

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

Ming Liu

Shandong University

yemei li (✉ 161611173@csu.edu.cn)

Shandong University <https://orcid.org/0000-0001-7577-5001>

Research Article

Keywords: Cleaner-production fraud, Enterprise social responsibility, Government regulation

Posted Date: September 17th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-750923/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published at Environmental Science and Pollution Research on February 8th, 2022. See the published version at <https://doi.org/10.1007/s11356-022-18776-0>.

Study on the Effect of Income Perception on Cleaner-Production

Fraud

Ming Liu¹, Yemei Li^{1, *}

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.

Keywords: Cleaner-production fraud, Enterprise social responsibility, Government regulation
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

45 supply chain, the modeling in our study is mainly related to the second category of cleaner
46 production fraud. Nowadays, there are usually several third-party touch-points in the consumption
47 market, such as vendors, suppliers, transporters, packers, third-party manufacturers or
48 subcontractors, distributors, stockiest, or service providers and so on. The participation of multiple
49 subjects can conspicuously increase the risk of collusive cost-based frauds, and it is harder to detect.
50 At the same time, e-commerce is becoming a burgeoning distribution channel for relative consumer
51 products companies, especially for the FMCG Enterprise. The supply chain has become an
52 important source of new fraud risks (Muwoderi, 2019; Van Wilsem, 2013; Norris et al., 2019). For
53 example, some online products to sale by third-party sellers at highly discounted prices, without
54 authorized brand protection, usually obtain from the supply chain leakage. The relevant products
55 are likely to come from highly polluting enterprises that have not been approved by the Ministry of
56 Environmental Protection.

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

85 Although there are more articles on production fraud, product fraud, there are fewer articles on
86 cleaner production fraud. Therefore, the following is a review of the relevant literature on production
87 fraud and product fraud. Production fraud and product fraud are harmful to both the society and the
88 citizens (Wheatley and Spink, 2013). For consumer products industry, fraud can be a pressing

89 challenge for it with the potential to impact finances (Wang and Winton, 2014), erode customer trust
90 (Kendall et al., 2018) and impact brand value (Johnson et al., 2014). For enterprises whose patent
91 rights are infringed, production fraud affects their innovation effort, reduces their innovation
92 performance, and then affects the overall innovation environment of society. Besides that, when it
93 comes to food fraud, the effect of which to citizens' health and social stability is incalculable (Spink
94 and Moyer, 2011; Breitenbach et al., 2018). Shears (2010) found that thousands of consumers suffer
95 from the injury of food production fraud in the United Kingdom every year. In recent years, the
96 "melamine event" (Zhang et al., 2009; Douglas et al., 2017), "Clenbuterol event" (Spiller et al.,
97 2013; Zhou, 2015), "Horsemeat event" (Lopez et al., 2014; Reisch, 2014; Ellis et al., 2015) and
98 "fraudulent wines event" (Moore et al., 2012) have been come to light. Especially for the scandal
99 of melamine, it rocked global food and beverage industry (Morehouse and Cardoso, 2011). It
100 demonstrated that although our detective technology and modern safeguards become more and more
101 advanced, the food supply chain is still vulnerable to disruption or contamination. Furthermore, it
102 is shocked that a single instance of fraud resulting from economic gain can have global
103 consequences. It significantly affects enterprise's brands, industry's performance, peoples' lives and
104 even the entire countries' reputation. Bouzembrak and Marvin (2015) found that fraud in food
105 production mainly for food sanitation certificate, incorrect date, misleading and fraudulent use of
106 labels and so on. These vicious food production frauds are not only harmful to human health, but
107 also have a great threat to the social stability. Moreover, it makes food enterprises suffering from an
108 unprecedented crisis of confidence (Gong et al., 2013; Falkheimer and Heide, 2015; Vallee and
109 Charlebois, 2015). There are a number of production fraud cases in other industries (Button et al.,
110 2009). Such as financial fraud (Li et al., 2018; Liao et al., 2019), retail forest products fraud
111 (Wiedenhoeft et al., 2019), car production fraud (Braithwaite and John, 1979) and so on. However,
112 because of the atypical nature of such cases, we will not go into detail.

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

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

133 of further study.

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

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

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

157 **2 Methodology**

158 *2.1 The model description and assumptions*

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

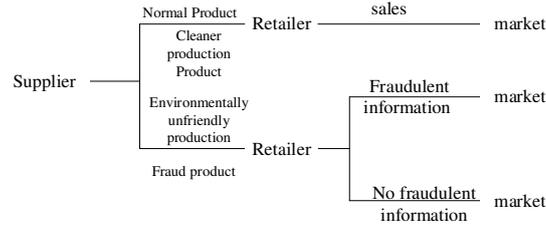


Fig.1 behaviors of suppliers and retailers in product supply chain

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 $\alpha + t\theta_s$, where α is the basic income of the supplier who did not engage in cleaner production fraud, t is the excess income of involving

208 cleaner production fraud, and θ_s is the income perception of production fraud. Similarly, unit income
 209 of a retailer's product sales also consists of two parts. One is the basic price differential income of
 210 selling products, and the other is the excess income formed by the discounted price given by the
 211 supplier to reward its behavior when it chooses to provide false information. The retailer's unit
 212 income is specifically expressed as $\beta + \gamma\theta_r$, where β is the unit income of product retail, γ is the
 213 proportion of false information provided by the overall false information, and θ_r is the perception
 214 of the retailer's sales of the product involved in fraud.

