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CSR investment timing in a duopoly: The threat of responsibility violations in the context of socially conscious customers[☆]

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ABSTRACT

Sustainability in supply chains is increasingly important. Firms risk losing customers if they delay corporate social responsibility (CSR) investments but may gain customers from competitors by acting early. Using a dynamic model, we analyze CSR investment timing in a duopoly. We study when firms adopt responsible strategies to meet socially conscious customers' expectations to avoid disclosure risks. Small firms invest early to attract customers from larger competitors. In markets with high penalties or disclosure risks, large firms invest relatively early. However, when socially conscious customers dominate, large firms delay investment relative to the small company, leading to a crowding-out effect.

1. Introduction

Corporate Social Responsibility (CSR) is now a central component of strategic decision-making in many firms given its importance for long-term success (see e.g. McWilliams and Siegel, 2001; Albuquerque et al., 2019; Verdu et al., 2012; Servaes and Tamayo, 2013; Orlitzky et al., 2003; Eccles et al., 2014). Growing regulatory pressure, changing consumer preferences, and increasing stakeholder expectations increase the pressure to align operations and supply chains with environmental, social, and governance (ESG) standards. For example, IKEA now sources sustainable cotton (IKEA, 2015) and Apple enforces internal supplier standards, removing 231 manufacturers since 2009 and blocking 11% of potential suppliers since 2020 (Apple, 2024). However, CSR investments often entail significant upfront costs and uncertain future returns. Hence, some firms may take early action while others delay, especially under regulatory uncertainty (see Chowdhury et al., 2025). Exemplary, ArcelorMittal, one of the world's largest steel producers, recently postponed planned green investments in the EU due to regulatory uncertainty and concerns over carbon border adjustments.[1]

This hesitation can be costly. In competitive markets, early movers may gain first-mover advantages such as capturing environmentally conscious consumers, securing regulatory goodwill, and building reputational leadership. Thus, the strategic timing of CSR investments under uncertainty and competition becomes a critical determinant of long-term firm performance.

While the economic literature has addressed various aspects of CSR and its implications for firm value, most existing models remain relatively static in nature. For example, Guo et al. (2013) focus on firms' decisions to adopt CSR under the risk of losing customers while Schinkel et al. (2022) analyze how production agreements impact sustainability levels. Alike, Liu et al. (2015) show how CSR certification impacts competition. Instead, a real options approach can be applied to better understand the dynamic nature of investment decisions under uncertainty and competitive pressure (Dixit and Pindyck, 1994; Chevalier-Roignant et al., 2011; Lacerda et al., 2021). These models offer valuable insights into how firms balance the value of waiting against the potential costs of inaction. In particular, research suggests that market uncertainty deters investment (Sarkar, 2000; Wong, 2007; Lukas and Welling, 2014; Ifwarsson et al., 2021) while competition creates strategic timing games (Huisman and Kort, 2015; Huberts et al., 2015; Delaney, 2019) that hastens investments.

Nevertheless, few studies focus on CSR-related investment decisions within this framework. Exemplary, Nishihara (2023) finds that ESG risk accelerates CSR investment while Shi et al. (2025) show that agency conflicts lead to lower CSR. Alike, Oga et al. (2024) study the effect of goodwill on CSR investment policies. However, the interaction of CSR timing and competition has received little attention. This paper fills this gap by embedding CSR investment decisions into a real options framework under strategic competition. Building on the static model of Guo et al. (2013), we develop a dynamic model where investment

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[1] See www.reuters.com/markets/commodities/arcelormittal-says-it-is-delaying-planned-green-investments-eu-2024-11-22

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timing is affected by the threat of losing socially conscious customers. This extends the real option literature focusing on competition by introducing heterogeneous customers. Our results indicate that investment strategies depend on market share and the threat of preemption. The small firm benefits from flexibility due to lower costs and its ability to attract customers. While uncertainty tends to delay investment, it can prompt strategic shifts in relative timing. High penalties or regulatory risks accelerate investment for both firms, with the large firm often following earlier (crowding-in). A large share of socially conscious customers accelerates investment but may delay the large firm's action due to the small firm's advantage (crowding-out).

