Efficiency, Leverage and Exit: The Role of Information Asymmetry in Concentrated Industries

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Abstract

This paper develops a real options model of imperfect competition with asymmetric information that analyzes firms' exit decisions. Optimal exit decision is linked to firm characteristics such as financial leverage and efficiency. The model shows that informational asymmetries can lead more efficient and less leveraged firms to leave the product market prematurely. It also demonstrates how firm efficiency can increase debt capacity relative to rival firms. The model also has implications for firm risk and asset returns. Specifically, the paper shows that, when there is information asymmetry among rivals, rival actions can have a "news effect" that change a firm's dynamic risk structure.

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1 Introduction

Exit and contraction decisions are an important part of a firm's strategic planning as much as investment and expansion policies. A number of factors related to the states of the economy and the industry as well as to the firm characteristics can contribute to a firm's exit decision from its product market. For instance, firms may be operating in mature industries in which demand may be shrinking, rendering firms unable to cover their costs. Likewise, a recessionary period may lead a firm to experience difficulties it has not encountered in a boom period with high asset values.[1] Industry concentration and firm characteristics can be another crucial factor in the exit decision. In an oligopolistic market, for example, a firm may engage in predatory pricing, in expectation of inducing higher exit probability of a weaker competitor (see Chevalier and Scharfstein (1996) and Klemperer (1995)). In sum, exit decisions can be attributed to a complex interplay of several factors ranging from the aggregate to the individual firm level.

Firm characteristics can be perceived as a channel through which macroeconomic conditions and industry factors determine the exit decision. The same economic factors will affect firms differently as they exhibit cross-sectional asymmetries. One important firm characteristic is the financial structure. Over the past two decades, there has been a surge in interest in the relationship between product market competition, on the one hand, and capital structure on the other hand. Some theoretical models such as those of Brander and Lewis (1986) and Maksimovic (1988) predict a more

[1]Part of the difficulties experienced by firms in the current financial and economic turmoil can be ascribed to the fact that while asset values have suffered considerably in value their stock of debt has remained in place.

aggressive competitive behavior as a result of higher leverage while others[2] show that leverage makes product market competition softer. The relationship has also come under scrutiny in the empirical literature that focuses on pricing and exit decisions. Chevalier (1995), for example, explores the effect of leveraged buyouts (LBOs) on the pricing in the supermarket industry. She finds that in markets in which rival firms are also highly leveraged, prices rise following the LBO.[3] She also finds evidence of predatory pricing in markets in which the LBO firm faces less leveraged rivals. Similarly, Phillips (1995) and Phillips and Kovenock (1997) investigate the effect of large recapitalizations on the subsequent product market performance and survival of firms. They find that firms that have undergone a large recapitalization are less likely to invest and more likely to shut down plants.

Although understanding the role of financial leverage in pricing and exit decisions is important, the picture remains inherently incomplete without understanding the link between firm efficiency and financial leverage and its implications for firm exit decisions. Dun and Bradstreet (1980) report, for instance, that about 90% of business failures in the United States and Canada relate to firm inefficiencies. More recently, studies by Zingales (1998) and Khanna and Tice (2005) present evidence that both factors are crucial in product market pricing and exit decisions. Zingales (1998) investigates firm survival in the trucking industry around the exogenous shock of the 1979 deregulation. He points to the role of capital market imperfections and shows evidence that high leverage increases the probability of exit 8 years after the deregulation, particularly in the more imperfectly competi-

[2]See, for instance, Poitevin (1898), Bolton and Scharfstein (1990) and Dasgupta and Titman (1998)

[3]This is consistent with the theoretical literature that predicts a softer product market competition as leverage increases. Competition can be considered to be soft if the expected price to cost margin is relatively high.

tive segment of the industry. Interestingly, although efficiency and survival probability are positively related, he also finds that efficient high-debt firms leave the market after a negative shock. His study ties the negative effect of leverage to the reduced investment and the post-deregulation induced price war. Similarly, Khanna and Tice (2005) explore the exit and pricing decisions of discount stores across business cycles. They present evidence that confirm a positive relation between financial leverage and probability of exit and a negative relation between efficiency and probability of exit. The interesting result in Khanna and Tice (2005) is that, during recessions, efficient highly leveraged firms are more likely to exit the market. Like Zingales (1998), Khanna and Tice (2005) relate this finding to the price cutting behavior of the rivals in markets with heterogeneously levered firms. In sum, both papers demonstrate the importance of capital market imperfections: these imperfections can lead to the exit of the otherwise "fit" firms out of the product markets.