215 The intensity of enterprise social responsibility and environmental protection perception
 216 directly affects the magnitude of income perception. When $\theta_i < 0$, the enterprise provides products
 217 involved in cleaner production fraud with a non-positive perception of income. At this time, its
 218 fraudulent behavior negatively affects the enterprise's overall income, and the enterprise will refuse
 219 to participate in fraudulent cleaner-production behavior. Conversely, when $\theta_i \geq 0$, the enterprise
 220 has a certain possibility to participate in fraudulent cleaner-production activities driven by monetary
 221 interests. However, whether to participate depends on the enterprise's analysis of expected benefits.
 222 If the expected loss caused by the punishment is too high, it is clear that the enterprise will give up
 223 participating in fraud. To be specific, if $0 < \theta_i < 1$, the enterprise has a strong sense of social
 224 responsibility, and its fraudulent acts will produce a certain sense of guilt, but its desire to chase
 225 money makes it still willing to involve in cleaner production fraud. If $\theta_i = 1$ (where $i = s, r$),
 226 If $a=1$, the enterprise's income perception of fraudulent products is neutral. At this time, the sense
 227 of social responsibility will not affect the enterprise's income from fraudulent behavior. Finally, if
 228 $\theta_i > 1$, the enterprise's sense of social responsibility is extremely weak and the desire to chase
 229 interests is extremely strong. Fraudulent behavior positively affects the overall income of the
 230 enterprise. Based on the above assumptions, the main variables in our paper follow as the table
 231 below.

232 Table1 Main variables and basic definition

Variables	Definition
R_s	Unit income of supplier
R_r	Unit income of retailer
e	Efforts made by retailers to provide false information
ϕ_s	Government's unit penalties received by the supplier when fraud discovered
ϕ_r	Government's unit penalties received by the retailer when fraud discovered
α	Unit income of supply for cleaner-production products

t	Additional unit income of products involved in cleaner-production fraud
θ_s	Supplier's perception of income from producing products involved in fraud
β	Unit income of retailer from selling cleaner-production products
θ_r	Retailer's perception of income from providing products involved in fraud
y	Price discount the supplier gives to the retailer when the retailer participates in fraud
τ	Time cost for consumers to detect production fraud

233 2.2 payment function

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

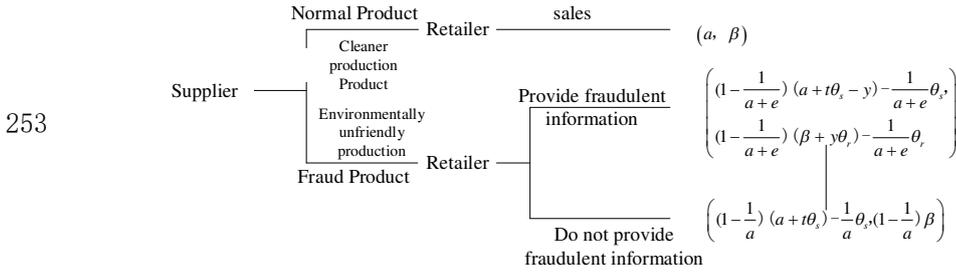
236 When a supplier chooses to provide a cleaner-production product, the retailer sells the product
 237 normally. Both the retailer and the supplier have basic income. At this time, the income of the
 238 supplier $R_s = \alpha$; the income of the retailer $R_r = \beta$. When a supplier provides a product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

242 Table 2 The income matrix of the two when supplier provides products involved in cleaner production fraud

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

244 The above table lists the probabilities and benefits in different situations. It can be obtained
 245 that when the retailer chooses to provide false information. The supplier's expected income is
 246 $R_s = (1 - \frac{1}{a+e})(\alpha + t\theta_s - y) - \frac{1}{a+e}\phi_s$; the retailer's expected income is
 247 $R_r = (1 - \frac{1}{a+e})(\beta + y\theta_r) - \frac{1}{a+e}\phi_r$. When the retailer gives up collusion and chooses not to provide
 248 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
 249 expected income is $R_r = (1 - \frac{1}{a})\beta$. Based on the above analysis, the game tree between suppliers
 250 and retailers is shown in the figure below.

252



253

Figure 2 The game tree of supplier and retailer

254

2.3 Game process

255

256

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

257

258

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.

259

260

261

262

263

264

265

266

267

268

269

270

271

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 $a=0$.

272

273

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

274

275

276

277

278

279

280

its expected return is $(1 - \frac{1}{a+1})(\beta + y\theta_r) - \frac{1}{a+1}\phi_r$. It can be seen that $(1 - \frac{1}{a+1})(\beta + y\theta_r)$ is

281

excess income of fraud, and $\frac{1}{a+1}\phi_r$ is the expected loss after cleaner production fraud is

282

discovered. In addition, the expected benefit of the retailer not providing false information is

283

$(1 - \frac{1}{a})\beta$.

