factories are scattered, bringing serious water pollution and solid waste pollution. Due to the low cost of entry for companies in the garment industry and the low cost of employee training, the number of such small garment factories has increased steeply in recent years. Based on the development of unqualified small garment factories, genuine and fake clothes produced in these factories without clean production facilities are often mixed and sold in the market, and the situation is very complicated. Based on the above analysis, we analyze the sensitivity of important factors through the numerical analysis of brand A clothes. Suppose there are a supplier and a retailer in the market.

Assuming that the supplier’s unit cost for producing a shirt is 13 yuan, the retailer’s purchase cost is 15 yuan, and the retailer’s selling price is 21 yuan. In order to simplify the calculation, the price unit in this article is 1 yuan, that is, the supplier’s production cost is 13, the retailer’s purchase cost is 15, and the sales price is 21. It can be calculated that the unit income of the supplier $\alpha = 2$, and unit income of the retailer’s shirt sales is $\beta = 6$. For recording convenience, the unit will not be described below.

Suppose that the supplier chooses to produce shirts without environmentally friendly equipment to obtain higher incomes, after that, counterfeit brand B trademarks to make their own products into the market. Assume $\phi_s = 6$. If the retailer chooses to collude with the supplier and provide consumers with false information, such as concealing the source of purchase, forging the authorization certificate, etc., it can get a certain discount from the supplier. Assuming $y = 2$. For clothing produced in unqualified garment factory, there is an odor sometimes. More generally, the presence of formaldehyde exceeds the standard. Consumers may be physically damaged after purchase and wear. After that, they may complain to the Consumer Association about their purchases. Retailers and suppliers involved will be punished if their actions are found. Assume that the retailer’s fine $\phi_r = 6$ and the supplier’s fine $\phi_s = 9$. Assume that the probability of fraud being detected follows an exponential distribution with a parameter $\lambda$, and $\lambda = 2 + e$, $e$ is the degree of effort of the retailer to participate in fraud.

### 3.1 the impact of fraudulent income perception on behavioral decisions

Assume that both the retailer and the supplier have a three-level fraud income perception factor, the value is -2, 0, 2. From the above analysis, it is clear that when the perceived benefit of fraud is negative, the enterprise has a high sense of social responsibility. When the perceived benefit of fraud is positive, enterprises have the motivation to provide product involving cleaner production fraud.

From Lemma 3, the establishment condition for a supplier to provide a product involving cleaner production fraud is $\theta_s \geq \frac{(a + e)\gamma + \phi_s + \alpha - y}{(a + e - 1)\gamma}$. In this numerical case, $\theta_s \geq \frac{(a + e)\gamma + \phi_s + \alpha - y}{(a + e - 1)\gamma} = \frac{5}{4}$; the supplier tends to provide a product involving cleaner production fraud. That is, an unqualified shirt. Therefore, when the supplier’s fraudulent income perception factors are -2 and 0, the supplier chooses to give up cleaner production fraud. At this time, the supplier’s unit income is $R_s = 2$. Correspondingly, the retailer’s unit income is $R_r = 6$. And when the supplier’s fraudulent income perception is $\theta_s = 2$. Suppliers will choose to provide unqualified shirts.

From Lemma 2, when the retailer provides false information with an income perception factor that meets the condition $\theta_r \geq \frac{a\phi_r - \beta}{a^2\gamma}$, the retailer will tend to engage in fraud to obtain higher returns. Substituting the value into the above conditions, we can get $\theta_r \geq \frac{a\phi_r - \beta}{a^2\gamma} = \frac{5}{4}$; the retailer will provide false information, and the critical value for colluding with the supplier is $\frac{a\phi_r - \beta}{a^2\gamma}$. In
In this case, when the retailer’s perceived income factor is not positive, that is, \( \theta_1 = -2 \), \( \theta_2 = 0 \), the retailer tends to give up providing false information. At this time, the supplier’s unit expected return \( R_s = 2.5 \), and the retailer’s unit expected return \( R_r = 3 \). When \( \theta_3 = 2 \), the retailer participates in the fraud process and provides consumers with false information. At this time, the supplier’s expected return \( R_s = 5 \), and the retailer’s expected unit return \( R_r = 14/3 \).