In this paper, I propose a real options model of imperfect competition with asymmetric information that analyzes a firm's exit decision. The decision to exit is linked to macroeconomic factors such as the level of interest rates, industry characteristics such as demand growth and volatility as well as to firm characteristics represented by financial leverage and firm efficiency. Importantly, I investigate the impact of information asymmetry as part of industry characteristics. Information asymmetry, particularly in concentrated industries, is a crucial factor that impacts the strategic behavior of incumbent firms. Firms form their competitive strategies conditioning on the amount of information they are able to gather about their rivals. In the model, firms update their conjectures based on the actions of their rivals.

Given these conjectures, firms optimally choose when to exit the market. The model links this exit decision to firm leverage. However, I define *firm* leverage more broadly as the sum of *financial* leverage and *operating* leverage. Operating leverage arises due to the fixed costs incurred to continue operations. I use operating leverage as the efficiency parameter: an efficient firm has a lower operating leverage, *ceteris paribus*. Using this specification allows me to capture the idea that high financial leverage and high inefficiency are the measures of firm weakness and make the firm more likely to exit market, as documented in the literature. It also allows me to define various competitive environments based on firms' relative strength. Different competitive environments, in turn, have different equilibrium implications.

There are several interesting results that emerge from the model. First, I show that, under certain competitive environments, rival actions reveal private information.[4] The *information revelation* allows the stronger firm in terms of total firm leverage to outlive its competitor. At the same time, without conditioning on business cycles, the model does capture the Khanna and Tice (2005) evidence that high-debt efficient firm can be driven out of the market. I show that this is the case so long as the portion of total firm leverage accounted for by debt is above a certain threshold, which, in turn, depends on the total leverage of the product market rivals. This new finding has important implications for the capital structure choice of firms in concentrated industries. In particular, the relation implies that a firm's debt capacity is a function of its rivals' leverage. To the best of my knowledge, this is a new prediction in the literature.

[4]In the context of real options, information revelation through option exercise is not a new idea. In another seminal work, Grenadier (1999) addresses the issue of information revelation through option exercise to explain information cascades.

Second, I derive the equilibrium conditions under which information revelation breaks down and devise an equilibrium that supports the exit of the stronger firm. This result is particularly important as it raises the possibility that informational asymmetries can prove to be crucial in the outcome of product market competition. The result relies on the ability of a weaker firm to imitate a stronger firm. This ability is linked to the competitive environment. In a sense, this result augments the empirical finding of Zingales (1998), predicting that not only the "fittest" and the "fattest" but also the most informationally advantageous firms survive.

Third, the model illustrates the conditions under which capital structure can be used as a strategic tool to signal information. Specifically, the model shows that a sufficiently less levered firm can increase its financial leverage to avoid imitation by a weaker firm. For signaling to take place without distorting the competitive position, the firm must have a significant edge over the rival in terms of either efficiency (i.e. operating leverage) or financial leverage. This result has important ramifications for the *ex ante* capital structure choice of the firms. Specifically, it implies that a firm should also take its competitive position into account when designing financial contracts.

The model is also related to the literature pioneered by Berk, Green, and Naik (1999) that ties firms' investment and growth options to asset prices and returns. While most of these studies[5] focus on the role of growth options, little attention has been given to the role of disinvestment and/or exit decisions.[6] The literature offers rational explanations for the of book-

[5] See, among others, Kogan (2004), Gomes, Kogan, and Zhang (2003), Cooper and Priestley (2008) and Aguerrevere (2008).

[6] Carlson, Dockner, Fisher, and Giammarino (2009) and Cooper (2003) are notable exceptions.

to-market (B/M) and size effects documented by Fama and French (1992). In Carlson, Fisher, and Giammarino (2004), for example, the B/M effect arises due to the fixed operating costs porportional to the firm capital. I contribute to this literature by modeling exit decisions and incorporating financial leverage and information asymmetry. I also derive the implications for the firms' cost of capital. The model demonstrates that information asymmetry leads to jumps in firm value as well as risk dynamics and cost of capital. While the size of jumps depends on the extent of information asymmetry, the direction depends on industry characteristics. Specifically, the presence of competition has a tempering effect when the industry demand falls. At the same time, the presence of competition prevents a firm from capturing the monopoly rents. This tradeoff determines the direction of the jump. In addition, the model predicts that actions taken by product market rivals in concentrated industries are a risk factor and should be taken into account when assesssing expected returns. The intuition for this follows from the fact that information asymmetry and rival actions can potentially change the market structure. This, in turn, has impact on cash flows expected to be generated by the firm.