284

285

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

286 information. Therefore, when $(1 - \frac{1}{a+1})(\beta + y\theta_r) - \frac{1}{a+1}\phi_r - (1 - \frac{1}{a})\beta \geq 0$, the retailer chooses to
 287 provide false information. As for the retailer's perception of fraudulent income, after simplification,
 288 it can be obtained that when $\theta_r \geq \frac{a\phi_r - \beta}{a^2 y}$, the retailer's effort to choose fraudulent behavior is
 289 $e = 1$, on the contrary, if $\theta_r < \frac{a\phi_r - \beta}{a^2 y}$ the retailer tends to choose not to provide false information
 290 of products involved in cleaner production fraud, at this time, its chosen degree of effort $e = 0$.
 291 Based on the above analysis, Lemma 2 is obtained.

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

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

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

309 From the above, when $\theta_r \geq \frac{a\phi_r - \beta}{a^2 y}$, the retailer chooses to provide fraudulent information to
 310 obtain higher income. At this point, based on Lemma 1, the retailer's effort to choose fraudulent
 311 behavior is 1. Then, in this situation, the supplier's expected income is
 312 $(1 - \frac{1}{a+e})(\alpha + t\theta_s - y) - \frac{1}{a+e}\phi_s$. Similar to the above analysis of the retailer's expected income
 313 composition, $(1 - \frac{1}{a+e})(\alpha + t\theta_s - y)$ is the income from the supplier's production of products
 314 involved in cleaner production fraud, $\frac{1}{a+e}\phi_s$ is the expected loss that it has to bear when it is
 315 found that the products it produces involved in cleaner production fraud. When $\theta_r < \frac{a\phi_r - \beta}{a^2 y}$, the
 316 retailer chooses not to provide fraudulent information. Obviously, at this time $e = 0$, the retailer's
 317 sales activities do not change the probability of the supplier's product being seized, and the supplier's
 318 expected return is $(1 - \frac{1}{a+e})(\alpha + t\theta_s - y) - \frac{1}{a+e}\phi_s$.

319 By comprehensively analyzing and calculating the expected income in the two situations where
 320 the supplier provides products involved in cleaner production fraud and not producing relevant
 321 products, the specific conditions for the supplier to produce products involved in cleaner production
 322 fraud can be obtained. That is, when $(1 - \frac{1}{a+e})(\alpha + t\theta_s - y) - \frac{1}{a+e}\phi_s - \alpha \geq 0$, the supplier chooses

323 to provide products involved in cleaner production fraud, on the contrary, when
 324 $(1 - \frac{1}{a+e})(\alpha + t\theta_s - y) - \frac{1}{a+e}\phi_s - \alpha < 0$, the supplier chooses not to provide products involved in
 325 cleaner production fraud. In simplifying the calculation of the above formula, it can be obtained that
 326 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
 327 tends to choose to provide products involved in cleaner production fraud. Conversely, when
 328 $\theta_s < \frac{(a+e)y + \phi_s + \alpha - y}{(a+e-1)t}$, the supplier gives up providing products involved in cleaner production
 329 fraud and chooses to provide environmentally friendly products at this time. Based on the above
 330 analysis, Lemma 3 is obtained.

331 **Lemma 3:** When the supplier's income perception meets the condition
 332 $\theta_s \geq \frac{(a+e)y + \phi_s + \alpha - y}{(a+e-1)t}$, the supplier tends to provide products involved in cleaner production
 333 fraud. Conversely, when $\theta_s < \frac{(a+e)y + \phi_s + \alpha - y}{(a+e-1)t}$, the supplier tends to provide environmentally
 334 friendly products instead of products involved in cleaner production fraud. When $\theta_s < 0$, the
 335 supplier's perception of the benefits of providing products involved in cleaner production fraud is
 336 negative, and providing relevant products will produce negative benefits. Under the guilt brought
 337 by the sense of social responsibility, the supplier enterprise will give up providing products involved
 338 in cleaner production fraud. However, when $0 \leq \theta_s < \frac{(a+e)y + \phi_s + \alpha - y}{(a+e-1)t}$, although the
 339 enterprise's sense of social responsibility is not strong, and there exists a high perception of the
 340 benefits of products involved in cleaner production fraud, in view of the legal risks of providing
 341 products involved in cleaner production fraud or the high penalty costs from the government, the
 342 enterprise will also choose to give up producing products involved in cleaner production fraud.

343 2.4 Best discounts rate and best punishment

344 (1) the Best discounts rate

345 According to Lemma 3, when a supplier provides a product involved in cleaner production
 346 fraud, the supplier's fraudulent income perception factor meets the condition
 347 $\theta_s \geq \frac{(a+e)y + \phi_s + \alpha - y}{(a+e-1)t}$. At this time, the retailer has two behavioral choices, one is to collude

348 with the supplier, by providing efforts such as false information to prevent products from being
 349 detected as unqualified, the second is to give up false information and sell products honestly. Based
 350 on the principal-agent relationship between suppliers and retailers, in order to reduce the risk of
 351 detection of products involved in cleaner production fraud, suppliers tend to provide retailers with
 352 certain price discounts to encourage retailers to participate in fraud. From the above analysis, when

353 $(1 - \frac{1}{a+1})(\beta + y\theta_r) - \frac{1}{a+1}\phi_r - (1 - \frac{1}{a})\beta \geq 0$, the retailer will participate in fraud. Through

354 calculation, that is $y \geq \frac{a\phi_r - \beta}{a^2\theta_r}$ in this case. According to Lemma 3, when the supplier's fraudulent