To sum up, when the supplier’s fraudulent income perception factor \( \theta_s < 5/4 \), he chooses to give up fraud and produce environmentally friendly shirts. At this time, the supplier’s unit expected return is 2, that is, \( R_s = 2 \). The retailer’s unit expected return is 6. That is \( R_r = 6 \). When the supplier’s fraudulent income perception factor \( \theta_s \geq 5/4 \), the supplier chooses to produce products involved in cleaner production fraud. When the retailer’s fraudulent income perception factor \( \theta_r < 5/4 \), the retailer chooses to give up providing fraudulent information, and the supplier’s unit expected income is \( R_s = 2.5 \), and the retailer’s unit expected income is \( R_r = 3 \). When the supplier’s fraudulent income perception \( \theta_s = 2 \), and the retailer’s fraud income perception \( \theta_r \geq 5/4 \), both the retailer enterprise and the supply enterprise form cleaner production fraud conspiracy. At this time, the expected income per unit of the supplier is \( R_s = 5 \), and the expected income per unit of the retailer is \( R_r = 14/3 \).

Based on the above analysis, relax the value conditions of the retailer’s and supplier's perception of fraudulent income. When the perception of fraud income of the retailer and supplier changes, their behavioral decision changes are bounded by \( \theta_s = 5/4 \), divided into different behavior selection intervals, as showed in the figure below. When the perception of fraud income of the retailer and supplier changes, their behavioral decision changes are bounded by \( \theta_r = 5/4 \), divided into different behavior selection intervals, as shown in the figure below. When \( \theta_r < 5/4 \), the supplier gives up cleaner production fraud. When \( \theta_r \geq 5/4 \), the supplier chooses to produce products involved in cleaner production fraud. In this case, when \( \theta_s < 5/4 \), only the supplier commits cleaner production fraud and the retailer does not participate. On the contrary, when \( \theta_s \geq 5/4 \), the retailer and the supplier form a fraudulent collusion.

Fig. 3 different benefit perception of supplier and retailer of decision diagrams

Under different perceptions of fraudulent proceeds between retail companies and supply enterprises, there are differences in the income of suppliers and retailers, as showed in figure 4 below.
Fig. 4 Under different perceptions of fraudulent income, the income changes of retailers (right) and suppliers (left)

From figure 4 above, when the supplier’s sense of social responsibility is strong and the fraudulent benefit perception factor is small, that is, when \( \Theta_s < 5/4 \), the supplier will not choose to engage in cleaner production fraud. In this case, it will not produce unqualified shirts with false label ingredients or counterfeit brands. Retailers also have no possibility of fraud. At this time, the market is in good order, and the expected incomes of suppliers and retailers will not change in the short term. As the supplier’s perception of fraudulent income gradually increases, that is, when \( \Theta_s \geq 5/4 \), the supplier chooses to provide products involved in cleaner production fraud. In this case, it chooses to illegally smuggle waste and use false labels or counterfeit brands. When a supplier provides products involved in cleaner production fraud, the retailer’s decision-making changes with its perception of fraudulent proceeds. In addition, the greater the retailer’s perception of fraudulent income, less income perception the supplier needs for fraudulent production, and the greater the probability that the supplier engages in fraudulent production.

3.2 the impact of government fines on behavioral decisions

The following analyzes the strategic choices of retailers and suppliers under different government fines. Assuming that the retailer’s fraudulent income perception factor \( \phi_r \), and the supplier’s fraudulent income perception factor \( \phi_s \), are both 2. Based on basic facts, suppose that the government fines the supplier 1.5 times the amount of the retailer. That is, \( \phi_s = 1.5 \phi_r \).

First, suppose that the value of fines imposed by the government on retailers is divided into three levels, namely 6, 10, and 14. When the amount of the unit fine given to the retailer by the government is 6, that is, \( \phi_r = 6 \), it is easy to conclude that the supplier tends to provide products involved in cleaner production fraud from the behavioral selection analysis step of 3.1. In this case, it tends to illegally smuggle waste and fake the ingredients of shirts or counterfeit brands. Obviously, at this time, retailers tend to choose to provide false information. At this time, because the retailers choose to provide false information, the suppliers and retailers have formed a conspiracy. Then, the expected income per unit of the supplier \( R_s = 5 \), and the expected income per unit of the retailer \( R_r = 14/3 \).

