Responsible Manufacturing with Information Disclosure Under Regulatory Inspections

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Abstract. Different legislations are enacted to monitor and promote social sustainability performance. If any unsustainable manufacturing practice is found by the regulatory body, the firm will suffer from huge loss. As pressured by socially responsible purchasing and regulatory pressure, some manufacturing firms have begun to disclose social sustainability in their manufacturing process in audit reports periodically. In this paper, we examine how should a manufacturing firm choose its optimal socially-sustainable manufacturing effort, and how should the manufacturing firm set prices to successfully transmit social sustainability signals to first-stage consumers. We conduct a two-stage game-theoretic analysis to examine a manufacturing firm's socially-sustainable manufacturing effort and dynamic pricing decisions under regulatory pressure. Consumers are classified into socially conscious and non-socially conscious consumers. We find that when the gap of consumer's attitude towards responsibility is moderate, if the manufacturing firm insists on targeting both socially conscious and non-socially conscious consumers in the first period, consumers will believe that the firm is of low responsibility in manufacturing. Then in the second period when socially-sustainable manufacturing effort becomes a symmetric information, the belief that the manufacturing firm is irresponsible will hurt the manufacturing firm's profit. Thus, it is beneficial to target at socially conscious consumers in the first period so as to transfer quality information to consumers. Our findings help a firm to wisely make socially-sustainable manufacturing effort decisions and set an informative price so as to transfer responsible manufacturing information to early consumers.

Keywords: Price signaling · Social responsibility · Sustainable manufacturers · Information sharing · Regulatory inspections · Manufacturing

1 Introduction

The International Labour Organization (ILO) estimates that modern slavery may affect over 40 million individuals around the world (ILO 2017). Social misconduct in a supply chain comprises forced labor, child labor, poor working condition, low payment, worker treatment, and gender inequality, etc. Such social misconduct cut down the production cost and enable firms to set a more competitive price. However, modern slavery not only does harm to workers' interests, but also significantly affects both firm's long-term

profitability and brand image. For example, stressful working condition and low payment in Foxconn factories led to workers' suicides in 2016 (Forbes 2016). Nike's scandals related to social misconduct severely affected its profitability, hurt its brand image and disrupt consumers' trust (Tang and Zhou 2012). Modern slavery is found to be the cause of stagnant economic growth and leads to perpetuating the poverty zone (ILO Report 2014).

Although social responsibility is difficult to quantify, consumers nowadays are paying more attention to firms' social responsibility in manufacturing. It has been widely acknowledged that socially-conscious consumers are willing to pay a premium for responsible products. In reality, consumers are usually at information disadvantage about manufacturing firms' social sustainability at the time of purchase. Price commonly is the signal about a product's socially-sustainable manufacturing effort (Shao et al. 2020). A high price can transfer the information of high social sustainability to consumers (Jiang and Yang 2019). Information asymmetry provides reasons for unsustainable manufacturing firms pretend to be responsible by setting misleading high prices and defeating consumers. By doing so, they can be profitable in the single period transaction by investing not sufficiently in manufacturing sustainability while charging a high price.

Regulatory inspections put supply chains under scrutiny. Different legislations are enacted to monitor and promote social sustainability performance, such as the US-California Transparency Act (2010), the UK Modern Slavery Act (2015), the Australian Modern Slavery Act (2018). More recently, the leading fashion brand Boohoo is accused to be involved with forced labor and is currently being investigated by US Customs and Border Protection. Although the timeline for investigation has not been decided yet, it will suffer from huge loss (i.e., such as import bans, damaged brand images) if any unsustainable societal practice is found.

As pressured by socially responsible purchasing and regulatory inspection, some manufacturing firms have begun to disclose their socially-sustainable manufacturing effort. With the advance of publicizing social sustainability information in audit reports, consumers can learn the true socially responsible level periodically (Sodhi and Tang 2019). Therefore, in the multi-period setting, firms are motivated to increase socially-sustainable manufacturing effort to earn higher profits from the informed consumers coming at the later period. In this way, firms need to balance the gain by deceiving early consumers and the loss through revealing true responsibility to the late consumers.