355 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

356 cleaner production fraud, and in this case, the supplier's optimal discount price to the retailer is

$$357 y^* = \frac{a\phi_r - \beta}{a^2\theta_r}.$$

358 From the basic manifestation of the optimal discount price, the optimal discount rate provided

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

368 (2) the Best punishment

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

372 For retail enterprises, only when the fraud income they obtain is lower than the expected cost
373 brought by government supervision, they will give up the provision of product fraud information.
374 According to the above conditions for the retailer to commit fraud, the establishment conditions for
375 waiving the fraud information can be obtained. The details are as follows, $(1 - \frac{1}{a})\beta$ is the expected

376 income of the retailer not participating in the fraudulent behavior, and $(1 - \frac{1}{a+1})(\beta + y\theta_r) - \frac{1}{a+1}\phi_r$
377 is the expected income of the retailer participating in the fraudulent behavior. The difference
378 between the two is the basic condition for the retailer to give up providing fraudulent information.
379 Through calculations, the amount of fine that the government should take is

$$380 \quad (1 - \frac{1}{a})\beta - (1 - \frac{1}{a+1})(\beta + y\theta_r) - \frac{1}{a+1}\phi_r \geq 0, \quad \phi_r \geq ay\theta_r + \frac{\beta}{a}$$

381 Therefore, the government's minimum penalty for effectively controlling the retailer's
382 participation in product information fraud is $\phi_r^* = ay\theta_r + \frac{\beta}{a}$. Under the optimal conditions,

383 Government's penalty on the retailer is positively related to the supplier's discount factor for the
384 retailer's participation in fraud. The government's penalties on retailers are positively correlated with
385 retailers' perception of product fraud income and retailers' unit income from product sales.

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

$$395 \quad \alpha - [(1 - \frac{1}{a})(\alpha + t\theta_s) - \frac{1}{a}\phi_s] \geq 0, \quad \text{get } \phi_s \geq (a-1)t\theta_s - \alpha.$$

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

405 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 $t=6$. 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 λ , 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 $\theta_s \geq \frac{(a+e)y + \phi_s + \alpha - y}{(a+e-1)t}$. In this numerical case,

$\theta_s \geq \frac{(a+e)y + \phi_s + \alpha - y}{(a+e-1)t} = \frac{5}{4}$, 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 $\theta_{s3} = 2$. 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 $\theta_r \geq \frac{a\phi_r - \beta}{a^2y}$, the retailer will tend to engage in fraud to obtain higher

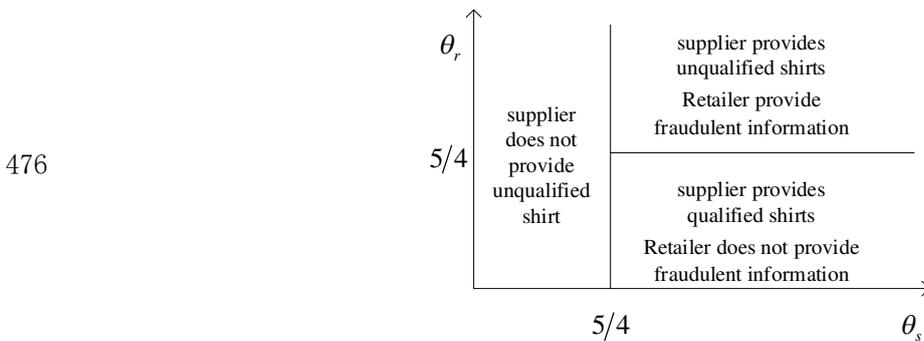
returns. Substituting the value into the above conditions, we can get $\theta_r \geq \frac{a\phi_r - \beta}{a^2y} = \frac{5}{4}$, the retailer

will provide false information, and the critical value for colluding with the supplier is $\frac{a\phi_r - \beta}{a^2y}$. In

450 this case, when the retailer's perceived income factor is not positive, that is, $\theta_{r1} = -2$, $\theta_{r2} = 0$,
 451 the retailer tends to give up providing false information. At this time, the supplier's unit expected
 452 return $R_s = 2.5$, and the retailer's unit expected return $R_r = 3$. When $\theta_{r3} = 2$, the retailer
 453 participates in the fraud process and provides consumers with false information. At this time, the
 454 supplier's expected return $R_s = 5$, and the retailer's expected unit return $R_r = 14/3$.

455 To sum up, when the supplier's fraudulent income perception factor $\theta_s < 5/4$, he chooses to
 456 give up fraud and produce environmentally friendly shirts. At this time, the supplier's unit expected
 457 return is 2, that is, $R_s = 2$. The retailer's unit expected return is 6. That is $R_r = 6$. When the
 458 supplier's fraudulent income perception factor $\theta_s \geq 5/4$, the supplier chooses to produce products
 459 involved in cleaner production fraud. When the retailer's fraudulent income perception factor
 460 $\theta_r < 5/4$, the retailer chooses to give up providing fraudulent information, and the supplier's unit
 461 expected income is $R_s = 2.5$, and the retailer's unit expected income is $R_r = 3$. when the
 462 supplier's fraudulent income perception $\theta_{r3} = 2$, and the retailer's fraud income perception
 463 $\theta_r \geq 5/4$, both the retailer enterprise and the supply enterprise form cleaner production fraud
 464 conspiracy. At this time, the expected income per unit of the supplier is $R_s = 5$, and the expected
 465 income per unit of the retailer is $R_r = 14/3$.

