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Michi NISHIHARA[†] Takashi SHIBATA[‡]

Abstract

This paper investigates the interactions between preemptive competition and leverage. We find that the second mover always leaves the duopoly market before the first mover, although the leader may exit before the follower's entry. We also see the leverage effects of debt financing increasing firm values and accelerating investment, even in the presence of preemptive competition. In addition to the case with optimal capital structure, we analyze a case with financing constraints that require firms to finance investment costs by debt. Notably, financing constraints can delay preemptive investment and improve firm values in preemptive equilibrium. Indeed, the leader's high leverage due to the financing constraints can lower the first-mover advantage and weaken preemptive competition. Especially with strong first-mover advantage, the financing constraint effects can dominate the leverage effects. These findings are almost consistent with empirical evidence that high leverage leads to competitive disadvantage and mitigates product market competition.

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1 Introduction

Since the seminal paper of Brander and Lewis (1986), a number of researchers have investigated the interactions between financial structure and product market competition. Although a wide range of competition among levered firms is covered in the existing literature (e.g., Faure-Grimaud (2000), Povel and Raith (2004)), few papers have analyzed the effects of leverage on preemptive competition. Analysis of preemptive competition is increasingly important as firms, such as Apple, lead a new market by technological innovation and gain great first-mover advantage all over the world. This paper sheds light on how financial structure interacts with preemptive competition.

This paper considers a situation in which two symmetric firms compete for a new market. When profit flows in a duopoly are lower than those in a monopoly (i.e., negative externalities), each firm has an incentive to preempt the competitor and gain monopolistic profit flows before the competitor's entry. In preemptive equilibrium, one of the firms, denoted by the leader, enters the market earlier than the other, denoted by the follower, but its first-mover advantage is offset by its sub-optimally early entry timing. After Fudenberg and Tirole (1985) first analyzed preemptive equilibrium in a case without market uncertainty, the literature including Dixit and Pindyck (1994), Grenadier (1996), and Huisman (2001), has examined cases with market uncertainty.

We examine the interactions between preemptive competition and leverage by extending the previous analysis to a setup in which firms can access debt financing on the market entry. In the levered setup, we consider firms that optimize capital structure based on the trade-off theory (e.g., Leland (1994), Goldstein, Ju, and Leland (2001)). Through the model analysis, we find key results as follows.

First, we find that the last in, first out (LIFO) scenario holds in a duopoly. This is mainly because the leader's entry trigger is much lower than the follower's entry trigger in preemptive equilibrium. Because of the early entry, the leader's debt issuance is very low and the follower issues more debt on the later entry timing. Our result is consistent with MacKay and Phillips (2005) who empirically show that leverage of new entrants is likely to be higher than that of incumbents. The LIFO scenario is also consistent with empirical findings that high debt tends to lead to disadvantage in product market competition (e.g., Phillips (1995), Chevalier (1995a), Chevalier (1995b)).

Second, we show that the leverage effects remain unchanged even if one takes account of preemptive competition. Indeed, compared to the unlevered case, the entry triggers (firm values) become lower (higher) in preemptive competition with optimal capital structure. The leverage effects are well known in corporate finance (e.g., Myers (1977)). The leverage effects are also identified in the investment timing models such as Hennessy (2004), Mauer and Sarkar (2005), and Sundaresan and Wang (2007a), but they focus on a monopoly. We ensure the robustness of the leverage effects even in the presence of preemptive competition.

In addition to analysis on firms with optimal capital structure, we consider financially constrained firms in which investment costs must be financed by debt issuance. This case approximates firms that have no cash reserves and cannot use external equity financing due to the high costs. Notably, we show that financing constraints can delay preemptive investment and improve firm values in equilibrium. The intuition is as follows. The financing constraints lead the leader to be highly leveraged, while it increases the value of the follower's option to wait for the leader's exit. Thus, the constraints reduce firms' incentive to move first, and then it alleviates preemptive competition.

The financing constraint effects can happen with a modest level of first-mover advantage and greatly increases as the first-mover advantage is stronger. When the financing constraint effects dominate the leverage effects, the preemptive entry trigger can be later than that of the unlevered case. Although the financing constraint effects in preemptive competition have yet to be tested rigorously, there are several findings related to the predictions. For instance, empirical evidence indicates that higher leverage can soften product market competition (e.g., Phillips (1995), Chevalier (1995a), Chevalier (1995b)). In our paper, higher leverage, which is caused by the financing constraints, delays the preemptive entry timing and increases firm values.

Our paper is most closely related to the following papers. Lambrecht (2001) studies the entry and exit decisions of levered firms in a duopoly. The paper exogenously assumes an incumbent with debt and examines the follower's entry and financing decision. Our paper complements the previous research by extending his model to a new market model in which two firms compete for first-mover advantage. Preemptive competition is frequently seen in technology-oriented industries, for example, information technology (IT) industries. Our analysis may foster better understanding of such industries. Zhdanov (2008), like our paper, examines a preemptive competition model with leverage. His model assumes that the leader survives as an all-equity firm after its default, while, as in Lambrecht (2001), we simply assume that the leader exits the market. Because of this simplification, our model is more tractable and easier to analyze. We reveal the effects of first-mover advantage and financing constraints that are not clarified by Zhdanov (2008). Nishihara and Shibata (2010) also study preemption with leverage, but the previous paper assumes that the follower cannot enter the market until the leader exits it. Because of the polar assumption, the model applicability is restricted to a situation involving extremely strong first-mover advantage. In this paper, we relax the assumption and show how the degree of first-mover advantage influences the results.

The remainder of this paper is organized as follows. As a benchmark, Section 2 introduces the investment policies of unlevered firms in a duopoly. In Section 3, we illustrate the investment and financing policies for levered firms in a duopoly. In Section 4, we exercise numerical analysis and provide empirical implications. Section 5 briefly summarizes the paper.

2 Unlevered firms in a duopoly

2.1 Setup

We use the same setup as the standard literature (e.g., Chapter 9 in Dixit and Pindyck (1994), Chapter 7 in Huisman (2001)). We consider two symmetric firms that have an opportunity to enter a new market. The entry to the market requires irreversible capital expenditure I. Throughout this paper, we assume that both firms are risk-neutral and have full information of each other. When only one of the firms is active in the market, the active firm receive an instantaneous cash flow $X(t)$ that is influenced by the market demand. Following the standard real options literature, we assume that $X(t)$ follows a geometric Brownian motion:

$$\mathrm{d}X(t) = \mu X(t)\mathrm{d}t + \sigma X(t)\mathrm{d}B(t) \ (t > 0), \quad X(0) = x, \tag{1}$$

where $B(t)$ denotes the standard Brownian motion defined in a probability space $(\Omega, \mathcal{F}, \mathbb{P})$ and $\mu, \sigma(> 0)$ and $x(> 0)$ are constants. We assume that the initial value is sufficiently low to exclude a firm' entry into a market at the initial time. For convergence, we assume that $r > \mu$[1], where r is a positive constant interest rate. When both firms are active in the market, the first mover, denoted by the leader, receives an instantaneous cash flow $Q_L X(t)$ while the second mover, denoted by the follower, receives $Q_F X(t)$. Assume that Q_L and Q_F are constants satisfying $0 < Q_F \leq Q_L < 1$, which means that the leader's profit in a duopoly is between the monopolistic profit and the follower's profit. We presume the negative externalities and first-mover advantage so as to focus on the analysis of preemptive competition.

2.2 Preemptive equilibrium

This section explains preemptive equilibrium following Dixit and Pindyck (1994), Huisman (2001), and Grenadier (1996), among others. In a duopoly game, we need consider the problem backwards. We denote the "Unlevered" case by the subscript U. Suppose that the leader has invested at time s. The follower optimally enters the market by solving the optimal stopping problem:

$$F_U(X(s)) = \sup_{T_{FU} \geq s} \mathbb{E}^{X(s)}[\int_{T_{FU}}^{\infty} \mathrm{e}^{-r(t-s)}(1-\tau)Q_F X(t)\mathrm{d}t - \mathrm{e}^{-r(T_{FU}-s)} I], \tag{2}$$

where T_{FU} runs over stopping times and $\mathbb{E}^{X(s)}[\cdot]$ denotes the expectation conditional on $X(s)$. We denote the corporate tax rate by positive constant τ. The value $F_U(X(s))$ corresponds to the follower's option value at time s. Because of the strong Markov property of $X(t)$, problem (2) can be reduced to

$$\sup_{T_{FU} \geq s} \mathbb{E}^{X(s)}[\mathrm{e}^{-r(T_{FU}-s)} \left(\frac{(1-\tau)Q_F}{r-\mu} X(T_{FU}) - I \right)]$$

[1]For economic rationale of the assumption, refer to Dixit and Pindyck (1994).

and has the explicit solution as follows:

$$F_U(X(s)) = \begin{cases} \left(\dfrac{(1-\tau)Q_F x^*_{FU}}{r-\mu} - I\right)\left(\dfrac{X(s)}{x^*_{FU}}\right)^{\beta} & (X(s) < x^*_{FU}) \\ \dfrac{(1-\tau)Q_F}{r-\mu}X(s) - I & (X(s) \geq x^*_{FU}), \end{cases} \tag{3}$$

where $\beta := 1/2 - \mu/\sigma^2 + \sqrt{(\mu/\sigma^2 - 1/2)^2 + 2r/\sigma^2} (> 1)$ is a positive characteristic root, and $x^*_{FU} := \beta(r-\mu)I/\{(\beta-1)(1-\tau)Q_F\}$ is the entry trigger. The follower's entry time is expressed as the optimal stopping time:

$$T^*_{FU} := \inf\{t \geq s \mid X(t) \geq x^*_{FU}\}. \tag{4}$$

Then, the leader's expected gain by investment at time s becomes

$$L_U(X(s)) = \mathbb{E}^{X(s)}[\int_s^{T^*_{FU}} \mathrm{e}^{-r(t-s)}(1-\tau)X(t)\mathrm{d}t + \int_{T^*_{FU}}^{\infty} \mathrm{e}^{-r(t-s)}(1-\tau)Q_L X(t)\mathrm{d}t], \tag{5}$$

where T^*_{FU} is defined by (4). Note that after T^*_{FU} the leader's profit flows will decrease to $Q_L X(t)$. By straightforward calculation, we have

$$L_U(X(s)) = \frac{1-\tau}{r-\mu}X(s) - \frac{(1-\tau)(1-Q_L)x^*_{FU}}{r-\mu}\left(\frac{X(s)}{x^*_{FU}}\right)^{\gamma}, \tag{6}$$

where $\gamma := 1/2 - \mu/\sigma^2 - \sqrt{(\mu/\sigma^2 - 1/2)^2 + 2r/\sigma^2} (< 0)$ is a negative characteristic root.