The paper fits naturally into the products markets and game theoretic real options literatures. Although these strands of literature focus more on investment decisions, there are papers that model exit decisions. Ghemawat and Nalebuff (1985) develop the equilibrium concept in a Cournot setting in which firms have different market shares and show that the firm with longer potential monopoly tenure outlasts its rival(s). The equilibrium concept of this paper resembles Ghemawat and Nalebuff's idea. Closely related to our paper is the study of Fudenberg and Tirole (1983). As in this article, they model exit decisions with incomplete information. However, they do not consider signaling possibilities to resolve the asymmetric information. A model that does consider the effect of capital structure choice on entry and exit decisions is that of Lambrecht (2001). He explores the strategic impact of debt in a duopoly and shows that debt renegotiation can provide competitive advantage. The model developed in this paper builds on the model developed in Lambrecht (2001). The main difference between his model and the model presented here is that Lambrecht analyzes a setting with complete information. More recently, Murto (2004) and Miltersen and Schwartz (2007) develop models of exit decisions. While the former incorporates a richer set of exit strategies, the latter analyzes not only exit decisions but also switching options. In this paper, I consider simple strategies and instead focus more on the use of debt as a strategic tool. The paper also relates to those of Grenadier (1999) and Lambrecht and Perraudin (2003). Although these papers present models of investment rather than divestment decisions, they deal with incomplete information and demonstrate that the state variable carries information on which firms can base their strategies. The informative role of the state variable is a crucial factor for the exit decision in the model presented here. However, the model also shows how the informative nature of the state variable can break down and how capital structure decisions can substitute in terms of information revelation.

The rest of the paper is organized as follows. Section 2 introduces the model and derives the equilibria of interest. In Section 3, the model is analyzed further through simulations. Economic implications and testable hypotheses are also discussed in Section 3. Finally, Section 4 concludes the paper.

2 The Model

2.1 Assumptions

For parsimony, the model is set up as a duopoly in reduced form. Both firms are assumed to have no further growth opportunities but they can exit the market. One can, therefore, think of two firms operating in a mature industry such as the airlines industry. The firms employ assets in their operations with salvage value $S_i > 0, i = 1, 2$. The salvage value of assets can be thought of as part of the opportunity cost of continuing to operate in the industry. When equityholders find that the opportunity cost of continuation is too high, they will leave the market. The salvage value can also be perceived as the fire sale value of assets. A firm with a higher salvage value, therefore, can be expected to leave the market sooner, *ceteris paribus*, since its assets command a higher price in the market. Since the focus of the model is the relation between leverage, exit and information asymmetry, I assume that both firms have the same salvage value fixed at S.

The assets of a firm generate an operating income of Πx_t (πx_t) if the firm operates as a monopolist (duopolist). The model assumes $\Pi > \pi > 0$, implying monopoly rents for the firm that outlasts its rival. This structure gives the firms the incentive to drive competitors out of the market. The state variable, x_t is stochastic and can be thought of as the demand shocks. It follows a standard geometric Brownian motion:

$$dx_t = \mu x_t dt + \sigma x_t dw_t \tag{1}$$

where μ, σ are constant drift and volatility terms and dw_t are the increments of a standard Wiener process. We assume that the drift term, μ, is strictly less than the riskless rate, r, to guarantee finite firm values.[7]

Both firms are initially assumed to be leveraged. Leverage is also the main source of heterogeneity across firms. Firm leverage in the model has two components. First, each firm has financial leverage. Financial leverage entails the payment of a fixed coupon, c_i, as long as the firm operates in the market. Though not modeled explicitly, the coupon is set such that the market value of debt at the initial date, $D(x_0; c_i)$ is equal to its face value, B. When exit occurs, a portion $\alpha \in [0, 1]$ of the salvage value is lost. Capital structure is taken as a static decision of the firm. This implies, in particular, that bondholders have a fixed claim on the firm in which seniority plays no role and that the value of debt remains unaffected when the rival firm exits the market.[8] Finally, the model does not consider any restrictive covenants and renegotiation possibilities.

The second component of firm leverage is the operating leverage. Operating leverage is defined as the fixed costs the firms must incur to continue to compete and proxies firm efficiency. These costs may arise due to supply chain management, location and facilities choice and organizational factors such as the efficiency of production processes and networks. Although operating leverage relates to the real decisions of the firm, it is analogous to the financial leverage in that it represents a fixed outlay from the firm. Just

[7]The initial value of the state variable, $x(0) = x_0$ is assumed to be sufficiently high so that the initial setting is a duopoly.