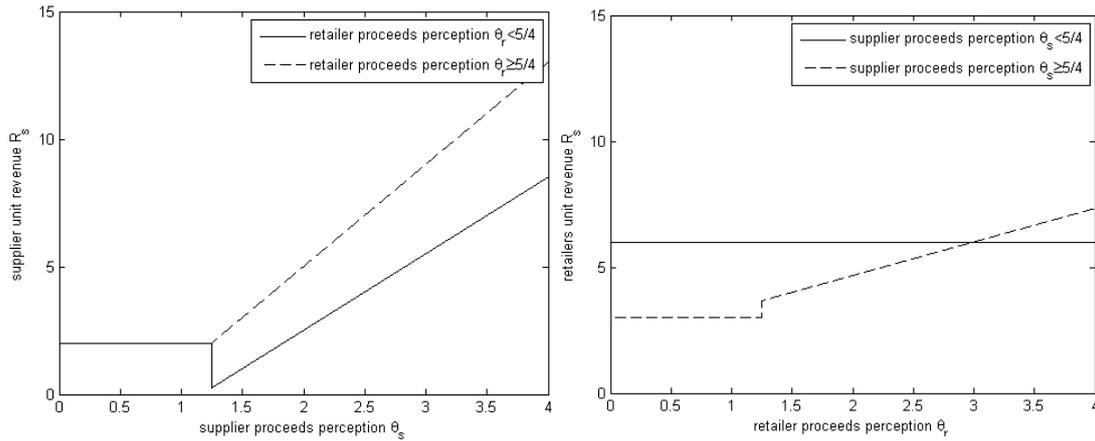
466 Based on the above analysis, relax the value conditions of the retailer's and supplier's
 467 perception of fraudulent income. When the perception of fraud income of the retailer and supplier
 468 changes, their behavioral decision changes are bounded by $\theta_i = 5/4$, divided into different behavior
 469 selection intervals, as showed in the figure below. When the perception of fraud income of the
 470 retailer and supplier changes, their behavioral decision changes are bounded by $a=0$, divided into
 471 different behavior selection intervals, as shown in the figure below. When $\theta_s < 5/4$, the supplier
 472 gives up cleaner production fraud. When $\theta_s \geq 5/4$, the supplier chooses to produce products
 473 involved in cleaner production fraud. In this case, when $\theta_r < 5/4$, only the supplier commits cleaner
 474 production fraud and the retailer does not participate. On the contrary, when $\theta_r \geq 5/4$, the retailer
 475 and the supplier form a fraudulent collusion.



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

478 Under different perceptions of fraudulent proceeds between retail companies and supply
 479 enterprises, there are differences in the income of suppliers and retailers, as showed in figure 4
 480 below.

481



482

Fig. 4 Under different perceptions of fraudulent income, the income changes of retailers (right) and suppliers (left)

483

484 From figure 4 above, when the supplier's sense of social responsibility is strong and the
 485 fraudulent benefit perception factor is small, that is, when $\theta_s < 5/4$, the supplier will not choose
 486 to engage in cleaner production fraud. In this case, it will not produce unqualified shirts with false
 487 label ingredients or counterfeit brands. Retailers also have no possibility of fraud. At this time, the
 488 market is in good order, and the expected incomes of suppliers and retailers will not change in the
 489 short term. As the supplier's perception of fraudulent income gradually increases, that is, when
 490 $\theta_s \geq 5/4$, the supplier chooses to provide products involved in cleaner production fraud. In this
 491 case, it chooses to illegally smuggle waste and use false labels or counterfeit brands. When a supplier
 492 provides products involved in cleaner production fraud, the retailer's decision-making changes with
 493 its perception of fraudulent proceeds. In addition, the greater the retailer's perception of fraudulent
 494 income, less income perception the supplier needs for fraudulent production, and the greater the
 probability that the supplier engages in fraudulent production.

495

3.2 the impact of government fines on behavioral decisions

496

497 The following analyzes the strategic choices of retailers and suppliers under different
 498 government fines. Assuming that the retailer's fraudulent income perception factor θ_r and the
 499 supplier's fraudulent income perception factor θ_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, $\phi_s = 1.5\phi_r$.

500

501 First, suppose that the value of fines imposed by the government on retailers is divided into
 502 three levels, namely 6, 10, and 14. When the amount of the unit fine given to the retailer by the
 503 government is 6, that is, $\phi_r = 6$, it is easy to conclude that the supplier tends to provide products
 504 involved in cleaner production fraud from the behavioral selection analysis step of 3.1. In this case,
 505 it tends to illegally smuggle waste and fake the ingredients of shirts or counterfeit brands. Obviously,
 506 at this time, retailers tend to choose to obtain price discounts from suppliers by providing false
 507 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 $R_s = 5$,
 508 and the expected income per unit of the retailer $R_r = 14/3$.