By comparing $L_U(X(s))$ with $F_U(X(s))$ we consider the situation in which neither firm has invested. In the region $F_U(X(s)) < L_U(X(s))$, both firms are better off becoming the first mover, whereas in the region $L_U(X(s)) < F_U(X(s))$, both firms are better off becoming the follower. In equilibrium, one of the firms, denoted by the leader, invests at time

$$T^*_{LU} := \inf\{t \geq 0 \mid X(t) \geq x^*_{LU}\}. \tag{7}$$

where x^*_{LU} is the solution to $F_U(x^*_{LU}) - L_U(x^*_{LU}) = 0$.[2] This investment is called preemptive investment. The follower invests later on the best response timing $T^*_{FU}(> T^*_{LU})$. See the top panel of Figure 1. Note that in equilibrium the first-mover advantage is exactly offset by inefficiency in the preemptive entry. Firms are indifferent between the roles of the leader or the follower. Depending on the parameter values, there may exist joint investment equilibrium in which both firms cooperate to invest at the same time which is later than T_{LU}. For example, see Huisman (2001) and Pawlina and Kort (2006). This paper focuses only on preemptive equilibrium because the main objective is to examine the levered case. Note that, in the levered case, no joint investment equilibrium arises.

[2]Because this is a model of symmetric firms, we cannot determine which one is exactly the first mover. Based on most of the literature including Dixit and Pindyck (1994) and Grenadier (1996), we exclude the possibility that both firms mistakenly invest at the same time x^*_{LU}.

3 Levered firms in a duopoly

3.1 Setup

Now, we proceed to examine how leverage affects preemptive competition. This section explains how we can solve preemptive equilibrium in the levered case. In addition to the setup in Section 2, we assume that both firms can issue console bonds on the investment timing. This assumption is standard in the literature regarding dynamic investment and capital structure (e.g., Sundaresan and Wang (2007a), Sundaresan and Wang (2007b), Shibata and Nishihara (2012)). The levered firms are evaluated in the framework of structural models by Leland (1994) and Goldstein, Ju, and Leland (2001). In the framework, after the issuance of debt, shareholders optimize the default timing to maximize the equity value, whereas debtholders receive coupon payment until the default. The optimal capital structure depends on the trade-off between costs associated with default and tax benefits from debt issuance. Throughout this paper, a firm determines its optimal capital structure and investment timing to maximize its firm value.[3] For simplicity, following Lambrecht (2001) and Nishihara and Shibata (2010), we assume that a bankrupt firm immediately leaves the market. The levered case greatly differs from the unlevered case in the possibility of the market exit. The analysis in the levered case will better fit preemptive competition in technological development; actually, in IT industries, the majority of venture businesses are forced to close after a boom.

3.2 Firms without a financing constraint

As in Section 2.2, we consider the problem backwards. We begin by deriving the follower's value in a duopoly. It depends on which firm exits the market first. However, as will be shown in numerical analysis, we always have the LIFO scenario, i.e., the follower leaves the market before the leader. From now on, we will explain the methodology to derive preemptive equilibrium in the LIFO scenario. For the state variable $X(s)$, the equity, debt, and firm values of the follower that has issued debt with coupon $C_F(> 0)$ are as

[3] We can say that shareholders maximize the ex-ante equity value under the assumption that debtholders are competitive.

follows:

$$
\begin{aligned}
&E_F(X(s),C_F)\\
=&\mathbb{E}^{X(s)}[\int_s^{T_F^d} \mathrm{e}^{-r(t-s)}(1-\tau)(Q_F X(t)-C_F)\mathrm{d}t]\\
=&\frac{(1-\tau)Q_F}{r-\mu}X(s)-\frac{(1-\tau)C_F}{r}-\left(\frac{(1-\tau)Q_F}{r-\mu}x_F^d-\frac{(1-\tau)C_F}{r}\right)\left(\frac{X(s)}{x_F^d}\right)^{\gamma} \qquad (8)\\
&D_F(X(s),C_F)\\
=&\mathbb{E}^{X(s)}[\int_s^{T_F^d} \mathrm{e}^{-r(t-s)}C_F\mathrm{d}t+\mathrm{e}^{-r(T_F^d-s)}K_F(x_F^d)]\\
=&\frac{C_F}{r}-\left(\frac{C_F}{r}-K_F(x_F^d)\right)\left(\frac{X(s)}{x_F^d}\right)^{\gamma} \qquad (9)\\
&V_F(X(s),C_F)\\
=&E_F(X(s),C_F)+D_F(X(s),C_F)\\
=&\frac{(1-\tau)Q_F}{r-\mu}X(s)+\frac{\tau C_F}{r}-\left(\frac{\tau C_F}{r}+\frac{(1-\tau)Q_F}{r-\mu}x_F^d-K_F(x_F^d)\right)\left(\frac{X(s)}{x_F^d}\right)^{\gamma}, \qquad (10)
\end{aligned}
$$

where T_F^d stands for the exit time and $K_F(x_F^d)$ denotes the liquidation value. Because of the smooth pasting condition, we have

$$T_F^d := \inf\{t \geq s \mid X(t) \leq x_F^d\}, \qquad (11)$$

where the default trigger is defined by $x_F^d := \gamma(r-\mu)C_F/\{(\gamma-1)rQ_F\}$. Eq. (8)–(10) presume $X(s) \geq x_F^d$. This argument is the same as that of the structural model by Goldstein, Ju, and Leland (2001).

For preparation, we derive a coupon that maximizes the firm value (10). Following Goldstein, Ju, and Leland (2001) and Lambrecht (2001), we assume a linear form $K_F(x_F^d) := (1-\alpha_F)(1-\tau)Q_F x_F^d/(r-\mu)$ for the liquidation value, where a constant $\alpha_F \in (0,1)$ measures costs associated with liquidation. By simple calculation, we have the optimal coupon:

$$C_F^*(X(s)) := \arg\max_{C_F} V_F(X(s),C_F) = \frac{r(\gamma-1)Q_F}{(r-\mu)\gamma h}X(s), \qquad (12)$$

where h is a constant defined by

$$h = \left[1-\gamma\left(1-\alpha_F+\frac{\alpha_F}{\tau}\right)\right]^{-\frac{1}{\gamma}} (>1). \qquad (13)$$

By substituting (12) into (10), we obtain

$$V_F(X(s),C_F^*(X(s))) = \frac{(1-\tau)Q_F}{\psi(r-\mu)}X(s), \qquad (14)$$

where ψ is a positive constant defined by

$$\psi = \left[1+\frac{\tau}{(1-\tau)h}\right]^{-1} (<1). \qquad (15)$$

For details of derivation, refer to Sundaresan and Wang (2007a) and Nishihara and Shibata (2010).

Next, we consider a situation in which only the leader is active. We need solve the leader's exit and follower's entry problems simultaneously. Denote the follower' entry time by $T_F^* := \inf\{t \geq s \mid X(t) \geq x_F^*\}$. Then, we have the follower's coupon $C_F^*(x_F^*)$ and default trigger $x_F^d = x_F^*/h$. We denote the leader's default timing before and after the follower's entry by T_L^{db} and T_L^d, respectively. Under the LIFO scenario, we have

$$T_L^d := \inf\{t \geq s \mid X(t) \leq x_L^d\}, \tag{16}$$

where the default trigger $x_L^d := \gamma(r-\mu)C_L/\{(\gamma-1)r\}(< x_F^d)$ depends on the leader's coupon payment $C_L(>0)$. Denote by x_L^{db} the leader's default trigger before the follower's entry. For the state variable $X(s) \in [x_L^{db}, x_F^*]$, the equity value of the leader that has issued debt with coupon $C_L(>0)$ is as follows:

$$\begin{aligned}
&E_L(X(s), C_L)\\
=&\mathbb{E}^{X(s)}[\int_s^{T_L^{db}\wedge T_F^*} \mathrm{e}^{-r(t-s)}(1-\tau)(X(t)-C_L)\mathrm{d}t\\
&+1_{\{T_F^*<T_L^{db}\}}\left\{\int_{T_F^*}^{T_F^d} \mathrm{e}^{-r(t-s)}(1-\tau)(Q_LX(t)-C_L)\mathrm{d}t + \int_{T_F^d}^{T_L^d} \mathrm{e}^{-r(t-s)}(1-\tau)(X(t)-C_L)\mathrm{d}t\right\}]\\
=&\frac{(1-\tau)}{r-\mu}X(s) - \frac{(1-\tau)C_L}{r} + A_LX(s)^\beta + B_LX(s)^\gamma,
\end{aligned} \tag{17}$$

where $\wedge$ and $1_{\{\}}$ stand for $\min(,)$ and the indicator function, respectively. Coefficients A_L and B_L in (17) are constants satisfying two value matching conditions, i.e.,

$$\frac{(1-\tau)}{r-\mu}x_L^{db} - \frac{(1-\tau)C_L}{r} + A_L{x_L^{db}}^\beta + B_L{x_L^{db}}^\gamma = 0 \tag{18}$$

and

$$\begin{aligned}
&\frac{(1-\tau)}{r-\mu}x_F^* - \frac{(1-\tau)C_L}{r} + A_L{x_F^*}^\beta + B_L{x_F^*}^\gamma\\
=&\frac{(1-\tau)Q_L}{r-\mu}x_F^* + \frac{\tau C_L}{r} + \frac{(1-\tau)(1-Q_L)}{r-\mu}h^{\gamma-1}x_F^* + \frac{(1-\tau)C_L}{r-\mu}\left(\frac{x_F^*}{x_L^d}\right)^\gamma.
\end{aligned} \tag{19}$$

(18) means that the equity value becomes zero on the default timing, while (19) denotes the equity value just after the follower's entry. In preparation for later, we calculate the debt value

$$\begin{aligned}
&D_L(X(s), C_L)\\
=&\mathbb{E}^{X(s)}[\int_s^{T_L^{db}\wedge T_F^*} \mathrm{e}^{-r(t-s)}C_L\mathrm{d}t + 1_{\{T_F^*<T_L^{db}\}}\left\{\int_{T_F^*}^{T_L^d} \mathrm{e}^{-r(t-s)}C_L\mathrm{d}t + \mathrm{e}^{-r(T_L^d-s)}K_L(x_L^d)\right\}\\
&+1_{\{T_F^*\geq T_L^{db}\}}\mathrm{e}^{-r(T_L^{db}-s)}K_L^b(x_L^{db})]
\end{aligned} \tag{20}$$

$$=\frac{C_L}{r} + \tilde{A}_LX(s)^\beta + \tilde{B}_LX(s)^\gamma, \tag{21}$$

where $K_L(x_L^d)$ and $K_L^b(x_L^{db})$[4] represent the liquidation value after the follower's exit and before the follower's entry, respectively, while $\tilde{A}_L$ and $\tilde{B}_L$ are constants satisfying the value matching conditions:

$$\frac{C_L}{r} + \tilde{A}_L {x_L^{db}}^\beta + \tilde{B}_L {x_L^{db}}^\gamma = K_L^b(x_L^{db}) \tag{22}$$

and

$$\frac{C_L}{r} + \tilde{A}_L {x_F^*}^\beta + \tilde{B}_L {x_F^*}^\gamma = \frac{C_L}{r} - \left(\frac{C_L}{r} - K_L(x_L^d)\right)\left(\frac{x_F^*}{x_L^d}\right)^\gamma. \tag{23}$$

(22) means that the debt value equals the liquidation value on bankruptcy, while the right-hand side of (23) corresponds to the debt value just after the follower's entry. The firm value is expressed as $V_L(X(s), C_L) := E_L(X(s), C_L) + D_L(X(s), C_L)$.