We conduct a two-stage game-theoretic analysis to examine a manufacturing firm's socially-sustainable manufacturing effort and dynamic pricing decisions under regulatory pressure. A monopoly manufacturing firm holds private socially-sustainable manufacturing effort information which is invisible to consumers. The firm decides on the optimal social sustainability effort in manufacturing which remains unchanged in the two periods and decides on the optimal selling price in two selling periods. At the first stage, consumers come at an early stage do not have knowledge about product's social sustainability information prior to purchase. Knowing that the firm has incentives to invest in social sustainability in manufacturing to attract later consumers, a rationale consumer will deduce socially-sustainable manufacturing effort information based on the charged price. In the second stage, the firm publicizes audit reports to share socially-sustainable manufacturing effort information with late consumers. Then consumers can

make purchase decision based on the knowledge of product's societal attribute. At the end of the second stage, regulator inspects on firm's societal conduct in the manufacturing process and the firm will occur a loss if any misconduct is found. To maximize profits in two periods, how should a firm make pricing and sustainable manufacturing decisions remain questionable. We examine the following questions: In the presence of regulatory pressure in monitoring supply chain social sustainability in manufacturing, how should a firm choose its optimal socially-sustainable manufacturing effort? How should the firm set prices to successfully transmit sustainable manufacturing signals to first-stage consumers?

2 Literature Review

Our paper relates to two stream of the literature: the socially responsible operations and price signaling.

In the stream of socially responsible operations literature, Gallear et al. (2012) empirically find that the decrease in profitability is a main obstacle in motivating socially responsible investment. Gong et al. (2019) suggest that higher social sustainability effort may or may not induce economic growth. Heyes and Martin (2017) claim that greater effort in social sustainability may conditionally hurt consumers' welfare. Cho et al. (2019) investigate the effect of both internal and external audit on firm's decisions of using child labor. Shao et al. (2020) examine the pricing and disclosure decisions of a retailer who can either source from a high or low socially responsible supplier. The above studies assume social sustainability investment exogenously. In our paper, we consider the manufacturing firm could invest more or less on social responsibility. Therefore, we assume the responsible effort is endogenous for the manufacturing firm. We conduct a two-stage game-theoretic analysis to examine a firm's optimal social sustainability effort under regulatory pressure. For more detailed information in this domain, please refer to the review paper Tang and Zhou (2012) and Sodhi and Tang (2019). The former one reviews sustainable operations under the principle of triple bottom line and the latter one discusses the role of information disclosure in socially responsible operations.

In the stream of price signaling, Jiang and Yang (2019) consider consumer to consumer quality-information sharing in two periods. They assume that the first-period consumers who bought the product will learn the true quality and reveal it to later consumers. However, they do not consider the inspection of regulatory body. We follow Jiang and Yang (2019) to model information sharing model. Differently, we tie firm's social sustainability effort decision with regulatory pressure, which induces firms to improve social sustainability effort to lower the probability of violation. However, as consumers enter the market over two periods, increasing the social sustainability effort reduces firm's profitability in the first stage. It could have provided low effort and deceive early consumers into believing the products are of high quality. Therefore, the firm has the trade-off for the payoff between two different periods. Our paper is also motivated by Shao et al. (2020) and Chen et al. (2019). They both examine supply chain decisions under NGO scrutiny. Shao et al. (2020) consider a static one-period price-signaling and cost information asymmetry. Chen et al. (2019) examine disclosure strategy facing regulatory body's uncertain inspection level. Differently, we consider both the capability and

social sustainability effort information asymmetry and the firm maximizes profits in two periods. For more detailed information in this domain, please refer to the review paper Shen et al. (2019), which has conducted the comprehensive review about information asymmetry in terms of price signals.