2. Model

Two firms $i \in (I, II)$ compete in the same market with exogenously given, asymmetric market share S_i. Firm 1 has the larger share $S_I = a$ while firm 2 has $S_{II} = (1-a)$, with $a > \frac{1}{2}$.[2] Both sell to similar customer bases, composed of $\theta \in (0,1)$ socially conscious and $1-\theta$ regular customers, at a fixed exogenously given price p. The firms have marginal costs c, currently operate with a normal supply chain (N) with marginal cost c_N and can decide to switch to responsible sourcing (R) under marginal costs c_R with $c_R > c_N$ by paying investment costs $S_i I$ relative to their size as indicated by market share.[3] Contribution margin $x(p-c)$ is subject to uncertainty $x(t)$ modeled as a geometric Brownian motion

$$dx(t) = \alpha dt + \sigma x(t) dW(t), x(0) = x_0 \geq 0, \tag{1}$$

where $dW(t)$ denotes a standard Wiener increment α and σ are constants.

In the normal supply chain, both firms face a known joint probability λdt of a responsibility violation, whereas responsible sourcing has a zero probability of a violation. Violations increase marginal costs by penalties v for mitigation, recovery or adjustment costs and loss of customers. Socially conscious customers θ switch to the responsible firm if only one firm produces responsible, or leave the market if neither does. Firms are risk-neutral and discount future cash flows at the risk-free rate r.

We first derive the optimal strategy for a monopolist as a benchmark in Section 2.1 and subsequently for the duopoly in Section 2.2.

2.1. Monopolist

Assume a monopolist with a market share $S = 1$. While continuous normal production yields a contribution margin of $x\left(p - c_N\right)$ and a project value of $V_M^N(x) = \frac{x(p-c_N)}{r-\alpha}$ without a violation, the detection of a violation leads to a drop in the customer base as the fraction θ will exit the market and increased production cost. Consequently, the contribution margin after a violation is $x\left(p - c_N - v\right)(1-\theta)$. By means of standard present value logic, we can derive the project value after a violation:

$$V_M^V(x) = \frac{x\left(p - c_N - v\right)(1-\theta)}{r-\alpha}. \tag{2}$$

However, if the violation is not yet detected, we have to account for the probability that V_M^N will drop to V_M^V. Hence, the monopolist's project value before violation occurs amounts to (see Appendix):

$$V_M(x) = \frac{x\left((1-\theta)\left(p - c_N - v\right)\lambda + (r-\alpha)\left(p - c_N\right)\right)}{(r-\alpha)(r-\alpha+\lambda)}. \tag{3}$$

In contrast, if the firm switches to responsible sourcing before the violation occurs, it generates $x\left(p - c_R\right)$ and a firm value of

$$V_M^R(x) = \frac{x\left(p - c_R\right)}{r-\alpha}. \tag{4}$$

By switching business models, the potential gain is $V_M^R(x) - V_M(x)$ with a net gain of

$$\begin{aligned}\Delta_M(x) &= V_M^R(x) - V_M(x) - I \\ &= \frac{x\left(\left(\left(p - c_N - v\right)\theta + v\right)\lambda + \left(c_R - c_N\right)(r-\alpha+\lambda)\right)}{(r-\alpha)(r-\alpha+\lambda)} - I\end{aligned} \tag{5}$$

from investing I to switch to responsible sourcing to prevent the threat of a violation.

Following standard real option reasoning, the firm holds the option to invest in CSR. The optimal investment policy that maximizes the option value $F(x)$ is to switch at the optimal investment threshold x^*, which is determined according to:

$$\max_{x^*} F(x) = \Delta\left(x^*\right)\left(\frac{x}{x^*}\right)^{\beta}, \tag{6}$$

where $(x/x^*)^\beta$ is the stochastic discount term of receiving the net gain $\Delta(x^*)$ at x^*. Hence, it measures the risk-neutral probability that the project state x reaches the investment threshold (see Dixit and Pindyck, 1994, p. 315f.).

Given $\Delta(x) = \Delta_M(x)$ and $x^* = x_M^*$, Proposition 1 summarizes the solution.