On the other hand, the follower's firm value before the entry is as follows:

$$\begin{aligned}
&F(X(s), C_L) \\
=&\mathbb{E}^{X(s)}[1_{\{T_F^* < T_L^{db}\}} \mathrm{e}^{-r(T_F^* - s)}\{V_F(x_F^*, C_F^*(x_F^*)) - I\} + 1_{\{T_F^* \geq T_L^{db}\}} \mathrm{e}^{-r(T_L^{db} - s)} M(x_L^{db})] \\
=&A_F X(s)^\beta + B_F X(s)^\gamma,
\end{aligned} \tag{24}$$

where C_L is the leader's coupon and $M(x_L^{db})$ is the option value in a monopoly, i.e.,

$$M(x_L^{db}) := \sup_{T_M} \mathbb{E}^{x_L^{db}}[\mathrm{e}^{-rT_M}\left(\frac{1-\tau}{\psi(r-\mu)} X(T_M) - I\right)] \tag{25}$$

$$= \left(\frac{(1-\tau)}{\psi(r-\mu)} x_M^* - I\right)\left(\frac{x_L^{db}}{x_M^*}\right)^\beta. \tag{26}$$

Note that (25) results from the same argument as (14). We denote by $x_M^* := \psi\beta(r - \mu)I/\{(\beta-1)(1-\tau)\}$ and we presume that $x_L^{db} \leq x_M^*$. We also note that the follower's option value $F(X(s), C_L)$ depends on the leader's coupon C_L. Coefficients A_F and B_F in (24) are constants satisfying the following value matching conditions:

$$A_F {x_L^{db}}^\beta + B_F {x_L^{db}}^\gamma = \left(\frac{(1-\tau)}{\psi(r-\mu)} x_M^* - I\right)\left(\frac{x_L^{db}}{x_M^*}\right)^\beta \tag{27}$$

and

$$A_F {x_F^*}^\beta + B_F {x_F^*}^\gamma = \frac{(1-\tau)Q_F}{\psi(r-\mu)} x_F^* - I. \tag{28}$$

(27) means that the firm value becomes the monopolist's option value if the leader leaves the market before the follower's entry, while the right-hand side of (28) corresponds to the follower's firm value in a duopoly minus investment costs.

Now, we like to determine triggers x_L^{db} and x_F^*. Recall that the leader's exit trigger x_L^{db} is determined so as to maximize its equity value (17), whereas the follower's entry x_F^* is determined so as to maximize its option value (24). Then, by the first order optimality conditions, we impose the smooth pasting conditions

$$\frac{1-\tau}{r-\mu} + \beta A_L {x_L^{db}}^{\beta-1} + \gamma B_L {x_L^{db}}^{\gamma-1} = 0 \tag{29}$$

[4]These liquidation values are not necessarily equivalent. One may assume non-linear forms for the functions, although we will assume the linear functions in Section 4.

for (18) and

$$\beta A_F {x_F^*}^{\beta-1} + \gamma B_F {x_F^*}^{\gamma-1} = \frac{(1-\tau)Q_F}{\psi(r-\mu)} \tag{30}$$

for (28). (29) corresponds to the fact that shareholders of the leader optimize the exit timing considering the follower's potential entry, while (30) corresponds to the fact that shareholders maximize the option value on the entry timing considering the leader's potential exit. For a fixed C_L, we can derive $x_L^{db}, x_F^*, A_L, B_L, A_F$, and B_F by solving (18), (19), (27), (28), (29), and (30) simultaneously. Technically, we do not have to solve these six equations simultaneously. We easily obtain A_L, B_L, A_F, and B_F as functions of x_L^{db} and x_F^* from (18), (19), (27), and (28). Then, we substitute them into (29) and (30) and solve two equations with two variables x_L^{db} and x_F^*. It is not difficult to numerically solve the problem of two equations with two variables if one uses the optimization toolbox in the Matlab.

Finally, we consider the situation in which neither firms has invested. The leader issues debt to maximize the firm value, and hence, the leader's investment at time s leads to debt with coupon

$$C_L^*(X(s)) = \arg\max_{C_L \geq 0} V_L(X(s), C_L). \tag{31}$$

The leader's expected gain is $L(X(s)) := V_L(X(s), C_L^*(X(s))) - I$. In equilibrium, the leader invests at time

$$T_L^* := \inf\{t \geq 0 \mid X(t) \geq x_L^*\}, \tag{32}$$

where x_L^* is the smallest solution to $L(x_L^*) - F(x_L^*, C_L^*(x_L^*)) = 0$, along with issuing debt with coupon $C_L^*(x_L^*)$. The follower's optimal response is described by the investment trigger x_F^* and coupon $C_F^*(x_F^*)$. The LIFO scenario presumes that $C_F^*(x_F^*) > C_L^*(x_L^*)$. Based on Lambrecht (2001) and Murto (2004), a firm with lower coupon payment wins the exit game and survives longer. The follower can deviate from the best policy under the LIFO scenario and choose the first in, first out (FIFO) scenario by decreasing coupon C_F below $C_L^*(x_L^*)$. However, in our numerical analysis, the deviation always decreases the follower's value, and hence, we omit the FIFO scenario. If $T_F^* < T_L^{db}$, the follower enters the market at time T_F^* and the duopoly goes on until T_F^d. The center panel of Figure 1 depicts a sample pass for this case. Otherwise, the leader exits the monopoly market first, and the follower takes the same strategy as that of the monopolist. In that case, the duopoly is not realized. See the lower panel of Figure 1 for a sample pass in the case.

As a special case in which $Q_F \downarrow 0$, we obtain preemptive equilibrium in Nishihara and Shibata (2010). In that case, we immediately have $x_F^* = \infty, T_F^* = \infty, x_L^{db} = x_L^d$ and $A_L = \tilde{A_L} = A_F = 0$. Suppose that $K_L^b(x_L^{db}) := (1-\alpha_F)(1-\tau)x_L^{db}/(r-\mu)$ for the leader's liquidation value. Similar to (12) and (14), we have $C_L^*(X(s)) = r(\gamma-1)X(s)/\{(r-\mu)\gamma h\}$ and $L(X(s)) = (1-\tau)X(s)/\{\psi(r-\mu)\} - I$ for the leader's value. For the follower's value we have

$$
\begin{aligned}
F(X(s), C_L^*(X(s))) =& \mathbb{E}^{X(s)}[\mathrm{e}^{-r(T_L^d - s)} M(x_L^d)] \\
=& \left(\frac{(1-\tau)}{\psi(r-\mu)} x_M^* - I\right) \left(\frac{x_L^d}{x_M^*}\right)^{\beta} \left(\frac{X(s)}{x_L^d}\right)^{\gamma} \\
=& \left(\frac{(1-\tau)}{\psi(r-\mu)} x_M^* - I\right) \left(\frac{X(s)}{x_M^*}\right)^{\beta} h^{\gamma-\beta} \qquad (33)
\end{aligned}
$$

where in (33) we used $x_L^d = X(s)/h$. In equilibrium, the leader invests as soon as $(1-\tau)X(s)/\{\psi(r-\mu)\} - I$ equals (33). Because of $T_F^* = \infty$, the follower never enters the market until the leader exits the market at time T_L^d. After the leader's exit, the follower takes the monopolistic strategy. This equilibrium corresponds to Proposition 2 in Nishihara and Shibata (2010).

We also note that joint investment equilibrium never appears in the levered case. Suppose that both firms enter a new market and issue debt at the same time. Each firm always has an incentive to decrease its coupon payment just below the level of the competitor's coupon because in this way it can survive and receive monopolistic profit flows after the competitor's exit. Then, there is no equilibrium in which levered firms invest at the same time. Next, suppose that both unlevered firms enter a new market at the same time. In this case, each firm always has an incentive to optimize its capital structure and increase its own value. In any case, there is no possibility that both firms invest at the same time in equilibrium when they can adjust debt financing.

3.3 Firms with financing constraints

In Section 3.2, we assume that firms have sufficient internal funds to cover investment costs. In other words, debt issuance is merely a means for firms to optimize capital structure. However, in some cases, debt issuance is a means for firms to fund investment projects. For instance, when one analyzes preemptive competition among venture businesses in IT industries, the lack of internal funds places one of critical limitations on investment behavior. This section supplements the previous analysis of optimal capital structure by studying financially constrained firms. In the financially constrained case, we simply assume that investment costs must be financed by debt. Povel and Raith (2004) consider similar constraints, although they analyze a static model based on Brander and Lewis (1986).

Under the financing constraints, the follower's optimal coupon needs to satisfy

$$
D_F(x_F^*, C_F^*(x_F^*)) \geq I. \qquad (34)
$$

According to our numerical analysis, (34) always holds because of the follower's high entry trigger x_F^*. Then, we explain how to compute equilibrium under the presumption of (34). We do not need change the discussion from (12) to (30). However, the leader's optimal policy in the previous subsection does not necessarily satisfy the financing constraint

$$D_L(x_L^*, C_L^*(x_L^*)) \geq I. \tag{35}$$

This is because the leader's entry trigger x_L^* is very low due to preemptive competition. Note that debt value $D_L(x_L^*, C_L^*(x_L^*))$ decrease as x_L^* is lower. While Povel and Raith (2004) exogenously assume that one firm is financially constrained and the other is unconstrained, our model endogenously determines which firm is financially constrained in equilibrium. Indeed, in equilibrium, not the follower but the leader is financially constrained whenever financing constraints become binding.

We now turn to the case that (35) does not hold because equilibrium remains unchanged from Section 3.2 under (35). In the case, we need modify derivation after (30). We must solve

$$C_{LC}^*(X(s)) = \arg \max_{\substack{C_L \geq 0 \\ D_L(X(s), C_L) \geq I}} V_L(X(s), C_L) \tag{36}$$

and calculate the financially constrained leader's value $L_C(X(s)) := V_L(X(s), C_{LC}^*(X(s))) - I$. Subscript C stands for the "Constrained" case. When the financing constraints are binding, the optimal coupon $C_{LC}^*(X(s))$ satisfies $D_L(X(s), C_{LC}^*(X(s))) = I$. In equilibrium, the leader invest at time

$$T_{LC}^* := \inf\{t \geq 0 \mid X(t) \geq x_{LC}^*\}, \tag{37}$$

where x_{LC}^* is the smallest solution to $L_C(x_{LC}^*) - F(x_{LC}^*, C_{LC}^*(x_{LC}^*)) = 0$, along with issuing debt with coupon $C_{LC}^*(x_{LC}^*)$. If $T_F^* < T_L^{db}$, the follower enters the market at time T_F^* and the duopoly goes on until T_F^d (cf. the center panel of Figure 1). Otherwise, the leader leaves the market prior to the follower's entry (cf. the lower panel of Figure 1).