509

510 When the retailer receives fines $\phi_r = 10$ from the government, according to the critical value
 511 analysis of the retailer's behavior strategy selection in 3.1, if the supplier chooses to provide
 512 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

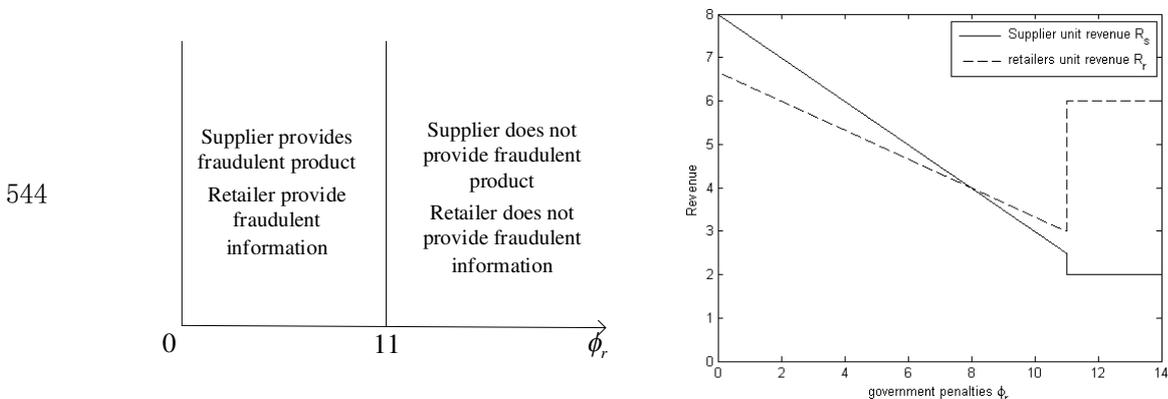
513 cleaner production fraud, the retailer chooses to provide false information. In the case of a
 514 conspiracy between the two, the supplier's unit expected return is $R_s = 3$, and the retailer's unit
 515 expected return is $R_r = 10/3$. And if the supplier provides fake and inferior products with false
 516 signs, the retailer does not make efforts to falsify product information. At this time, the income of
 517 the supplier and the retailer are $R_s = -1/2$ and $R_r = 3$ respectively. According to the basic theory
 518 of Nash equilibrium, comparing the returns under several sets of strategies, it can be found that the
 519 two forms a collusion as the dominant strategy. At this time, the supplier's expected return is $R_s = 3$
 520 and the retailer's expected return is $R_r = 10/3$.

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

526 In summary, when the government imposes a punishment on the retailer $\phi_r = 6$, the supplier's
 527 unit expected return $R_s = 5$, and the retailer's unit expected return $R_r = 14/3$. When the
 528 government penalizes the retailer $\phi_r = 10$, the supplier's unit expected return $R_s = 3$, and the
 529 retailer's unit expected return $R_r = 10/3$. When the government penalizes the retailer as $\phi_r = 14$,
 530 the supplier's unit expected return $R_s = 2$, and the retailer's unit expected return $R_r = 6$.

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

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



545 Figure 5 under different government penalties, supplier and retailer decisions (left) and income (right)

546 When the government's fine for cleaner production fraud is small, in this case, $\phi_r < 11$, in

547 order to obtain higher returns, suppliers choose to produce products involved in cleaner production
548 fraud and retailers choose to provide false information. Suppliers and retailers' unit expected income
549 will decrease as the government's punishment for cleaner production fraud increases. With the
550 gradual increase of government fines, when $\phi_r \geq 11$, suppliers no longer choose to provide
551 products involved in cleaner production, and retailers no longer choose to participate in fraud. When
552 they both give up fraud, the income of suppliers and retailers will no longer change with the increase
553 in government fines. At this time, the market can develop steadily and healthily.

554 **4.Discussion**

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

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

584 The increasing demand for cheaper products leads to more and more non-environmentally
585 friendly products. Such products will seriously endanger the environment, the market order and
586 reduce the innovation motivation of enterprises. However, it is difficult to increase the consumption
587 level of residents in the short term, so that such demand will continue to exist for a period of time.
588 The possibility of completely prohibiting the sale of products involving in cleaner production fraud

589 in the short term is very slim, and the efficiency of government supervision is also greatly reduced.
590 Under the background of existing administrative supervision, the government can mobilize the role
591 of social supervision. By propagating laws in advance, such as popularizing environmental
592 protection law, patent laws and infringement-related laws, enterprises and consumers can
593 understand the relevant legal knowledge and have an awareness of the consequences and harm of
594 illegal acts. On the basis of broadening the channels for public opinion reflection, mobilize the
595 power of the masses to reduce the occurrence of such frauds at a lower cost. The conclusions of our
596 paper confirm that the improvement of enterprise social responsibility will significantly reduce the
597 possibility of cleaner production fraud. Based on this, future research can use field investigations
598 and empirical analysis methods to analyze the influencing factors of enterprise social responsibility
599 in different industries. In order to improve enterprise social responsibility and environmental
600 awareness at a lower cost, thereby reducing the possibility of cleaner production fraud.

601 **5.Conclusion**

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

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

629 In addition, the impact of government fines on enterprise cleaner production fraud was
630 explored in our paper through analytical solutions and numerical simulation. When the overall level
631 of government fines is low, and the interest perception factors of both suppliers and retailers are

632 large, suppliers and retailers collude to fraud. With the increase of government fines, product fraud
633 has gradually decreased. Until reaching a certain critical value, both the supplier and the retailer
634 give up cleaner production fraud. At this time, the government increases the fines to no avail.
635 Increasing fines will only increase the government supervision costs and market transaction costs,
636 doing harm to development of the product market. In practice, due to the complexity of the social
637 environment, demand and price decisions, etc., it is difficult to measure the optimal government
638 fines accurately for cleaner production fraud.