3 The Model

Consider a supply chain model consisting of a monopoly manufacturing firm (we abbreviate it as firm) and its downstream consumers. To meet the growing needs of sustainable development, the firm makes an effort in social sustainability performance in the process of manufacturing, such as providing workers health and safe working conditions, resisting the recruitment of child labor and forced labor, giving workers' a decent pay, etc. Production cost is normalized to zero as we mainly focus on investment in social sustainability. The firm's social sustainability performance is jointly determined by two factors: cost efficiency and social sustainability effort. The firm can be of two types in terms of cost efficiency. We use $i = \{1, 2\}$ to denote high efficiency type and low efficiency type respectively. Cost efficiency and true sustainability effort are denoted by c_i and γ_i respectively where $c_1 < c_2$ (i.e., the type-1 firm has higher efficiency and spends a lower marginal cost than the type-2 firm). Then, the firm's quadric socially-sustainable manufacturing cost function is given by $c_i \gamma_i^2$ (Jiang and Yang 2019). Consumers' prior probability of the firm's type satisfies $Pr(c_i = c_1) = \beta$ and $Pr(c_i = c_2) = 1 - \beta$.

With the popularity of the concept of social sustainability, more consumers are becoming conscious of sustainable development. Socially conscious consumers care about social sustainability and are willing to pay a higher price for social sustainable products. Considering heterogeneity of consumers attitudes towards socially-sustainable manufacturing effort, we use $j = \{H, L\}$ to label consumer's type and θ_j to represent consumer's willingness to pay (WTP). Socially conscious consumers (i.e. H-type) has higher WTP than non-socially conscious consumers (i.e. L-type), which gives $\theta_H > \theta_L$. Consumer's net utility is modeled as $U_j = \theta_j \gamma_i - p$, where p is the price of the product. A consumer will buy the product if her expected utility is larger than zero. Without loss of generality, the number of consumers is normalized to 1. The proportion of H-type consumers accounts for $\alpha \in (0, 1)$, whereas L-type consumers accounts for the remaining $1 - \alpha$. We denote H-type and L-type consumer's maximum willingness-to-pay as $\overline{p_H}$ and $\overline{p_L}$. By denoting market demand as N, if the firm charges the first-period price at $\overline{p_H}$, then only H-type consumers will be targeted and the market demand $N_i^{(1)}$ equals to α. If the firm charges the first-period price at $\overline{p_L}$, then both types of consumers will be targeted and the market demand $N_i^{(1)}$ equals to 1. Utility of non–socially conscious consumers will not be affected by violation. In contrast, socially conscious consumers' WTP will change from θ_H to θ_L if violation occurs. The probability of violation relates to firm's socially-sustainable manufacturing effort γ_i. Greater effort reduces the possibility of being involved with social misconduct. Thus, the expected utility of socially conscious consumers is $E(U_H) = \gamma_i(\theta_H \gamma_i - p) + (1 - \gamma_i)(\theta_L \gamma_i - p)$.

New consumers come into the market over two different selling periods. In the first period, the firm will decide the first-period's price, which will be a signal of socially-sustainable manufacturing effort to consumers. A high price would indicate a higher

socially-sustainable manufacturing effort. As the audit report has not been published yet, consumers who come at an early stage do not have knowledge about product's social sustainability information prior to purchase. A rationale consumer deduces such information based on the first-period's price and makes purchase decisions. Whether the firm's efficiency type as public knowledge will influence consumer's expectations. In the second stage, the firm goes through a periodical audit, which will be released in public. Then, consumers can learn about product's true societal attributes and make purchase decisions. Following Shao et al. (2020), consumers make their purchase decisions before they know whether a violation has occurred. A higher effort can decrease the probability of violation of social sustainability. If the violation is discovered and revealed by the regulator body, the firm will suffer from a penalty cost κ, which includes either a penalty, a reputation damage or the cost of remediation. In this stage, consumers can learn about the product's true societal attribute and make purchase decisions. We can derive the profit function as follows: $\pi_i = \left(p_i^{(1)} - c_i\gamma_i^2\right)N_i^{(1)} + \left(p_i^{(2)} - c_i\gamma_i^2\right)N_i^{(2)} - (1 - \gamma_i)\kappa$.