4 Numerical analysis and implications

4.1 Base case

This section numerically examines the properties of equilibrium in the precious section. To do this, we need specify the leader's liquidation values, i.e., $K_L(x_L^d)$ after the follower's exit and $K_L^b(x_L^{db})$ before the follower's entry. For simplicity, similar to Goldstein, Ju, and Leland (2001) and Lambrecht (2001), we assume the linear functions $K_L(x_L^d) := (1-\alpha_L)(1-\tau)x_L^d/(r-\mu)$ and $K_L^b(x_L^{db}) := (1-\alpha_L^b)(1-\tau)x_L^{db}/(r-\mu)$. Although both values are the liquidation values in a monopoly, we should reduce the latter by taking account of the potential entry of the other firm. For simplicity, we assume that $\alpha_L^b = \alpha_L/Q_L$. The base parameter values are set as follows:

$$r = 0.08, \mu = 0.06, \sigma = 0.2, \tau = 0.15, \alpha_L = \alpha_F = 0.3, Q_L = Q_F = 0.5. \tag{38}$$

The parameter values, except for Q_L and Q_F, are similar to Leland (2004) and Sarkar (2008) based on empirical evidence. The investment costs I and initial value $x = X(0)$ are not substantial because they can be normalized. For expositional purpose, we set $I = 10$ and $x = 0.2$.

[Insert Figure 2 here]

The upper panel of Figure 2 presents $L_C(X(s))$ and $F(X(s), C_{LC}^*(X(s))$ in the levered case, whereas the lower panel presents $L_U(X(s))$ and $F_U(X(s))$ in the unlevered case. To check whether financing constraints are binding, the center panel shows the leader's debt $D_L(X(s), C_{LC}^*(X(s))$. $D_L(X(s), C_{LC}^*(X(s))$ is equal to $I(= 10)$ when $X(s)$ is lower than 0.54. In this region, the financing constraints bind the leader, and then the leader needs adjust the debt issuance to meet the investment costs. Especially for $X(s) <= 0.4$, the leader under the financing constraints cannot finance the project because we have $\max_{C_L} D_L(X(s), C_L) < I$. Thus, in the upper panel, we show the leader's and follower's values only for the region $X(s) > 0.4$. In preemptive equilibrium, the leader's trigger x_{LC}^* is the smallest solution to $L_C(x_{LC}^*) - F(x_{LC}^*, C_{LC}^*(x_{LC}^*)) = 0$. The trigger is equal to 0.65, for which the financing constraints are not binding. Accordingly, we have $x_{LC}^* = x_L^* = 0.65$, i.e., financing constraints are not binding in the base case.

As noted in Section 3, we need check that the follower does not prefer the strategic choice of the FIFO scenario. When the leader's strategy is fixed, we compute the optimal policy of the follower issuing debt with a coupon that is lower than $C_{LC}^*(x_{LC}^*) = 1.03$. In the FIFO scenario, the follower invests at the trigger 1.97 with issuing debt with coupon just below 1.03. The follower also invests when $X(t)$ decreases below 0.4, which is the leader's exit trigger in duopoly under the assumption of the FIFO scenario. However, the optimal policy in the FIFO scenario leads to the value 9.14, which is lower than $F(x_{LC}^*, C_{LC}^*(x_{LC}^*)) = 9.31$ in the LIFO scenario, and then the follower has no incentive to deviate from the LIFO scenario. Throughout our numerical analysis, the follower never likes the FIFO scenario mainly because the leader's coupon payment $C_{LC}^*(x_{LC}^*)$ is low due to the the early entry, whether financial constraints bind the leader or not. Then, we have the first observation as follows.

Observation 1 *In equilibrium, the LIFO scenario usually happens.*

This result is consistent with findings by Lambrecht (2001) and Zhdanov (2008). Lambrecht (2001) shows that the LIFO scenario prevails, except for the case in which the leader has an extraordinary debt to repay. Zhdanov (2008) shows that the LIFO scenario happens because the leader's preemptive entry makes its coupon payment lower than the follower's. Observation 1 is also in line with the standard findings that more established firms with lower debt repayment are more likely to survive.

[Insert Table 1 here.]

In equilibrium, we have Table 1. "Value" denotes the option value, which is evaluated for an initial value $x = 0.2$. Note that the option value is the same for both firms because in equilibrium the leader invests on the preemptive entry timing in which the first-mover advantage is offset by the follower's option value. The firm value in the levered case is higher than that of the unlevered case. This is because both firms can optimize the capital structure. We can see from "Entry" of Table 1 that the entry triggers for both levered leader and follower are lower than those of the unlevered firms.

Observation 2 *Compared to the unlevered case, levered firms' entry takes place earlier and levered firms' values become higher.*

Access to debt financing increases firm value, and thus levered firms can invest earlier than unlevered firms. The leverage effects are similar to that of the seminal work by Myers (1977). The same results are seen in the real options studies, including Hennessy (2004), Mauer and Sarkar (2005), and Sundaresan and Wang (2007a), based on the monopoly setup. Observation 2 complements the existing literature by showing the robustness of the leverage effects in the presence of preemptive competition.

In "Exit" for the leader of Table 1, we present two exit triggers x_L^d and x_L^{db}. We always have $x_L^d < x_L^{db}$. This can be naturally explained by the leader who faces the follower's potential entry as being more likely to exit compared to the case with no fear. If $X(t)$ hits 0.28 first, then the leader leaves the market prior to the follower's entry. In this case, the follower chooses the monopolist's entry trigger 1.13 and exit trigger 0.56. In the base case, the probability that the leader exits before the follower's entry is approximately 30% according the simulations.

"Leverage," "Credit spread," and "Coupon" of Table 1 show the values on the entry timing. In other words, we present $D_L(x_L^*, C_L^*(x_L^*))/V_L(x_L^*, C_L^*(x_L^*))$, $C_L^*(x_L^*)/D_L(x_L^*, C_L^*(x_L^*)) - r$, and $C_L^*(x_L^*)$ for the leader and $C_F^*(x_F^*)/D_F(x_F^*, C_F^*(x_F^*)) - r$, $D_F(x_F^*, C_F^*(x_F^*))/V_F(x_F^*, C_F^*(x_F^*))$ and $C_F^*(x_F^*)$ for the follower. As financing constraints are not binding for either firm, the leverage and credit spreads are optimal. The leader's values are slightly lower than the follower's values, which are equal to the optimal levels in a monopoly. This is probably because the leader decreases the level of coupon payment taking into account the follower's potential entry. This finding is consistent with that of Zhdanov (2008). It is also consistent with MacKay and Phillips (2005) who empirically showed that the average leverage ratio of incumbents is lower than that of new entrants. Although Table 1 shows the leader's leverage on the leader's entry trigger 0.65, the leader's leverage on the follower's entry trigger 2.27 is equal to 0.20, which is much smaller than the follower's leverage 0.66. This is because the leader's coupon payment $C_{LC}^*(x_{LC}^*) = 1.03$ is much smaller than the follower's coupon payment 2.94. There are many empirical findings that highly levered firms suffer from competitive disadvantage (e.g., Phillips (1995), Chevalier (1995a), Chevalier (1995b)). Observation 1 is also in line with the findings.

4.2 Effects of first-mover advantage

In this section, we examine the effects of first-mover advantage from two aspects. First, following Pawlina and Kort (2006), we consider the symmetric case, i.e., $Q_L = Q_F$, and change the level of $Q_L = Q_F$. A decrease in the level of $Q_L = Q_F$ denotes the profit decrease in a duopoly, increasing the incentive for firms to move first and monopolize profit flows until the follower's entry. To examine preemptive equilibrium, we focus only on the case of negative externalities, i.e., $Q_L = Q_F < 1$.

[Insert Figures 3 and 4]

Figures 3 and 4 plot firm values, entry and exit triggers, leverage, and credit spread for varying levels of $Q_L = Q_F$. The other parameter values are set at the base case (38). Throughout the paper, except for firm values, the left panels represent the leader's values, whereas the right panels represent the follower's values. In all figures, the triangle, cross, and circle marks in the panels denote the levered case with financing constraints, the levered case without a constraint, and the unlevered case, respectively. When $Q_L = Q_F$ is lower than 0.4, financing constraints become binding for the first mover. For any $Q_L = Q_F$, as noted in Section 3, the financing constraints are not binding for the follower. A profit decrease in a duopoly –in other words, an increase in competition in a duopoly– forces the leader to suffer from the constraints.

We can see from the top panel that a decrease in $Q_L = Q_F$ decreases firm values in any cases. This result is natural because the profit decrease in a duopoly damages firm values. More interestingly, we find that the decrease in firm values is mitigated by financing constraints. Indeed, for $Q_F = Q_L = 0.2$ and 0.3 in the top panel of Figure 3 , firm values in the constrained case are highest among three cases. If firms face no financing constraints, a decrease in $Q_L = Q_F$ straightforwardly intensifies preemptive competition and greatly reduces firm values in equilibrium. However, the financing constraints, which increase the first mover's leverage beyond the optimal level, decrease the leader's value while they enhance the follower's value of the option to invest after the leader's exit. This effect of high leverage of the leader on the potential entrant is the same as that of Lambrecht (2001), although he exogenously assumes an incumbent with debt repayment. Thus, the financing constraints decrease first-mover advantage and moderate preemptive competition. Firm values with financing constraints become higher than that with no financing constraints. A similar mechanism is explained in Nishihara and Shibata (2010), although the previous model focuses only on the polar case ($Q_F = 0$). Especially for a low level of $Q_F = Q_L$, the gap between firm values in the constrained and unconstrained cases (financing constraint effect) is larger than the gap between firm values in the unconstrained and unlevered cases (leverage effect).

We turn to entry and exit triggers (see center and lower panels in Figure 3). A decrease in $Q_L = Q_F$ decreases the leader's entry trigger and increases the follower's entry trigger.

The former is due to the intensified preemptive competition, while the latter is due to the decreased profit of the follower. In the center panels of Figure 3, the entry triggers in the levered case without a financing constraint are always lower than those in the unlevered case. As mentioned in Section 4.1, this is due to the leverage effect. However, with financing constraints, which weaken preemptive competition, the leader's entry trigger can increase beyond the level of the unlevered case (see $Q_L = Q_F = 0.2$ in the center-left panel). In this case, the financing constraint effects overwhelm the leverage effects. For $Q_L = Q_F = 0.2$ and 0.3 in the lower-left panel of Figure 3, we see that the default triggers in the case with financing constraints are higher than those without a financing constraint. This is because the financing constraints impose higher leverage on the leader. On the other hand, whether the leader suffers from the financing constraints little influences the follower's entry and exit triggers. Note that the follower's exit trigger always satisfies $x_F^d = x_F^*/h$ because of its optimal capital structure.