Proposition 1. *The monopolist will switch to the new business model as soon as x hits the optimal investment threshold, i.e.*

$$x_M^* = \frac{\beta}{\beta-1} \frac{(r-\alpha)(r-\alpha+\lambda)}{\left(\left(\left(p - c_N - v\right)\theta + v\right)\lambda + \left(c_R - c_N\right)(r-\alpha+\lambda)\right)} I, \tag{7}$$

from below. The corresponding option value is

$$F_M(x) = \begin{cases} \Delta_M\left(x_M^*\right)\left(\frac{x}{x_M^*}\right)^{\beta} & \text{if } x < x_M^* \\ \Delta_M(x) & \text{otherwise,} \end{cases} \tag{8}$$

with $\beta = \frac{1}{2} - \frac{\alpha}{\sigma^2} + \sqrt{\left(\frac{\alpha}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2(r+\lambda)}{\sigma^2}} > 1.$

2.2. Duopoly

To characterize the firms' optimal investment policies, we model their interaction as an investment timing game solved by backward induction. We begin with the follower's optimal investment threshold; the leader's strategy then follows as a best response, conditional on the follower's behavior and the current market state x. In a Stackelberg setting with exogenously assigned roles, three outcomes arise. When the market is weak, the leader delays investment ("wait to deter"). At intermediate market states, the leader invests immediately and deters the follower ("deter"). In both cases, investment is sequential. When the market is sufficiently large, the follower invests immediately after the leader and both invest simultaneously ("accommodation").

Endogenizing the roles introduces competition for leadership. Each firm has a preemption threshold at which it prefers to be leader rather than follower. A firm can follow its leader strategy as long as its rival's preemption threshold is higher. If the rival's threshold is lower, a preemption race emerges, with the firm with the lowest threshold investing first. If the market already exceeds both firms' thresholds, both invest immediately.

In the following, we first derive the duopoly project values in the same way as in the monopol in 2.2.1 and then derive optimal investment policies within the Stackelberg and preemption setting in 2.2.2.

[2] We assume different market shares because both firms are already active in the market and the different market shares are a result of past investment (of different size) to gain access to the market.

[3] Hence, both firms are symmetric except for their asymmetric market share.

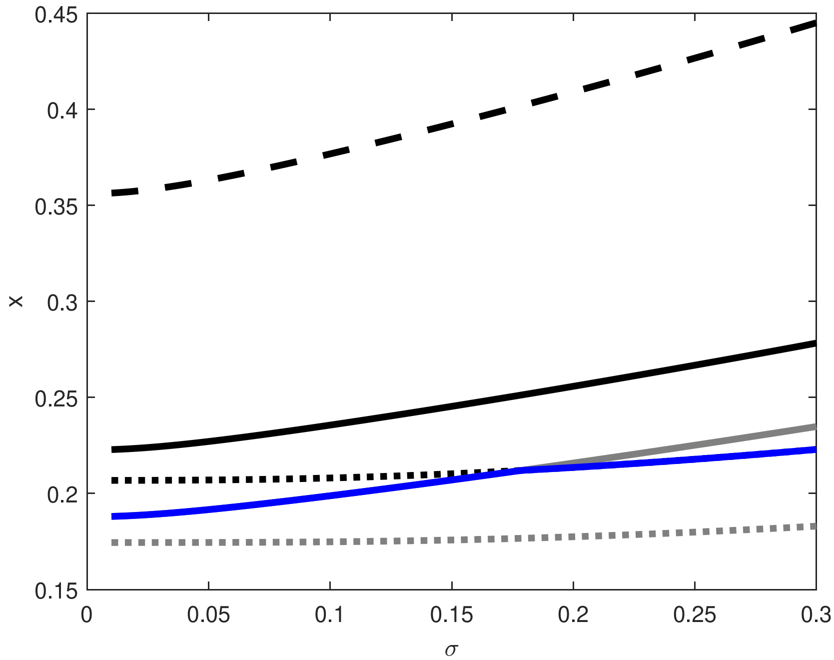

Fig. 1. Deter x_i^{det} (solid) and preemption x_i^{pre} (dotted) thresholds for the large (black) and small (gray) firm, with the follower strategy x^F (dashed) for both and the small firm' s chosen strategy (blue) over uncertainty σ.