Socially-sustainable manufacturing effort and cost efficiency are firm's private information which are invisible to consumers. We analyze symmetric and asymmetric capability information respectively in Sect. 4. Game sequence is shown in Fig. 1. First, nature decides firm's type of capability (i.e. c_i) and consumers have prior belief about the firm's type. Second, the firm endogenously decides on the social sustainability effort which is firm's private information. All other parameters are common knowledge. Third, the firm sets selling price $p^{(1)}$ in the first stage. In the second period, the firm's socially-sustainable manufacturing effort is published in the periodical audit report, then later consumers can know the true social sustainability effort of the products and make the purchase decision. Lastly, the regulatory body inspects the firm's socially-sustainable manufacturing effort which may last for a quite long time. If the firm violates regulations, it should pay for its social misconduct. The firm sets selling price $p^{(2)}$ in the second stage.

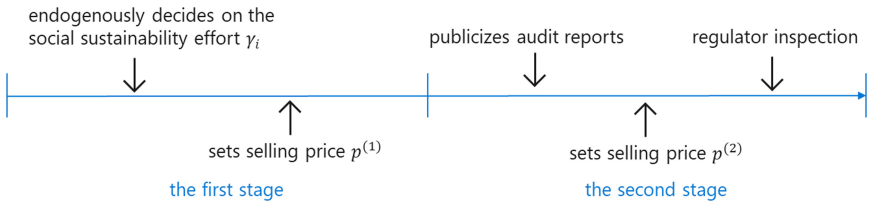**Fig. 1.** Game sequence.

4   Equilibrium Analysis

The pros and cons of enhancing effort are the major trade-off. On the one hand, making more socially-sustainable manufacturing effort lowers the possibility of being punished from violation. It can also earn higher profits from the informed socially conscious consumers in the second period. On the other hand, the firm has incentives to provide

low quality in the first period to profit from early ignorant consumers. Therefore, the firm will make socially-sustainable manufacturing effort and price decisions to maximize total profits in two periods.

We use the abbreviation H to represent target only H-type consumers and HL to represent target both two types of consumers. We first examine the second period targeting decisions. Results are shown in Lemma 1.

Lemma 1. *Regardless of the type of the equilibrium,*

(i)   *When* $\theta_H > \theta_L + \frac{(1-\alpha)c_i[2\kappa\theta_L+(1+2\alpha)\theta_L^2-\kappa^2]}{\alpha(\kappa+\theta_L)^2}$, *the firm targets at only H-type consumers in the second period;*

(ii)   *When* $\theta_L + \frac{(1-\alpha)c_i[\alpha\theta_L(2\kappa+(2+\alpha)\theta_L)-\kappa^2]}{\alpha(\kappa+\theta_L)^2} < \theta_H \leq \theta_L + \frac{(1-\alpha)c_i[2\kappa\theta_L+(1+2\alpha)\theta_L^2-\kappa^2]}{\alpha(\kappa+\theta_L)^2}$, *the firm targets at the same type of consumers in the second period as in the first period;*

(iii)   *When* $\theta_H \leq \theta_L + \frac{(1-\alpha)c_i[\alpha\theta_L(2\kappa+(2+\alpha)\theta_L)-\kappa^2]}{\alpha(\kappa+\theta_L)^2}$, *the firm targets at both H-type and L-type consumers in the second period.*

Lemma 1 summarizes the second period targeting decisions with asymmetric social sustainable effort. We list the optimal social sustainable effort and the corresponding profit in Table 1.

Figure 2 shows the firm's second-period targeting sales given the targeting decision in the first-period. From Fig. 2, we can observe that with the increase in consumer's heterogeneity in social sustainable awareness, the incentive of targeting H-type consumers grows. This result is well-acknowledged as the firm would have higher motivations to make the consumers recognize their high responsibility level and earn substantial profits from the high social-awareness consumers. If the gap between consumers' valuation of social responsibility is sufficiently low, then it is trivial to differentiate the firm to build a high responsible image. It will be more profitable to set a lower price which is affordable to both types of consumers. The increase in market demand outweighs the drop in the sales price.