We now examine leverage and credit spreads (see Figure 4). We see from the right panels that the follower's leverage and credit spreads do not depend on the level of $Q_L = Q_F$. Because financing constraints never bind the follower, the follower maintains the optimal capital structure in which leverage is 0.66 and credit spread is 0.0047. On the other hand, the leader's leverage and credit spread depend on the level of $Q_L = Q_F$. Without a financing constraint, a decrease in $Q_L = Q_F$ slightly decreases the leverage and credit spread. This is because the leader lowers the leverage and credit spread by considering the potential decrease in profit flows in a duopoly. With financing constraints binding, a decrease in $Q_L = Q_F$ adversely increases the leader's leverage and credit spread. This means that a decrease in $Q_L = Q_F$ forces the leader to take riskier capital structure. The leader's leverage being higher than the follower's is not necessarily inconsistent with MacKay and Phillips (2005). Indeed, if one sees the leader's leverage on the follower's entry trigger, it remains around 0.2, which is much lower than the follower's leverage.

Next, we examine the other aspect of the first-mover advantage. We fix $Q_L + Q_F = 1$ and change the leader's share $Q_L/(Q_L + Q_F)$ in a duopoly. This measures the degree of barriers to the follower's entry. For instance, customers accustomed to the leader's product might prefer the leader's brand to the follower that has the same quality. This sort of asymmetric case is also treated in Lambrecht (2001) and Kong and Kwok (2007).

[Insert Figures 5 and 6]

Figures 5 and 6 plot firm values, entry and exit triggers, leverage, and credit spreads for varying levels of Q_L. The other parameter values are set at the base case (38). Overall, we find that an increase in Q_L in Figures 5 and 6 leads to the similar effects to a decrease in $Q_L = Q_F$ in Figures 3 and 4. The effects are much stronger because the level of $Q_L/(Q_L + Q_F)$ changes the first-mover advantage more directly than the level of $Q_L = Q_F$. Indeed, financing constraints become binding when Q_L is larger than 0.55. As mentioned, the financing constraints can play a positive role in moderating preemptive competition and increasing the firm value. See the top panel of Figure 5. Especially for $Q_L = 0.7, 0.8$, and 0.9, the value enhanced by the financing constraints are greater than the value enhanced by the leverage effects. An increase in Q_L, which increases the first-mover advantage, decreases the leader's entry trigger, but the decrease is mitigated by the financing constraints. The leader's entry trigger can be either higher or lower than that of the unlevered case depending on the trade-off between the financing constraint and leverage effects. Although the financing constraints increase firm values, they make the leader's investment riskier in terms of the leverage and credit spread.

Finally, we summarize interesting findings as follows:

Observation 3 *Financing constraints can delay the leader's preemptive entry and improve firm values. When the financing constraint effects dominate the leverage effects, the leader's entry trigger can be higher than that of the unlevered case.*

The effect of financing constraints on the investment trigger is similar to the standard result that financially constrained firms invest less than unconstrained firms (e.g., Fazzari, Hubbard, and Petersen (1988), Hubbard (1998)). Although Nishihara and Shibata (2010) point out the possibility that financing constraints can soften preemptive competition and improve firm values, we extend the previous setup ($Q_F = 0$) into a more general setup ($Q_F > 0$) and show that the positive effect can arise in such a general case. Indeed, we find that, with slight first-mover advantage, financing constraints can be binding and play a positive role. Thus, the empirical implications from this paper are not limited to extremely intensified competition but also apply to a wide range of market competition.

Observation 4 *Stronger first-mover advantage speeds up the leader's preemptive entry and reduces firm values. This first-mover advantage effect can be greatly mitigated by the financing constraint effects that increase with stronger first-mover advantage.*

The first sentence is in line with the standard result in preemptive competition (e.g., Huisman (2001), Pawlina and Kort (2006)). The interactions between financing constraints and first-mover advantage generate another empirical prediction. There are a number of papers that study the relation between leverage and product market competition, though few papers consider preemptive competition. The majority of research in this area shows empirical evidence that more leverage can lead to weaker product market competition (e.g., Phillips (1995), Chevalier (1995a), Chevalier (1995b)). These findings support our results of the financing constraint effects. Indeed, in our paper, financing constraints increase the leader's leverage and soften preemptive competition, Lambrecht (2001) also shows that high leverage of an incumbent moderates competition, but the paper does not analyze preemptive equilibrium. We complement the previous research by showing that similar results hold in preemptive equilibrium.

4.3 Effects of volatility σ

In this section, we analyze comparative statics with respect to the other key parameter σ. As our model includes strategic interactions, leverage, and financing constraints, we like to focus on how the market volatility influences those factors.

[Insert Figures 7 and 8]

Figures 7 and 8 plot firm values, entry and exit triggers, leverage, and credit spreads for varying levels of σ. The other parameter values are set at the base case (38). In all panels, we see that the dot marks overlap the cross marks. Actually, financing constraints are not binding for any σ.

We see from the top panel of Figure 7 that the firm value increases with σ in both levered and unlevered cases. In the center (lower) panels, we also see that the entry (exit) triggers increase (decrease) with σ in all cases. The standard real option theory argues that higher uncertainty increases a firm's option value and delays the exercise of its option. Our results regarding entry and exit triggers are in line with the standard theory. Most of the papers including Pawlina and Kort (2006) and Nishihara and Shibata (2010) show the same result in preemptive equilibrium. We conclude that the standard results are robust even if preemptive competition and leverage are taken into account.

In the center panels of Figure 7, we find another interesting property. The difference between the follower's entry triggers in the levered and unlevered cases clearly decreases with σ, although the difference in the leader's entry triggers scarcely changes. Since a higher σ increases the option value of waiting for the leader's exit, the follower has more incentive to delay the entry. For $\sigma = 0.4$, this effect becomes almost as strong as the leverage effect, and hence the difference in the levered and unlevered cases becomes nearly zero.

Figure 8 depicts the leverage and credit spreads on the entry timing. In all panels, we find that the leverage monotonically decreases with σ while the credit spread monotonically increases with σ. Because debt becomes riskier under high uncertainty, firms reduce debt issuance. These results are consistent with the standard results in the absence of strategic interactions (e.g., Leland (1994), Sundaresan and Wang (2007a)) as well as being consistent with empirical findings (e.g., Bradley, Jarrell, and Kim (1983)).

Now, we explore the effects of σ on financing constraints. To do this, we replace $Q_L = Q_F = 0.5$ with $Q_L = Q_F = 0.4$ in (38).

[Insert Figures 9 and 10]

Figures 9 and 10 show firm values, entry and exit triggers, leverage, and credit spreads for varying levels of σ. We see that financing constraints become binding when σ increases beyond 0.2. A higher σ intensifies the financing constraint effects. This result is similar to that of Nishihara and Shibata (2010). The intuition is as follows. For a higher σ, the optimal leverage (see the upper-left panel of Figure 10) becomes lower and so does the debt issuance. When σ exceeds a threshold level (in this example, 0.2), the debt value under the optimal capital structure falls short of the investment costs. Then, the financing constraints become binding under higher uncertainty about the market demand.

Observation 5 *A higher volatility delays firms' entry and improve firm values. This volatility effect can be slightly magnified by the financing constraint effects that increase with a higher volatility.*

Although a higher σ increases firm values and entry triggers in all cases, the financing constraint effects amplify the volatility effect for levered firms with financing constraints. Recall that, as explained in Section 4.2, financing constraints alleviate preemptive competition, thus increasing the leader's entry trigger and firm values. In Figures 9 and 10, the financing constraint effects are not very large compared to Figures 3–6. Indeed, for $\sigma = 0.25, 0.3, 0.35$, and 0.4, the firm value enhanced by the financing constraints are much smaller than the value enhanced by the leverage effects (see the top panel of Figure 9). We conclude that the financing constraint effects can be caused by a higher σ but they are relatively small.

5 Conclusion

In this paper, we shed light on how firms' financial structure influences preemptive competition. We found the LIFO scenario, i.e., the follower exits the duopoly market prior to the leader. This is primarily because, due to the entry lag, the follower issues much more debt than the leader. We also showed that the well-known leverage effects remain true in preemptive equilibrium. Actually, access to debt financing increases firm values and accelerates investment. This paper examined not only the case with optimal capital structure but also the case with financing constraints that require firms to finance investment costs by debt. Notably, we showed that the financing constraints can delay preemptive investment and improve firm values in equilibrium. Indeed, the leader's leverage increased by the financing constraints could lower first-mover advantage and mitigate preemptive competition. The financing constraint effects increase in a market with stronger first-mover advantage and higher volatility. Especially in the presence of relatively strong first-mover advantage, the financing constraint effects can potentially dominate the leverage effects and then preemptive investment occurs later than that in the unlevered case. Our findings are in line with empirical evidence that high leverage leads to competitive disadvantage and mitigates product market competition.

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Table 1: Base case.

	Value	Entry	Exit	Leverage	Credit spread	Coupon
Levered case	2.18					
Leader		0.65	0.20/0.28	0.63	0.0039	1.03
Follower		2.27	1.12	0.66	0.0047	2.94
Unlevered case	1.90					
Leader		0.77				
Follower		2.46				

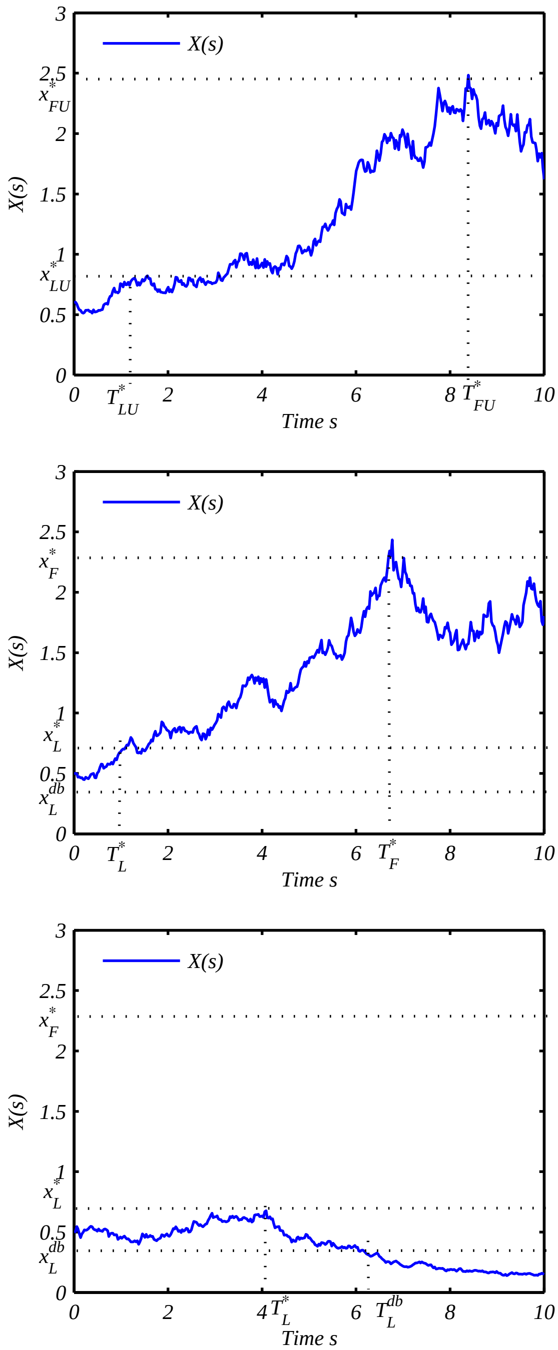

Figure 1: Simulation. We simulated $X(s)$ with the base parameter values (38) in Section 4. The top panel shows the leader and follower's entry triggers in the unlevered case. The center panel corresponds to the case in which the duopoly is realized, while the lower panel corresponds to the case in which the leader exits the market before the follower's entry.