2.2.1. *General business models*

As in the monopolist case, firms can choose between not investing and investing in CSR. In particular, if both firms adopt the same strategy, the duopoly's project value mirrors the monopoly's, split by market share. Consequently, should both operate under normal sourcing, both face the thread of a violation, leading to the penalty and customers leaving the market. Here, each firm gets its market share of the monopolist's project value, i.e.:

$$V_i(S_i, x) = S_i V_M(x) = \frac{S_i x\left((1-\theta)\left(p-c_N-v\right)\lambda + (r-\alpha)\left(p-c_N\right)\right)}{(r-\alpha)(r-\alpha+\lambda)}. \quad (9)$$

Should both decide to invest in responsible sourcing each of them get their fraction of the monopolist's CSR-project value:

$$V_i^R(S_i, x) = S_i V_M^R(x) = \frac{S_i x(p-c_R)}{r-\alpha}. \quad (10)$$

In contrast, one firm is the leader in the market if it has switched to responsible sourcing while the other has not. This leader not only avoids violation losses, but can also gain customers from the follower. Hence, the overall value of the business model, V_i^L, is comprised of the present value V_i^R and the expected added value due to the migration of responsible sensitive customers from its competitor in reaction to a CSR violation, i.e.:

$$V_i^L(S_i, x) = V_i^R(S_i, x) + \frac{\lambda(1-S_i)\theta x(p-c_R)}{(r-\alpha+\lambda)(r-\alpha)} \quad (11)$$

$$= \frac{x\left(p-c_R\right)\left(\left((1-\theta)S_i+\theta\right)\lambda + S_i(r-\alpha)\right)}{(r-\alpha)(r-\alpha+\lambda)} \quad (12)$$

In this case, the follower remains passive and is still exposed to the risk of the penalty and customer loss to the leader with a business model value:

$$V_i^F(S_i, x) = \frac{S_i x\left((1-\theta)\left(p-c_N-v\right)\lambda + (r-\alpha)\left(p-c_N\right)\right)}{(r-\alpha)(r-\alpha+\lambda)}. \quad (13)$$

Hence, its business model value equals $V_i^F = V_i$ because the firm faces the loss of customers both under normal operation and as being the follower (see Guo et al., 2013).

2.2.2. *Endogenous investment timing*

In the following, we will start with assigning exogenous roles. Both firms maximize their respective firm value, as stated in Eq. (6). From the leader's perspective the follower has a net gain $\Delta_i^F(S_i, x) = V_i^R(1-S_i, x) - V_i(1-S_i, x) - \left(1-S_i\right) I$ from investment or:

$$\Delta_i^F(S_i, x) = \frac{\left(1-S_i\right) x\left(\left(\left(p-c_N-v\right)\theta+v\right)\lambda + \left(c_R-c_N\right)(r-\alpha+\lambda)\right)}{(r-\alpha)(r-\alpha+\lambda)} - \left(1-S_i\right) I. \quad (14)$$

Using Eq. (6) and setting $\Delta(\cdot) = \Delta_i^F(\cdot)$ and $x^* = x^F$, we can determine the follower's optimal investment threshold x^F. It is easy to show that $x^F = x_M^*$ as $\Delta_i^F(S_i, x) = (1-S_i)\Delta_M(x)$.

Depending on the state of the market x, the leader can either accommodate or deter the follower (Huisman and Kort, 2015). In the accommodation strategy (at high x), the leader waits long enough for the follower to invest immediately afterward with a net gain of $\Delta_i^{acc}(S_i, x) = V_i^R(S_i, x) - V_i(S_i, x) - S_i I$. Using Eq. (6) and setting $\Delta(\cdot) = \Delta_i^{acc}(\cdot)$ and $x^* = x^{acc}$, we can determine the leader's optimal investment threshold x^{acc}. Alike, it is easy to show that $x^{acc} = x_M^*$ as $\Delta_i^{acc}(S_i, x) = S_i \Delta_M(x)$.