Now we turn to the targeting decisions in the first period. In equilibrium, the price signal is convincing to consumers only if the firm cannot make extra profits from deviating its claim. The firm can claim that it is of high social responsibility by charging $\gamma_i[\gamma_i\theta_H + (1 - \gamma_i)\theta_L]$ and targeting only H-type consumers; Or the firm can set prices at $\gamma_i\theta_L$ to target both types of consumers. According to the second period decisions shown in Lemma 1, we investigate the following three different parameter regions. Results are shown in Lemma 2.

Lemma 2. *When the firm's cost efficiency is common knowledge, its optimal quality and prices are:*

(i)   *When* $\theta_L < \theta_H < min\left\{\theta_L + \frac{(1-\alpha^2)c_i(\theta_L-\kappa)}{2\alpha(\kappa+\theta_L)}, \theta_L + \frac{(1-\alpha)c_i[\alpha\theta_L(2\kappa+(2+\alpha)\theta_L)-\kappa^2]}{\alpha(\kappa+\theta_L)^2}\right\}$, *the firm will target at both types of consumers in two periods (i.e. (HL, HL)) and* $\widetilde{\gamma}_i^* = \frac{\kappa+\theta_L}{4c_i}, \tilde{p}_i^{(1)*} = \tilde{p}_i^{(2)*} = \frac{\theta_L(\kappa+\theta_L)}{4c_i}, \widetilde{\pi}_i^* = \frac{\kappa^2-8\kappa c_i+4\kappa\theta_L+3\theta_L^2}{8c_i}$.

Table 1. Conditional social sustainability effort and second-period targeting.

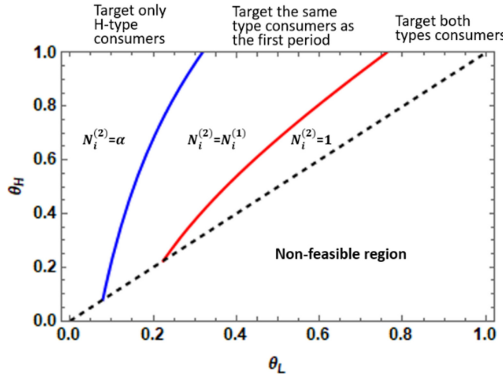| θ_H		$\left(\theta_L+\dfrac{(1-\alpha)c_i[2\kappa\theta_L+(1+2\alpha)\theta_L^2-\kappa^2]}{\alpha(\kappa+\theta_L)^2},\infty\right)$	$\left(\theta_L+\dfrac{(1-\alpha)c_i\left[\alpha\theta_L[2\kappa+(2+\alpha)\theta_L]-\kappa^2\right]}{\alpha(\kappa+\theta_L)^2},\;\theta_L+\dfrac{(1-\alpha)c_i[2\kappa\theta_L+(1+2\alpha)\theta_L^2-\kappa^2]}{\alpha(\kappa+\theta_L)^2}\right)$	$\left(\theta_L,\;\theta_L+\dfrac{(1-\alpha)c_i\left[\alpha\theta_L(2\kappa+(2+\alpha)\theta_L)-\kappa^2\right]}{\alpha(\kappa+\theta_L)^2}\right)$
$N_i^{(1)}=\alpha$	$N_i^{(2)}$	α	α	1
	γ_i	$\dfrac{\kappa+\alpha\theta_L}{2\alpha(2c_i-\theta_H+\theta_L)}$	$\dfrac{\kappa+\alpha\theta_L}{2\alpha(2c_i-\theta_H+\theta_L)}$	$\dfrac{\kappa+\theta_L}{2(1+\alpha)c_i}$
	π_i	$\alpha\overline{p}H-\kappa+\dfrac{\kappa^2+\alpha\theta_L(2\kappa+\alpha\theta_L)}{4\alpha(2c_i-\theta_H+\theta_L)}$	$\alpha\overline{p}H-\kappa+\dfrac{\kappa^2+\alpha\theta_L(2\kappa+\alpha\theta_L)}{4\alpha(2c_i-\theta_H+\theta_L)}$	$\alpha\overline{p}H+\dfrac{(\kappa+\theta_L)^2}{4(1+\alpha)c_i}-\kappa$
$N_i^{(1)}=1$	$N_i^{(2)}$	α	1	1
	γ_i	$\dfrac{\kappa+\alpha\theta_L}{2(c_i+\alpha c_i-\alpha\theta_H+\alpha\theta_L)}$	$\dfrac{\kappa+\theta_L}{4c_i}$	$\dfrac{\kappa+\theta_L}{4c_i}$
	π_i	$\overline{p}L-\kappa+\dfrac{\kappa^2+\alpha\theta_L(2\kappa+\alpha\theta_L)}{4[(1+\alpha)c_i-\alpha(\theta_H-\theta_L)]}$	$\overline{p}L+\dfrac{(\kappa+\theta_L)^2}{8c_i}-\kappa$	$\overline{p}L+\dfrac{(\kappa+\theta_L)^2}{8c_i}-\kappa$