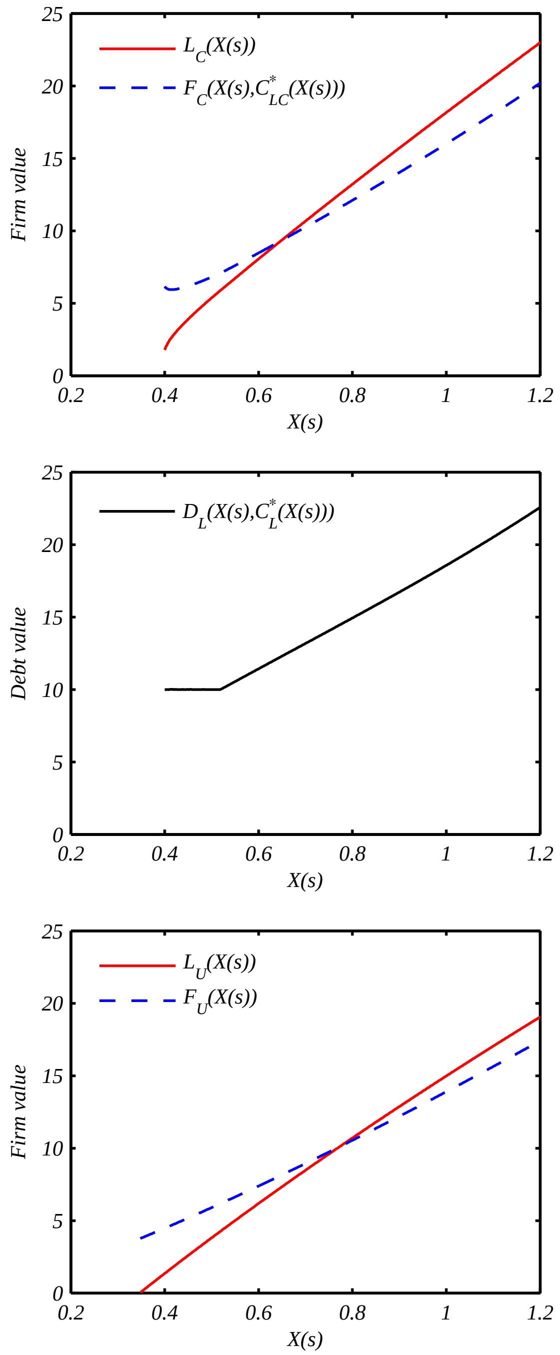

Figure 2: The base case. The top and bottom panels represent the leader and follower's values in the levered case with financing constraints and the unlevered case, respectively. The center panel show the leader's debt value $D_L(X(s), C^*_{LC}(X(s)))$.

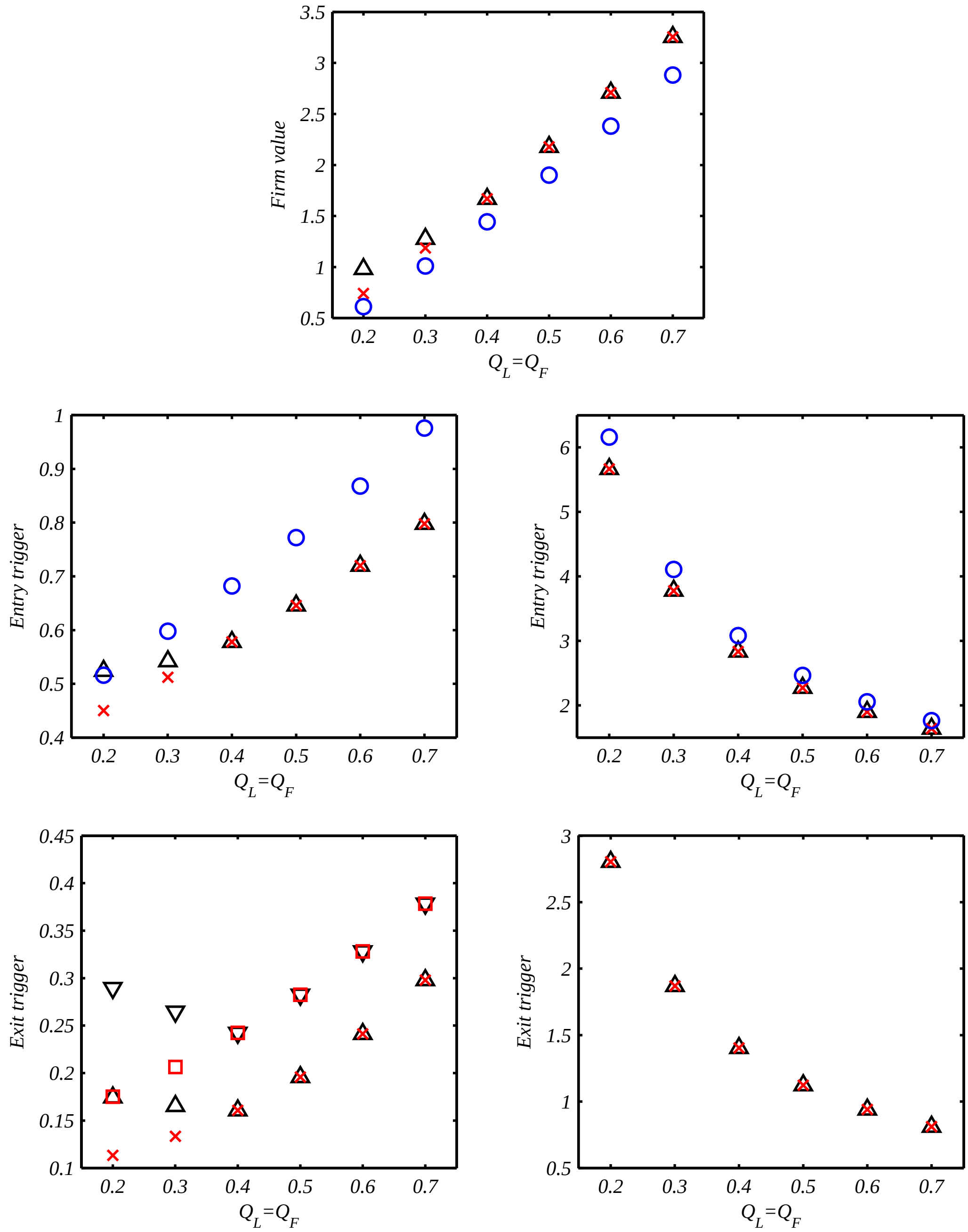

Figure 3: Option values, entry triggers, and exit triggers with varying levels of $Q_L = Q_F$. The other parameter values are set at the base case (38). The left panels represent the leader's values, whereas the right panels represent the follower's values. The triangle, cross, and circle marks in the panels denote the levered case with financing constraints, the levered case without a constraint, and the unlevered case, respectively. In the lower-left panel, triangle (down-pointing triangle) and cross (square) marks represent the leader's exit triggers after (before) the follower's entry in the constrained and unconstrained cases, respectively.

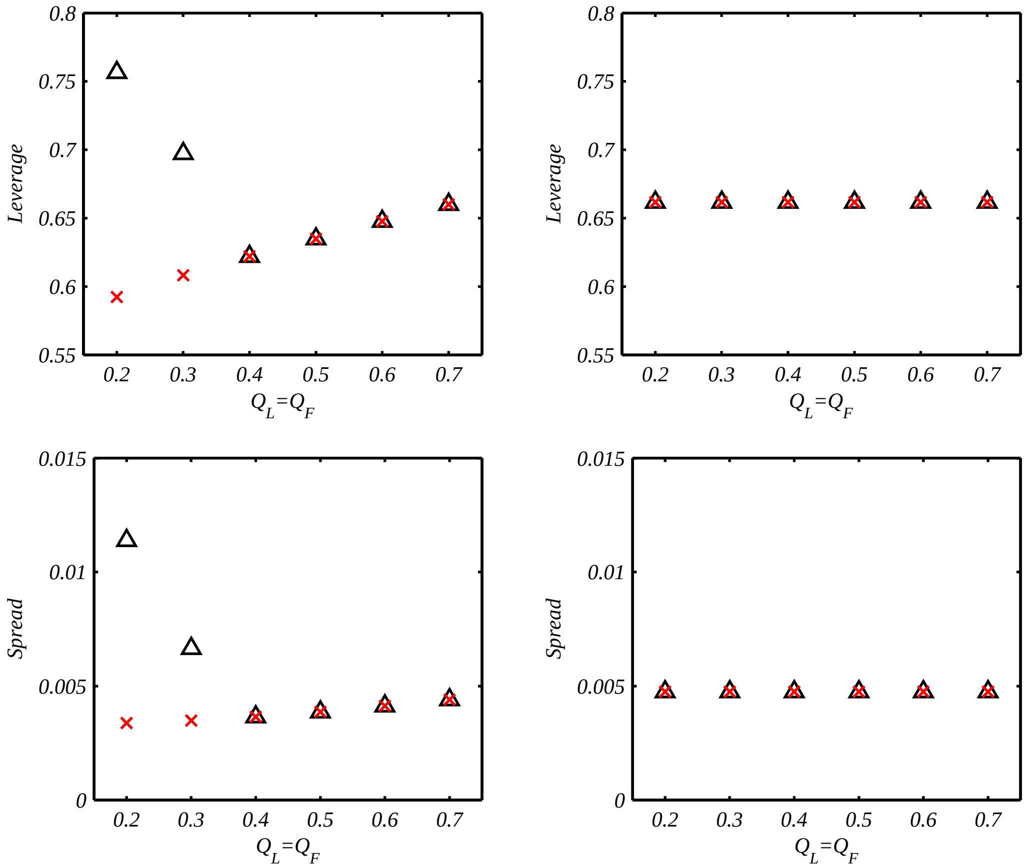

Figure 4: Leverage and credit spreads with varying levels of $Q_L = Q_F$. The other parameter values are set at the base case (38). The left panels represent the leader's values, whereas the right panels represent the follower's values. The triangle, cross, and circle marks in the panels denote the levered case with financing constraints, the levered case without a constraint, and the unlevered case, respectively.