In the deter strategy (at low x), the leader invests early to delay the follower's entry to receive leader value V_i^L until the follower invests at x^F, and the leader receives V_i^R, with a net gain $\Delta_i^{det}(S_i, x) = \left[V_i^L(S_i, x) - V_i(S_i, x)\right] - S_i I + \left(\frac{x}{x^F}\right)\left[V_i^R(S_i, x) - V_i^L(S_i, x)\right]$ or:

$$\Delta_i^{det}(S_i, x) = \left[\frac{x\left(\left((\theta-1)\left(v+c_N-c_R\right)\lambda - \left(v-c_R\right)(r-\alpha)\right)S_i - \lambda\theta\left(p-c_R\right)\right)}{(r-\alpha)(r-\alpha+\lambda)}\right] - S_i I + \left(\frac{x}{x^F}\right)^{\beta}\left[\frac{x^F\left(p-c_R\right)\lambda\theta(S_i-1)}{(r-\alpha)(r-\alpha+\lambda)}\right]. \quad (15)$$

Using Eq. (6) and setting $\Delta(\cdot) = \Delta_i^{det}(\cdot)$ and $x^* = x_i^{det}$, we can again determine the leader's optimal investment threshold x_i^{det}. It is worth mentioning that although the option to wait for the accommodation strategy exists, it is less profitable than exercising the deter strategy immediate for $x_i^{det} < x < x^{acc}$. The strategies for both firms are given in Proposition 2.

Proposition 2. *From the leader's perspective with market share S_i, the follower and leader investment thresholds under the accommodation strategy*