Fig. 2. Conditional targeting in the second period.

(ii)   When $min\left\{\theta_L + \frac{(1-\alpha^2)c_i(\theta_L-\kappa)}{2\alpha(\kappa+\theta_L)}, \theta_L + \frac{(1-\alpha)c_i[\alpha\theta_L(2\kappa+(2+\alpha)\theta_L)-\kappa^2]}{\alpha(\kappa+\theta_L)^2}\right\} < \theta_H < \theta_L +$

$\frac{(1-\alpha)c_i[\alpha\theta_L(2\kappa+(2+\alpha)\theta_L)-\kappa^2]}{\alpha(\kappa+\theta_L)^2}$, the firm will target at H-type consumers in the first period and both types of consumers in the second period (i.e. (H, HL)) and $\overset{\sim*}{\gamma}_i = \frac{\kappa+\theta_L}{2(1+\alpha)c_i}$, $\tilde{p}_i^{(1)*} = \frac{(\kappa+\theta_L)(\theta_H(\kappa+\theta_L)-\theta_L(\kappa-2(1+\alpha)c_i+\theta_L))}{4(1+\alpha)^2c_i^2}$, $\tilde{p}_i^{(2)*} = \frac{\theta_L(\kappa+\theta_L)}{2(1+\alpha)c_i}$, $\overset{\sim*}{\pi}_i = \frac{\kappa^2-8\kappa c_i+4\kappa\theta_L+3\theta_L^2}{8c_i}$.

(iii)   When $\theta_H > \theta_L + \frac{(1-\alpha)c_i[\alpha\theta_L(2\kappa+(2+\alpha)\theta_L)-\kappa^2]}{\alpha(\kappa+\theta_L)^2}$, the firm will target at H-type consumers in both periods (i.e. (H, H)) and $\overset{\sim*}{\gamma}_i = \frac{\kappa+\alpha\theta_L}{2\alpha(2c_i-\theta_H+\theta_L)}$, $\tilde{p}_i^{(1)*} = \tilde{p}_i^{(2)*} = \frac{(\kappa+\alpha\theta_L)[\theta_H(\kappa-\alpha\theta_L)+\theta_L(4\alpha c_i+\alpha\theta_L-\kappa)]}{4\alpha^2(2c_i-\theta_H+\theta_L)^2}$, $\overset{\sim*}{\pi}_i = \frac{-8\alpha\kappa c_i^2+c_i(\kappa^2+8\alpha\kappa\theta_H-4\alpha\kappa\theta_L+3\alpha^2\theta_L^2)-\alpha(\theta_H-\theta_L)[2\kappa\theta_H+\theta_L(-\kappa+\alpha\theta_L)]}{2\alpha(2c_i-\theta_H+\theta_L)^2}$.