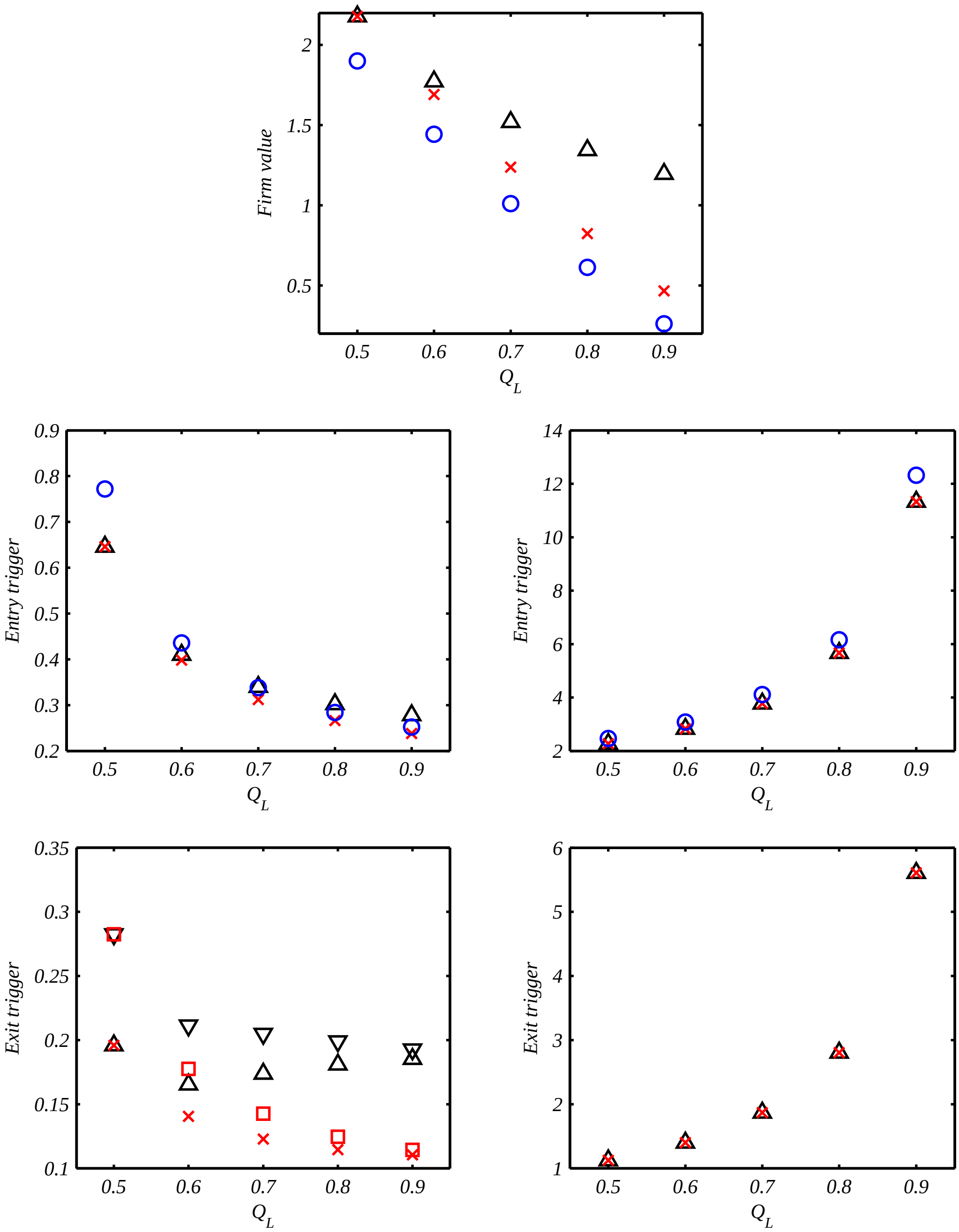

Figure 5: Option values, entry triggers, and exit triggers with varying levels of Q_L. The other parameter values are set at the base case (38). The left panels represent the leader's values, whereas the right panels represent the follower's values. The triangle, cross, and circle marks in the panels denote the levered case with financing constraints, the levered case without a constraint, and the unlevered case, respectively. In the lower-left panel, triangle (down-pointing triangle) and cross (square) marks represent the leader's exit triggers after (before) the follower's entry in the constrained and unconstrained cases, respectively.

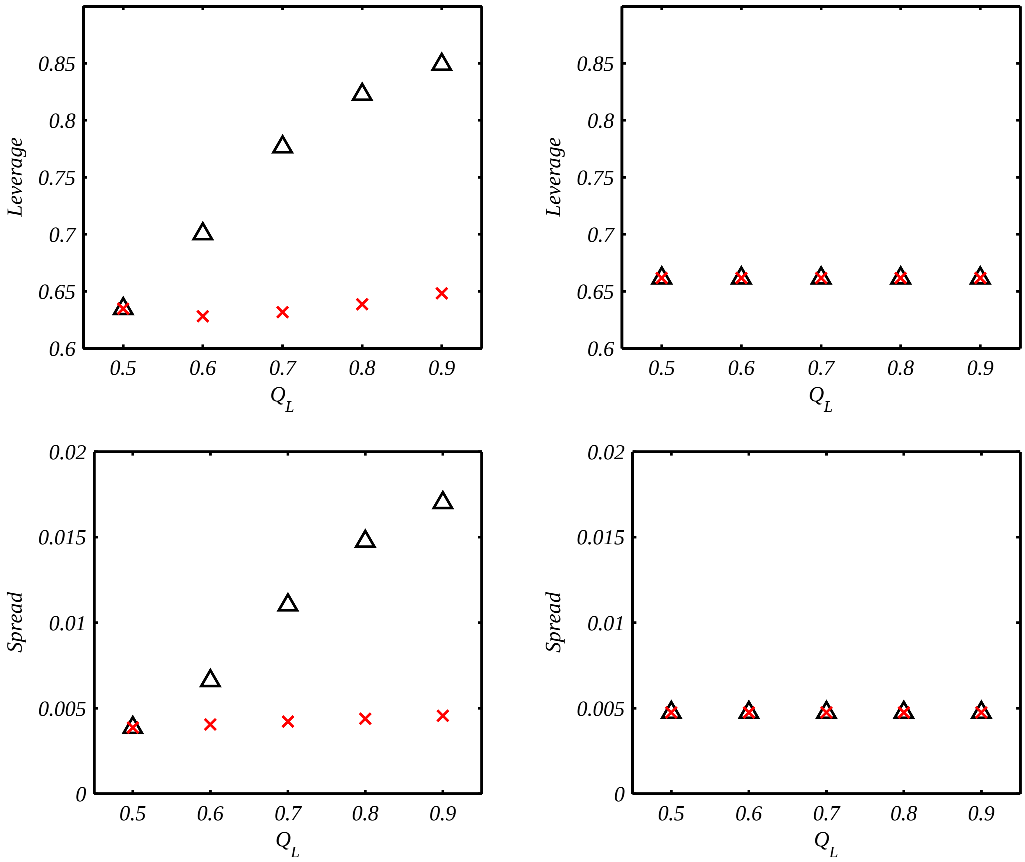

Figure 6: Leverage and credit spreads with varying levels of Q_L. The other parameter values are set at the base case (38). The left panels represent the leader's values, whereas the right panels represent the follower's values. The triangle, cross, and circle marks in the panels denote the levered case with financing constraints, the levered case without a constraint, and the unlevered case, respectively.

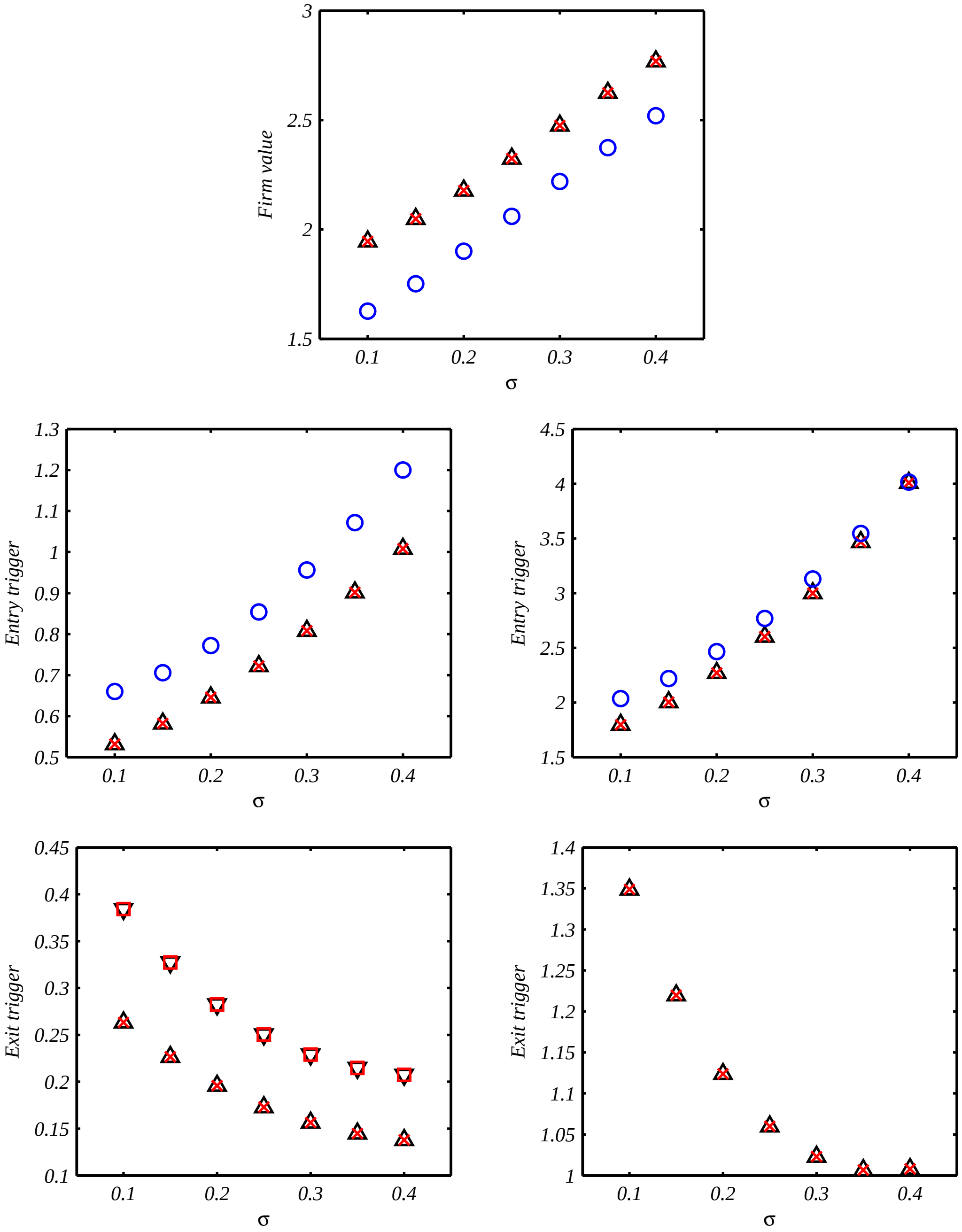

Figure 7: Option values, entry triggers, and exit triggers with varying levels of σ. The other parameter values are set at the base case (38). The left panels represent the leader's values, whereas the right panels represent the follower's values. The triangle, cross, and circle marks in the panels denote the levered case with financing constraints, the levered case without a constraint, and the unlevered case, respectively. In the lower-left panel, triangle (down-pointing triangle) and cross (square) marks represent the leader's exit triggers after (before) the follower's entry in the constrained and unconstrained cases, respectively.