When the retailer receives fines \( \phi_r = 10 \) from the government, according to the critical value analysis of the retailer's behavior strategy selection in 3.1, if the supplier chooses to provide environmentally friendly products. In this case, the expected returns of the supplier and the retailer are \( R_s = 2 \) and \( R_r = 6 \) respectively. If the supplier chooses to provide products involved in
cleaner production fraud, the retailer chooses to provide false information. In the case of a conspiracy between the two, the supplier’s unit expected return is \( R_s = 3 \), and the retailer’s unit expected return is \( R_r = 10/3 \). And if the supplier provides fake and inferior products with false signs, the retailer does not make efforts to falsify product information. At this time, the income of the supplier and the retailer are \( R_s = -1/2 \) and \( R_r = 3 \) respectively. According to the basic theory of Nash equilibrium, comparing the returns under several sets of strategies, it can be found that the two forms a collusion as the dominant strategy. At this time, the supplier’s expected return is \( R_s = 3 \) and the retailer’s expected return is \( R_r = 10/3 \).

When the government imposes a penalty on the retailer \( \phi_r = 14 \), the process of obtaining possession solution is similar to that in the case of \( \phi_r = 10 \). It is the dominant strategy that the supplier can provide environmentally friendly products and the retailer does not provide false information. In this case, the supplier’s unit expected return \( R_s = 3 \) and the retailer’s unit expected return \( R_r = 10/3 \).

In summary, when the government imposes a punishment on the retailer \( \phi_r = 6 \), the supplier’s unit expected return \( R_s = 5 \), and the retailer’s unit expected return \( R_r = 14/3 \). When the government penalizes the retailer \( \phi_r = 10 \), the supplier’s unit expected return \( R_s = 3 \), and the retailer’s unit expected return \( R_r = 10/3 \). When the government penalizes the retailer as \( \phi_r = 14 \), the supplier’s unit expected return \( R_s = 2 \), and the retailer’s unit expected return \( R_r = 6 \).

![Figure 5 under different government penalties, supplier and retailer decisions (left) and income (right)](image)

Based on the above analysis, relaxing the numerical value conditions of government punishments, we can get the influence of government punishments on the decision changes of suppliers and retailers. Suppliers and retailers have different expected benefits under different government penalties. When the supplier does not produce products involved in cleaner production fraud, the expected return obtained by the supplier \( R_s = 2 \), and the expected return obtained by the retailer \( R_r = 6 \). When the supplier chooses to produce products involved in cleaner production fraud and the retailer chooses to provide false information to form a conspiracy with the supplier, the supplier’s expected return \( R_s = 8 - \phi_r / 2 \) and the retailer’s expected return \( R_r = (20 - \phi_r) / 3 \). When the supplier produces products involved in cleaner production fraud, and the retailer chooses not to provide false information, the supplier’s expected return \( R_s = 7 - 3\phi_r / 4 \) and the retailer’s expected return \( R_r = 3 \).

Based on the above analysis, under different government penalties, retailers and suppliers’ strategic choices and income changes are shown in figure 5 below.

When the government’s fine for cleaner production fraud is small, in this case, \( \phi_r < 11 \), in
order to obtain higher returns, suppliers choose to produce products involved in cleaner production fraud and retailers choose to provide false information. Suppliers and retailers’ unit expected income will decrease as the government's punishment for cleaner production fraud increases. With the gradual increase of government fines, when \( \phi \geq 11 \), suppliers no longer choose to provide products involved in cleaner production, and retailers no longer choose to participate in fraud. When they both give up fraud, the income of suppliers and retailers will no longer change with the increase in government fines. At this time, the market can develop steadily and healthily.

4. Discussion

Based on the status of cleaner production fraud in developing countries, our paper uses the enterprise fraud income perception factor, as a proxy variable of enterprise social responsibility, and constructs a secondary supply chain game model that includes supplier and retailer. We explore the impact of enterprise social responsibility on cleaner production fraud participation behaviors of supplier and retailer. Then from the government's perspective, we explored the optimal cleaner production fraud supervision. According to the analytical solution and numerical analysis results, enterprises with a strong sense of social responsibility are significantly less likely to participate in cleaner production fraud. The government can effectively reduce the possibility of cleaner production fraud by increasing the fines for fraud to a certain extent.

In recent years, cleaner production fraud has occurred frequently, including both general cleaner production fraud with less harmful and vicious fraud with extremely high social harm. Given that developing countries are mostly to the left of the axis of symmetry of the Kuznets curve, this phenomenon coincides with the Kuznets curve of the environment. Our research generally categorizes cleaner production fraud into one major category in order to explain the common causes of cleaner production fraud and common solutions more scientifically. But it is difficult to solve practical problems to a certain extent. In future research, we can consider classifying cleaner production fraud behaviors for more detailed research. For vicious cleaner production fraud with extremely high social harm, administrative measures should be used to prevent such fraud. For example, the dairy melamine incident, cadmium leek that shocked China and foreign countries, all of the vicious food cleaner production fraud incidents have extremely high social harm. In order to prevent such incidents from happening, the government should establish emergency response plans before, during and after the event when facing relevant suppliers and retailers. In advance, improve its own testing level, establish a more rigorous and scientific sampling mechanism, and strictly prevent related companies with low social responsibility from taking advantage of the loopholes. During the incident, once discovered, high-hazard problem products should be recalled in time to prevent the situation from expanding. After the incident, severe punishment measures should be taken, such as revoking the business license, to prevent such incidents from happening again. As for product fraud incidents with low social harm. First of all, we must realize that the emergence and growth of such production fraud are the result of market supply and demand.