The findings in Lemma 2 are depicted in Fig. 3. From Lemma 2 we can also easily derive corollary 1.

Corollary 1. *The firm has more tendency to apply a niche responsible strategy (i.e. target at only H-type consumers in two periods) if consumers have higher valuation heterogeneity.*

It is natural that higher consumer heterogeneity increases firm's incentives in targeting at only H-type consumers. The firm can make profit from the higher premium from the socially-responsible consumers although the non-socially-responsible consumers are not its targeting objectives any more. Moreover, the firm's optimal sustainable investment also increases in consumers' different attitudes towards social sustainability (i.e.

supported by $\frac{\partial\overset{\sim*}{\gamma}_i}{\partial\theta_L} = -\frac{\kappa-2\alpha c_i+\alpha\theta_H}{2\alpha(2c_i-\theta_H+\theta_L)^2} < 0$ and $\frac{\partial\overset{\sim*}{\gamma}_i}{\partial\theta_H} = \frac{\kappa+\alpha\theta_L}{2\alpha(2c_i-\theta_H+\theta_L)^2} > 0$). If the socially-responsible consumers have small difference of valuation compared with non-socially-responsible one, it is better to serve both types consumers without the need to inform consumers of its responsibility information. When the gap of consumer's attitude towards responsibility is moderate, we can see that the first period targeting decisions

shifts to be only H-type consumers. The reason is that if the firm insists on targeting at both types of consumers in the first period, consumers will believe that the firm is of low responsibility. Then in the second period when social responsibility effort becomes a symmetric information, profit will be hurt by holding the belief that the firm is irresponsible. Thus, it is beneficial to target H-type in the first period so as to transfer quality information to consumers.
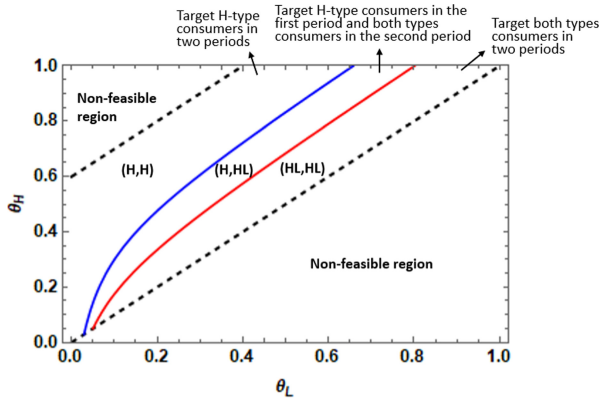

Fig. 3. Firm's optimal targeting decisions.

From Lemma 2, it is also obvious that a high-efficiency firm has more tendency to target H-type consumers. It makes higher social sustainable efforts, sets higher retail prices and earns higher profits. Meanwhile, the higher amount of penalty induces the firm to invest more in social sustainability and target at only H-type consumers in two periods.

5 Conclusion

In recent decades, managing supply chains in a socially responsible manner has become an important and appealing issue (Tang and Zhou 2012). The growing consciousness of CSR from both consumers and regulatory bodies has placed pressure on firms to cope with social challenges. An increasing number of consumers are willing to pay a premium for products' social sustainability. Different legislations are enacted to monitor and promote social sustainability performance. If any unsustainable societal practice is found by the regulatory body, the firm will suffer from huge loss. As pressured by socially responsible purchasing and regulatory pressure, some firms have begun to disclose their social sustainability in audit report periodically. We conduct a two-stage game-theoretic analysis to examine a firm's social sustainability effort and dynamic pricing decisions under regulatory pressure. We find that the extent of consumers' heterogeneity is critically important in firm's responsibility and pricing decisions. Our findings help a firm to wisely make social sustainability effort decisions and set an informative price so as to transfer responsibility information to early consumers. The effects of cost efficiency and the amount of penalty are analyzed as well.

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