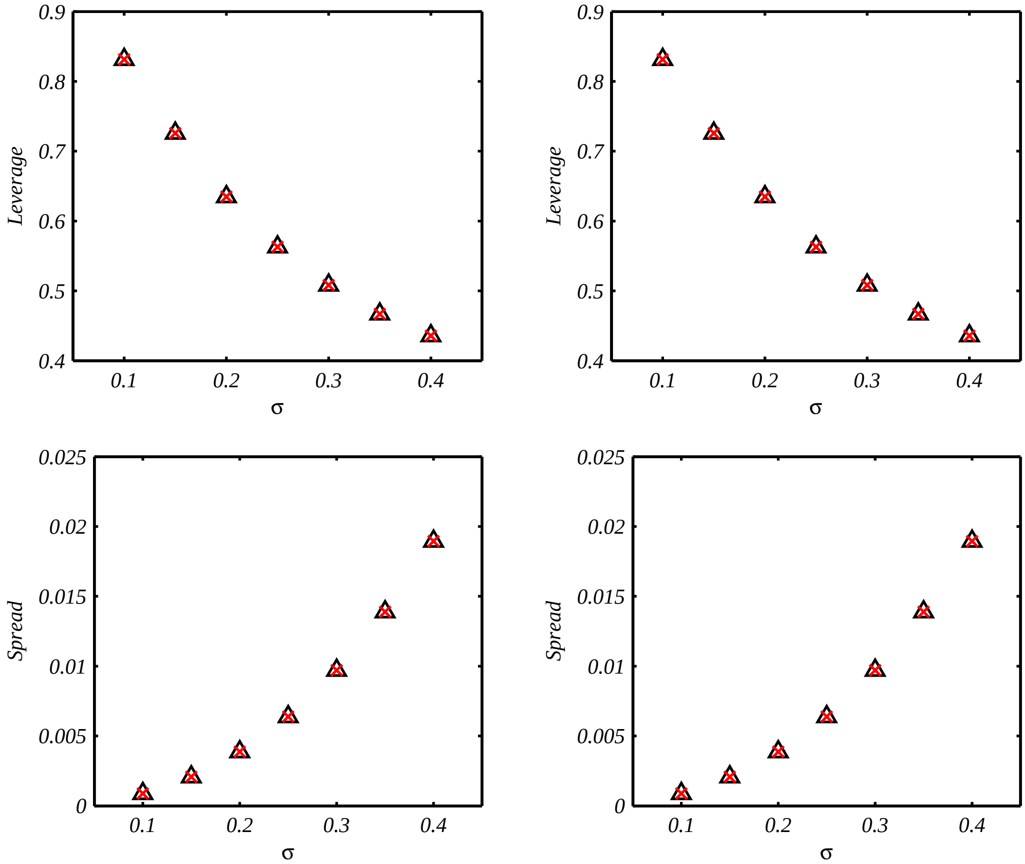

Figure 8: Leverage and credit spreads with varying levels of σ. The other parameter values are set at the base case (38). The left panels represent the leader's values, whereas the right panels represent the follower's values. The triangle, cross, and circle marks in the panels denote the levered case with financing constraints, the levered case without a constraint, and the unlevered case, respectively.

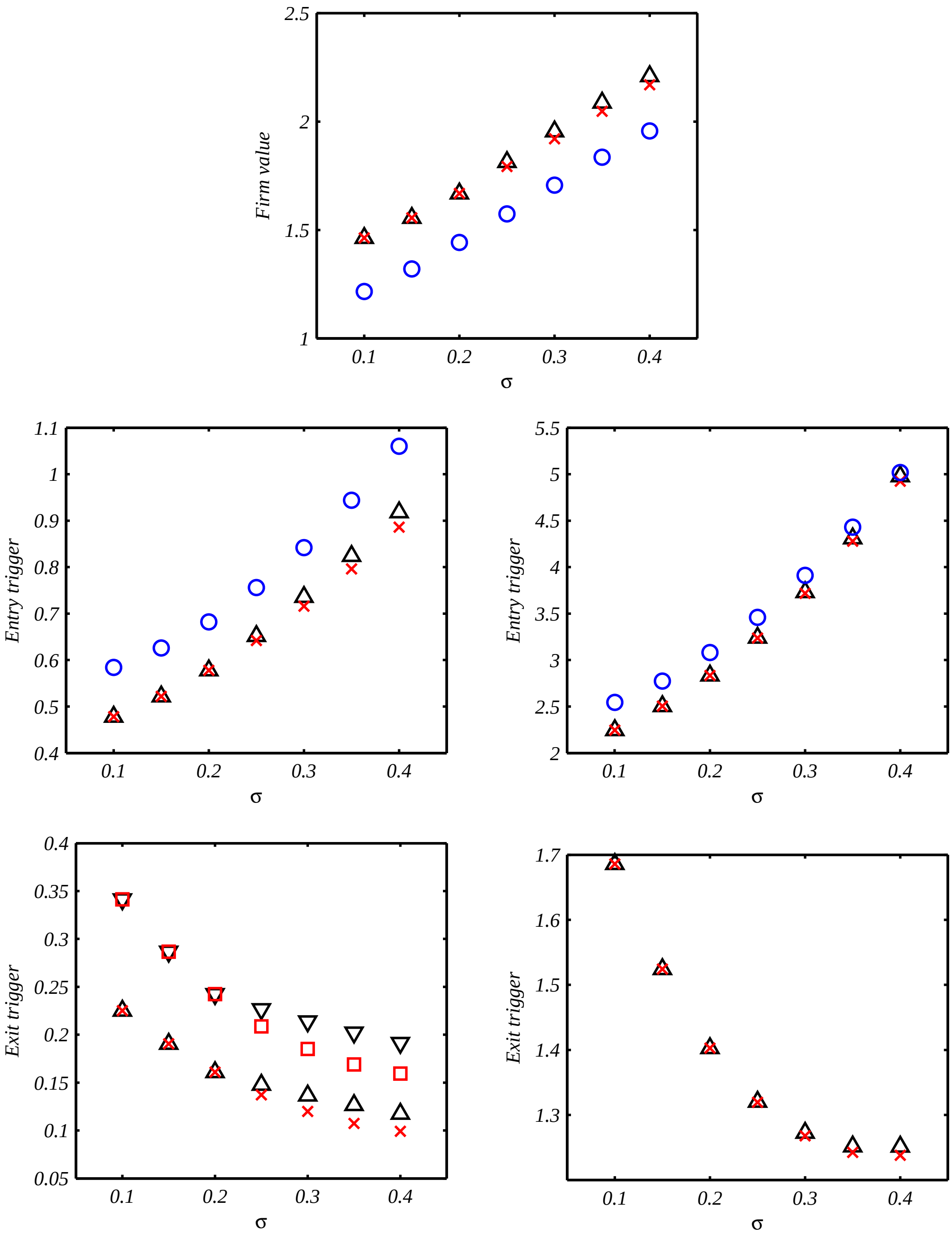

Figure 9: Option values, entry triggers, and exit triggers with varying levels of σ. We set $Q_L = Q_F = 0.4$. The other parameter values are set at the base case (38). The left panels represent the leader's values, whereas the right panels represent the follower's values. The triangle, cross, and circle marks in the panels denote the levered case with financing constraints, the levered case without a constraint, and the unlevered case, respectively. In the lower-left panel, triangle (down-pointing triangle) and cross (square) marks represent the leader's exit triggers after (before) the follower's entry in the constrained and unconstrained cases, respectively.

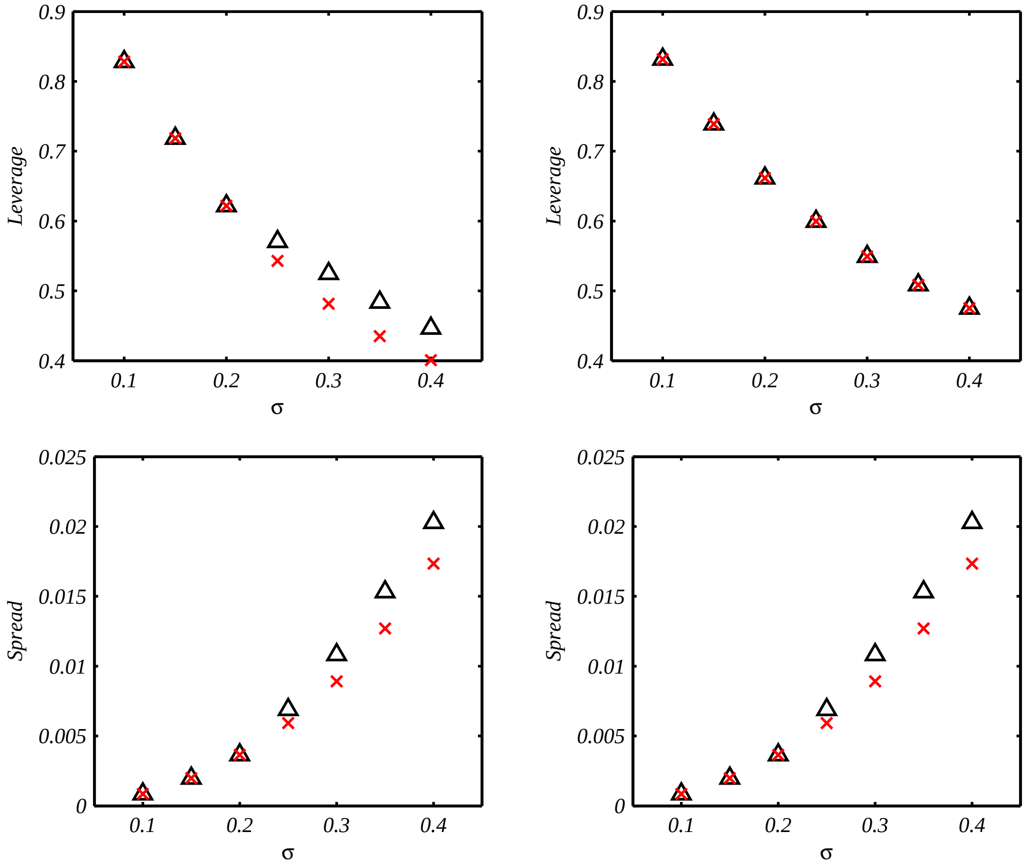

Figure 10: Leverage and credit spreads with varying levels of σ. We set $Q_L = Q_F = 0.4$. The other parameter values are set at the base case (38). The left panels represent the leader's values, whereas the right panels represent the follower's values. The triangle, cross, and circle marks in the panels denote the levered case with financing constraints, the levered case without a constraint, and the unlevered case, respectively.