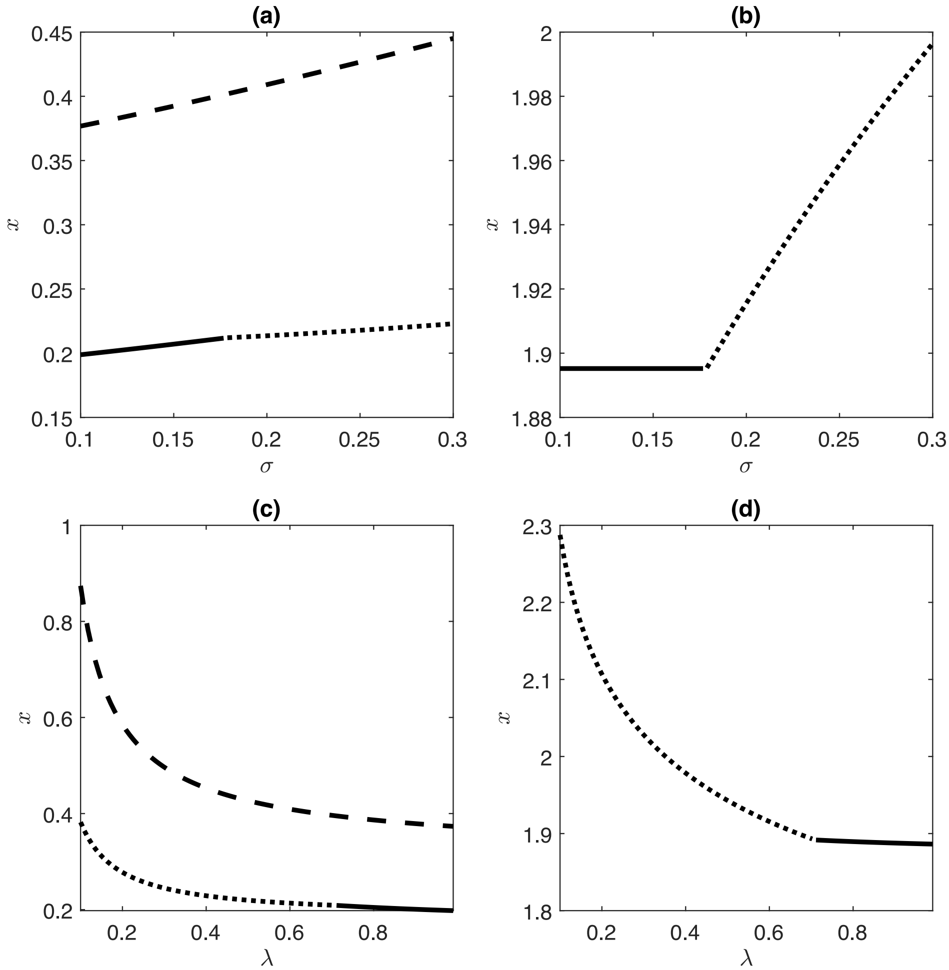

Fig. 2. The optimal strategies of the follower (large firm) and leader (small firm) for market uncertainty σ and violation threat λ. On the left: the deter x_{II}^{det} (solid) and preemption x_{I}^{pre} (dotted) threshold of the leader for the region in which they are the optimal strategy together with the follower x_{F}^{*} (dashed) threshold. On the right: the relative timing strategy x_{II}^{det}/x^{F} (solid) and x_{I}^{pre}/x^{F} (dotted).

are:

$$x^{acc} = x^{F} = x_{M}^{*} \tag{16}$$

with the follower's option value

$$F^{F}(S_i, x) = \begin{cases} \Delta_i^{F}(S_i, x^{acc}) \left(\frac{x}{x^{acc}}\right)^{\beta} & \textit{if } x < x^{acc} \\ \Delta_i^{F}(S_i, x) & x^{acc} \ll x \end{cases} \tag{17}$$

and the leader's option value

$$F^{acc}(S_i, x) = \begin{cases} \Delta_i^{acc}(S_i, x^{acc}) \left(\frac{x}{x^{acc}}\right)^{\beta} & \textit{if } x < x^{acc} \\ \Delta_i^{acc}(S_i, x) & x^{acc} \ll x. \end{cases} \tag{18}$$

The investment threshold under the deter strategy is

$$x_i^{det}(S_i) = \frac{\beta}{\beta - 1} \times \frac{(r - \alpha + \lambda)(r - \alpha)}{\left(\left((\theta - 1)\left(\upsilon + c_N - c_R\right)\lambda - \left(\upsilon - c_R\right)(r - \alpha)\right)S_i - \lambda\theta\left(p - c_R\right)\right)} I \tag{19}$$

with option value

$$F_i^{det}(S_i, x) = \begin{cases} \Delta_i^{det}(S_i, x_i^{det}) \left(\frac{x}{x_i^{det}}\right)^{\beta} & \textit{if } x < x_i^{det} < x^{F} \\ \Delta_i^{det}(S_i, x) & \textit{if } x_i^{det} \le x < x^{F}. \end{cases} \tag{20}$$

Interestingly, the accommodation threshold of both firms matches the monopolist's strategy and is independent of market share S_i, consistent with the static case in Guo et al. (2013), though firm values are still affected ($F^{acc} \neq F^{F}$). In contrast, the deter strategy's threshold depends on the leader's market share (see Eq. (20)).

Finally, both firms may seek to preempt the other, preferring to be the leader. The preemption condition is $\Delta_i^{det}(x_i^{pre}) = F^{F}(x_i^{pre})$, with x_i^{pre} as the lowest x where the firm wants to be the leader. Our findings extend Guo et al. (2013), showing that competition accelerates CSR investment. Moreover, unlike in Guo et al. (2013), both firms eventually adopt responsible sourcing in large markets.

3. Numerical study

We use $\alpha = 0.05$, $r = 0.1$, $\sigma = 0.2$, $p = 5$, $I = 10$, $\lambda = 0.6$, $\theta = 0.6$, $c_R = 3$, $c_N = 2.5$, $\upsilon = 1.7$ for the numerical analysis of the strategic interaction. While values of r, α, σ, and I are in line with standard real option literature (e.g. Dixit and Pindyck, 1994; Lukas and Welling, 2014; Lacerda et al., 2021), values of p, c_R, c_N, and υ are chosen arbitrarily to generate a positive cash flow but do not drive our main results. Parameters λ and θ are studied in a comparative static in 2 (λ is 0.1 in Nishihara, 2023, and 0.3 in Oga et al., 2024).