The increasing demand for cheaper products leads to more and more non-environmentally friendly products. Such products will seriously endanger the environment, the market order and reduce the innovation motivation of enterprises. However, it is difficult to increase the consumption level of residents in the short term, so that such demand will continue to exist for a period of time. The possibility of completely prohibiting the sale of products involving in cleaner production fraud
in the short term is very slim, and the efficiency of government supervision is also greatly reduced. Under the background of existing administrative supervision, the government can mobilize the role of social supervision. By propagating laws in advance, such as popularizing environmental protection law, patent laws and infringement-related laws, enterprises and consumers can understand the relevant legal knowledge and have an awareness of the consequences and harm of illegal acts. On the basis of broadening the channels for public opinion reflection, mobilize the power of the masses to reduce the occurrence of such frauds at a lower cost. The conclusions of our paper confirm that the improvement of enterprise social responsibility will significantly reduce the possibility of cleaner production fraud. Based on this, future research can use field investigations and empirical analysis methods to analyze the influencing factors of enterprise social responsibility in different industries. In order to improve enterprise social responsibility and environmental awareness at a lower cost, thereby reducing the possibility of cleaner production fraud.

5. Conclusion

In recent years, environmental pollution brought about by production has become increasingly serious. Especially for developing countries, cleaner production fraud adds to the burden of environmental governance on governments. Our study explores solutions to such production-based environmental pollution through the lens of cleaner production fraud. By constructing a game model, our research analyzes the causes of cleaner production fraud in the supply chain and the corresponding solutions. Firstly, based on the maximization of expected income, it analyzes the retailer's optimal fraud effort level through a decision tree, and the basic establishment conditions for both the supplier and the retailer to commit fraud. Secondly, our paper optimal analyzed the price discount for retailers participating in collusion with suppliers, and the optimal punishment for the government to avoid cleaner production fraud. Finally, through numerical simulation, we analyzed the impact of enterprise fraud's income perception and government punishment on enterprise fraud. The main conclusions are as follows.

The perception of fraud income significantly affects its probability of participating in cleaner production fraud. When the benefits perceived on cleaner production fraud are negative, fraud participation will directly reduce its overall expected income. In this case, both retailer and supplier choose to produce or sell environmentally friendly products. On the contrary, when the benefits perceived on cleaner production fraud are positive, the fraudulent behavior can bring income to the enterprise to some extent, and motivation to produce or sell products involved in cleaner production fraud. However, the behavior of retailers and suppliers depends on the relative magnitude between the expected income of cleaner production fraud and the expected loss of the government punishment. When the expected income is greater than the expected loss, they tend to conspire to fraud. On the contrary, they conduct environmentally friendly production or sales. Therefore, it is significant to the enterprise choice that the enterprise social responsibility represented by the perception of fraudulent proceeds. A strong sense of social responsibility or environmental awareness is equivalent to invisibly raising the threshold toward violate the law. In views of government, it is necessary to improve the satisfaction of business owners, and sense of social responsibility, through commercial system reform, tax concessions.

In addition, the impact of government fines on enterprise cleaner production fraud was explored in our paper through analytical solutions and numerical simulation. When the overall level of government fines is low, and the interest perception factors of both suppliers and retailers are
large, suppliers and retailers collude to fraud. With the increase of government fines, product fraud
has gradually decreased. Until reaching a certain critical value, both the supplier and the retailer
give up cleaner production fraud. At this time, the government increases the fines to no avail.
Increasing fines will only increase the government supervision costs and market transaction costs,
doing harm to development of the product market. In practice, due to the complexity of the social
environment, demand and price decisions, etc., it is difficult to measure the optimal government
fines accurately for cleaner production fraud.

Above all, in order to better protect the environment and promote the healthy and orderly
development of the market, as for the cleaner production fraud supervision in different industries,
the government should establish a sound policy implementation feedback mechanism, and timely
adjust the policies.

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