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

643 **Ethical Approval:**

644 All analyses were based on previous published studies; thus, no ethical approval and written consent
645 are required.

646 **Consent to Participate:** Not applicable

647 **Consent for publication:** Not applicable

648 **Funding :** Not applicable

649 **Availability of data and materials:** The data sets supporting the results of this article are
650 included within the article

651 **Authors Contributions:** Liu ming: Data curation, Writing- Original draft preparation,
652 Li yemei: Conceptualization, Methodology, Software, Writing- Reviewing, Editing, Validation,
653 Formal analysis, Visualization

654 **Competing Interests:**

655 The authors declared that they have no conflicts of interest to this work. We declare that we do not
656 have any commercial or associative interest that represents a conflict of interest in connection with
657 the work submitted.

658 **References**

659 Beeson M. The coming of environmental authoritarianism[J]. *Environmental politics*, 2010, 19(2):
660 276-294.

661 Bouzemrak Y, Marvin HJP. Prediction of food fraud type using data from Rapid Alert System for
662 Food and Feed (RASFF) and Bayesian network modeling [J]. *Food Control*, 2015, 61: 180-187.

663 Braithwaite, John. *An exploratory study of used car fraud*. 1979.

664 Breitenbach R, Rodrigues H, Brandão J B. Whose fault is it? Fraud scandal in the milk industry and
665 its impact on product image and consumption–The case of Brazil[J]. *Food Research International*,
666 2018, 108: 475-481.

667 Button M, Lewis C, Tapley J. Fraud typologies and the victims of fraud: Literature review[J]. 2009.

668 Das P, Horton R. Pollution, health, and the planet: time for decisive action[J]. *The Lancet*, 2018,
669 391(10119): 407-408.

670 Darby M R, Karni E. Free competition and the optimal amount of fraud[J]. *The Journal of law and*
671 *economics*, 1973, 16(1): 67-88.

672 Dodd, Nick J. "The psychology of fraud." *Profiling property crimes*. Routledge, 2018. 219-242.

673 Donaldson C. Food fraud: ensuring the integrity of our food supply [J]. *Perspectives in Public Health*,
674 2014, 134(6): 311-311

675 Douglas C M, Jonathan W D, John S. The economics of a food fraud incident – Case studies and

676 examples including Melamine in Wheat Gluten [J]. *Food Control*, 2017, 71: 358-364.

677 Dove M. *The Psychology of Fraud, Persuasion and Scam Techniques: Understanding What Makes*

678 *Us Vulnerable*[M]. Routledge, 2020.

679 Duffield, Grace M., and Peter Nils Grabosky. *The psychology of fraud*. Vol. 199. Canberra:

680 *Australian Institute of Criminology*, 2001.

681 Ellis D I, Muhamadali H, Haughey S A, et al. Point-and-shoot: rapid quantitative detection methods

682 for on-site food fraud analysis - moving out of the laboratory and into the food supply chain [J].

683 *Analytical Methods*, 2015, 7(22): 9401-9414.

684 Falkheimer J, Heide M. Trust and brand recovery campaigns in crisis: Findus Nordic and the

685 horsemeat scandal [J]. *International Journal of Strategic Communication*, 2015, 9(2): 134-147.

686 Fisher K. *The Psychology of Fraud: What Motivates Fraudsters to Commit Crime?*[J]. Available at

687 *SSRN 2596825*, 2015.

688 Gallagher M, Thomas I. Food fraud: the deliberate adulteration and misdescription of foodstuffs [J].

689 *European Food & Feed Law Review*, 2010, 5(6): 347-353.

690 Gong Q, Zhang Y L, Yu J Y. Incentives, Information and Food Safety Regulation [J]. *Economic*

691 *Research Journal*, 2013(3): 135-147.(In Chinese)

692 Handford C E, Campbell K, Elliott C T. Impacts of milk fraud on food safety and nutrition with

693 special emphasis on developing countries [J]. *Comprehensive Reviews In Food Science and Food*

694 *Safety*, 2016, 15(1): 130-142.

695 Harjoto M A. Corporate social responsibility and corporate fraud[J]. *Social Responsibility Journal*,

696 2017.

697 Hens L, Block C, Cabello-Eras J J, et al. On the evolution of “Cleaner Production” as a concept and

698 a practice[J]. *Journal of cleaner production*, 2018, 172: 3323-3333.

699 Jiang Q J, Zhu Y. Confronting the crisis of food safety and revitalizing companies' social

700 responsibility in the People's Republic of China [J]. *Asia Pacific Business Review*, 2013, 19(4): 600-

701 616

702 Johnson W C, Xie W, Yi S. Corporate fraud and the value of reputations in the product market[J].

703 *Journal of Corporate Finance*, 2014, 25: 16-39.

704 Kendall H, Naughton P, Kuznesof S, et al. Food fraud and the perceived integrity of European food

705 imports into China[J]. *PloS one*, 2018, 13(5): e0195817.

706 Leroy P, Crabb A. *The handbook of environmental policy evaluation*[M]. Earthscan, 2012.

707 Li, Pei; Shen, Bingyu; Dong, Weishan. An anti-fraud system for car insurance claim based on visual

708 evidence. *arXiv preprint arXiv:1804.11207*, 2018.