We find the small firm exhibits a distinct strategy shift, either following its deter strategy or slightly preceding the large firm's preemption threat. Fig. 1 , in line with real options theory, shows that

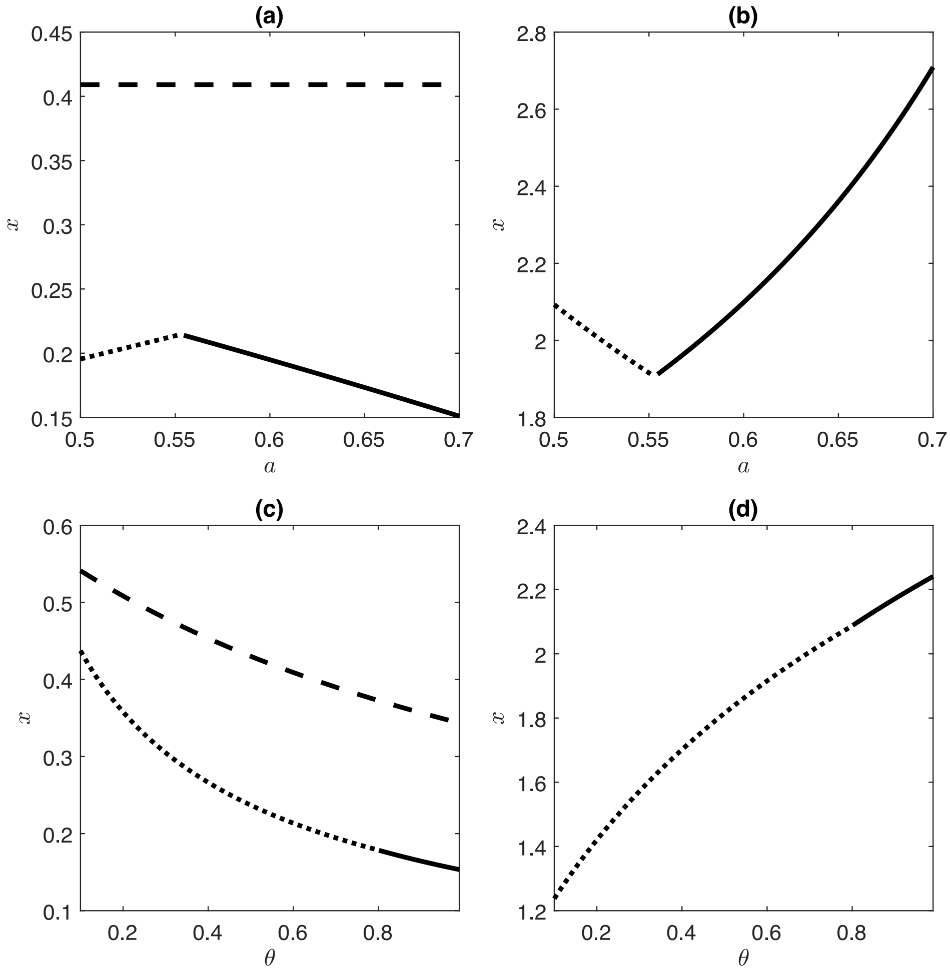

Fig. 3. The optimal strategies of the follower (large firm) and leader (small firm) for market share a and share of socially conscious costumers θ. On the left: the deter x_{II}^{det} (solid) and preemption x_I^{pre} (dotted) threshold of the leader (small firm) for the region in which they are the optimal strategy together with the follower x_F^* (dashed) threshold. On the right: the relative timing strategy x_{II}^{det}/x^F (solid) and x_I^{pre}/x^F (dotted).

thresholds increase with uncertainty σ. However, preemption thresholds increase more slowly than deter thresholds, leading to a strategy shift for the small firm.[4] At low uncertainty, the small firm deters, as its deter threshold is below the large firm's preemption threshold ($x_I^{pre} > x_{II}^{det}$). Under high uncertainty, when $x_I^{pre} < x_{II}^{det}$, the large firm poses a credible threat, forcing the small firm to invest marginally before the large firm's preemption threshold x_I^{pre}.

The model predicts a timing advantage for the small firm, consistent with Guo et al. (2013), who found no cases where only the large firm prefers responsible sourcing. In our model, the small firm can invest earlier due to lower CSR compliance costs potentially attracting new customers. But as uncertainty increases, this advantage decreases. If markets grow large enough, the larger firm can justify large investments (see Nishihara, 2023), so the small firm accelerates investment to preempt.

Figs. 2 and 3 illustrate the relative strategies, i.e. x_i^{det}/x^F and x_2^{pre}/x^F. In Fig. 2(b), an increase in low uncertainty σ does not change the relative timing if the small firm can deter, but high uncertainty leads to relatively earlier investment by the small firm, crowding out the large firm. Higher violation probability λ encourages earlier investments of both firms to avoid CSR risk, leading to a crowding-in effect in Fig. 2(c) and (d) because of the higher pressure on the large firm. For high λ, the small firm can deter the large firm and capture more customers by investing early.

Fig. 3(a) shows a U-shaped effect of the large firm's market share on the small firm's timing. For equal market shares $a = 0.5$, we have the special case of symmetric firms. In this case, both firms have the same optimal and preemption thresholds. For low x, one firm becomes the leader and the other the follower, while for large x both invest simultaneously.[5] For nearly equal market shares, the small firm delays upon higher a due to a lower preemption threat. Under high inequality, it invests earlier to attract customers. This U-shape also appears in relative timing. Lastly, in Fig. 3(c), a higher share of CSR conscious customers θ pushes both firms to invest earlier, with a greater advantage for the small firm, leading to a crowding-out effect.

Our findings offer guidance for future empirical research. High penalties, high CSR violation risk, and a large share of socially conscious consumers encourage earlier investment by both firms. However, the effects differ: The first two create a crowding-in effect, with the large firm investing relatively earlier, while the latter causes a crowding-out effect. When market shares are balanced, the small firm may delay due to a weaker preemption threat. However, very small

[4] We assume that x_0 is small enough to not trigger immediate investment. Otherwise, if $x_{II}^{det} < x_0 < x_{II}^{pre}$ the small firm could still preempt. For $x_0 > x_{II}^{pre}$ both firms prefer to be the leader and invest immediately. As long as $x_0 < x^F$ one firm will become the leader by chance and get to deter the other, while for $x_0 > x^F$ both will invest immediately.

[5] We thank the anonymous referee for pointing out this special case.

firms invest early, benefiting from lower costs and the opportunity to attract customers if the large firm faces a violation.

4. Conclusion

We study how firms compete on timing and over customers. Our results show that strategies depend on the large firm's market share and preemption threat. The small firm holds a flexibility advantage due to lower investment costs and its ability to attract customers. Uncertainty generally delays investment, but it can trigger a strategy shift. High penalties or violation risks accelerate investment for both firms, with an additional crowding-in effect where the large firm follows earlier. A high share of socially conscious customers speeds up investment but leads to a crowding-out effect, delaying the large firm's commitment due to the small firm's competitive advantage.

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Appendix. Monopolist's firm value before violation occurs

Before the violation, project value

$$V_M(x) = x\left(p - c_N\right)dt + (1-\lambda dt)\mathbb{E}\left[V_M(x+dx)e^{-rdt}\right] + \lambda dt\mathbb{E}\left[V_M^V(x+dx)e^{-rdt}\right] \quad (21)$$

is the sum of the current contribution margin $x\left(p - c_N\right)$ over the small interval dt and its continuation value, which has a probability λdt for a violation to occur, where $\mathbb{E}(\cdot)$ denotes the expectation operator. Using Ito's Lemma and rearranging yields the differential equation:

$$\frac{1}{2}\sigma^2 x^2 \frac{\partial^2 V_M}{\partial x^2} + \alpha x \frac{\partial V_M}{\partial x} - rV_M + x\left(p - c_N\right) + \lambda\left(V_M^V - V_M\right) = 0 \quad (22)$$

which has the particular solution

$$V_M(x) = V_M^N(x) + \frac{\lambda x(p - c_N - v)(1-\theta)}{(r-\alpha)(r-\alpha+\lambda)}. \quad (23)$$

or

$$V_M(x) = \frac{x\left((1-\theta)\left(p - c_N - v\right)\lambda + (r-\alpha)\left(p - c_N\right)\right)}{(r-\alpha)(r-\alpha+\lambda)}. \quad (24)$$

Data availability

No data was used for the research described in the article.

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