709 Liao L, Chen G, Zheng D. Corporate social responsibility and financial fraud: evidence from

710 China[J]. *Accounting & Finance*, 2019, 59(5): 3133-3169.

711 Liu Q, Nie W, Hua Y, et al. Investigation of efficient dust control strategy for construction tunnels:

712 *Ventilation System's implications for cleaner production*[J]. *Building and Environment*, 2020, 180:

713 107032.

714 Lopez M L, Colomer N, Ruisanchez I, et al. Validation of multivariate screening methodology. Case

715 study: Detection of food fraud [J]. *Analytica Chimica Acta*, 2014, 827(3): 28-33.

716 Lu Z N, Chen H, Hao Y, et al. The dynamic relationship between environmental pollution, economic

717 development and public health: Evidence from China[J]. *Journal of Cleaner Production*, 2017, 166:

718 134-147.

719 Manning L, Soon JM. *Food Safety, Food Fraud, and Food Defense: A Fast Evolving Literature* [J].

720 Journal of Food Science, 2016, 81(4): 823–834

721 Michael L, Georgios Z. Fake It Till You Make It: Reputation, Competition, and Yelp Review Fraud
722 [J]. *Management Science*, 2016, 62: 3412-3427.

723 Moore J C, Spink J, Lipp M, Development and application of a database of food ingredient fraud
724 and economically motivated adulteration from 1980 to 2010 [J]. *Journal of Food Science*, 2012.
725 77(4): 118-126.

726 Morehouse J E, Cardoso L. Consumer product fraud–how to stop the fraud now[J]. *Supply Chain*
727 *Quarterly*, 2011.

728 Mu L, Dawande M, Mookerjee V. Improving the Milk Supply Chain in Developing Countries:
729 Analysis, Insights, and Recommendations [J]. *Production & Operations Management*, 2014, 23(7):
730 1098-1112.

731 Muwoderi N. The effectiveness of anti-fraud measures in curbing fraud in the retail sector. A case of
732 Harare Central Business District[D]. BUSE, 2019.

733 Norris G, Brookes A, Dowell D. The psychology of internet fraud victimisation: A systematic
734 review[J]. *Journal of Police and Criminal Psychology*, 2019, 34(3): 231-245.

735 Reisch M S. Fighting Food Fraud [J]. *Chemical & Engineering News*, 2014, 92(34): 10-15.

736 Rodgers W, Söderbom A, Guiral A. Corporate social responsibility enhanced control systems
737 reducing the likelihood of fraud[J]. *Journal of Business Ethics*, 2015, 131(4): 871-882.

738 Shears P. Food fraud is a current issue but an old problem [J]. *British Food Journal*, 2010, 112(2):
739 198-213.

740 Shnayder L, Rijnsoever F J V, Hekkert M P. Motivations for Corporate Social Responsibility in the
741 packaged food industry: an institutional and stakeholder management perspective [J]. *Journal of*
742 *Cleaner Production*, 2016, 122: 212-227.

743 Spiller H A, James K J, Scholzen S, et al. A descriptive study of adverse events from clenbuterol
744 misuse and abuse for weight loss and bodybuilding [J]. *Substance Abuse*, 2013, 34(3): 306-312.

745 Spink J, Moyer D C, Hyeonho P, et al. Introducing Food Fraud including translation and
746 interpretation to Russian Korean, and Chinese languages [J]. *Food Chemistry*, 2015, 189(12): 102-
747 107.

748 Spink J, Moyer D C. Defining the public health threat of food fraud [J]. *Journal of Food Science*,
749 2011, 76(9): 157-163.

750 Spink J, Moyer D C. Defining the public health threat of food fraud[J]. *Journal of food science*,
751 2011, 76(9): R157-R163.

752 Vallee J L, Charlebois S. Benchmarking global food safety performances: the era of risk intelligence
753 [J]. *Journal of Food Protection*, 2015, 78(10): 1896-1913.

754 Van Wilsem J. ‘Bought it, but never got it’ assessing risk factors for online consumer fraud
755 victimization[J]. *European Sociological Review*, 2013, 29(2): 168-178.

756 Wang T Y, Winton A. Product market interactions and corporate fraud[J]. Available at SSRN
757 2398035, 2014.

758 Wheatley V M, Spink J. Defining the public health threat of dietary supplement fraud[J].
759 *Comprehensive Reviews in Food Science and Food Safety*, 2013, 12(6): 599-613.

760 Wiedenhoeft A C, Simeone J, Smith A, et al. Fraud and misrepresentation in retail forest products
761 exceeds US forensic wood science capacity[J]. *PloS one*, 2019, 14(7): e0219917.

762 Zhang C P, Bai J F, Lohmar B T, et al. How do consumers determine the safety of milk in Beijing,
763 China? [J]. *China Economic Review*, 2009, 21(1): 45-54.

764 Zhou N. Impact effect of food safety incidents on price [J]. Advance Journal of Food Science and
765 Technology, 2015, 8(8): 598-602.
766 Zulfiqar F, Datta A, Thapa G B. Determinants and resource use efficiency of “better cotton”: An
767 innovative cleaner production alternative[J]. Journal of cleaner production, 2017, 166: 1372-1380.