[8]It could be argued that debt value should also be affected by the exit of the rival firm since this enables the firm to generate higher operating profits, which, in turn, might lead to a higher debt capacity. However, given the assumption of a static capital structure, only the own firm actions will influence the debt value.

as with the debt contract, equityholders are residual claimants as they must first pay out any fixed costs. I assume that information asymmetry in the model relates to the operating leverage. For expositional purposes, information asymmetry is not taken as reciprocal. That is, I assume that the fixed cost of firm 1, f_1, is common knowledge in the market. On the other hand, firm 1 knows only the distribution of the fixed costs of the rival firm 2. There is no other source of information asymmetry in the model. For simplicity, the fixed cost of firm 2 can be either low or high:

$$\tilde{f}_2 = \begin{cases} f_L, & with \quad p \\ f_H, & with \quad q \equiv 1-p \end{cases}$$

Having described both components, total leverage of a firm can now be defined as the sum of these two parts. For firm 1, $F_1 = c_1 + f_1$ denotes total leverage. Total leverage of firm 2, on the other hand, is given by:

$$\tilde{F}_2 = \begin{cases} c_2 + F_L, & with \quad p \\ c_2 + F_H, & with \quad q \equiv 1-p \end{cases}$$

Murto (2004) develops a theory of exit in an oligopoly under the assumption that the strategy space need not be connected sets as in Lambrecht (2001). In such a setting, firms can also exit the market with an *upward* movement of the state variable. In this paper, I restrict attention to strategies in which exit is triggered by a single threshold. This allows me to keep the model as simple as possible since, as Murto (2004) demonstrates, relaxing the connectedness assumption may under certain conditions result in multiple equilibria.

2.2 Real Options and Information Revelation

I start this section with the analysis of various claims on the firm to obtain total firm values. In the model, there are two groups of claimholders. The first group is the bondholders. The debt contract is a consol bond and promises bondholders a fixed payment of $c_i dt$ unless equityholders decide to exit the market. The value of the debt contract,therefore, comprises two parts. The first part is the present value of the cash flow streams represented by the coupon payments. The second component is associated with the flexibility of equityholders to determine the exit policy of the firm. This part captures the fact that, at firm exit, bondholders give up the stream of coupon payments and instead get a claim on the remaining value of the firm as the senior claimholders.

The second group of claimholders is the equityholders. The value of equity depends on the industry structure. To analyze equity value, therefore, assume, for now, that firm i eventually becomes the monopolist and firm j leaves the market at some optimal trigger value x_{jd}. The equity value for firm i is divided into two regions separated by the exit trigger of the rival. In each region, firm i continues to pay out F_i. However, when it operates as a duopolist, it generates an operating income of πx_t while, as a monopolist, operating revenues are Πx_t. Firm j, on the other hand, acts as a duopolist until its own exit. Therefore, its equity value can be characterized in a single region above its exit trigger, generating a net flow of $\pi x_t - F_j$. Proposition 1 formalizes the above discusssion.

Proposition 1: *(i) Debt value of both firms is given by:*

$$D_k(x; c_k) = \frac{c_k}{r} + A_k x^{\lambda_2}, k \in \{i, j\} \tag{2}$$

where $\lambda_2 < 0$ *is the root of the characteristic equation described in the Appendix and*

$$A_k = \begin{cases} 0, & if \;\; (1-\alpha)S \geq \frac{c_k}{r} \\ \left[(1-\alpha)S - \dfrac{c_k}{r}\right]\left(\dfrac{1}{x_k}\right)^{\lambda_2}, & otherwise \end{cases} \tag{3}$$

where $x_k, k = i, j$ *is the exit trigger of firm* k.
(ii) Equity value of the firm that leaves the market first, firm j*, is given by:*

$$\begin{aligned} E_j(x) &= \left(\frac{\pi x}{r-\mu} - \frac{F_j}{r}\right) + \left(\omega_j(1-\alpha)S + \frac{F_j}{r} - \frac{\pi x_{jd}}{r-\mu}\right)\left(\frac{x}{x_{jd}}\right)^{\lambda_2} \\ &= \left(\frac{\pi x}{r-\mu} - \frac{F_j}{r}\right) + B_j x^{\lambda_2} \end{aligned} \tag{4}$$

where x_{jd} *is optimally derived as:*

$$x_{jd} = \frac{-\lambda_2(r-\mu)(\omega_j(1-\alpha)rS + F_j)}{(1-\lambda_2)r\pi} \tag{5}$$

and $\omega_j(c_j)$ *is the portion of the salvage value recovered by equityholders after paying bondholders:*

$$\omega_j(c_j) = \begin{cases} (1-\alpha) - \dfrac{c_j}{rS}, & if \;\; (1-\alpha)S \geq \frac{c_j}{r} \\ 0, & otherwise \end{cases} \tag{6}$$

(iii) Equity value of the firm that becomes a monopolist, firm i*, is given by:*

$$E_i(x) = \begin{cases} E_{id}(x), & if \;\; t < \tau_j \\ E_{im}(x), & otherwise \end{cases} \tag{7}$$

where $\tau_j \equiv inf\,\{t > 0 : x_t \leq x_{jd}\}$ *is defined as the stopping time at which firm* j *leaves the market and* $E_{1d}(x)$ *and* $E_{1m}(x)$ *are determined, respectively, as:*

$$\begin{aligned} E_{id}(x) &= \left(\frac{\pi x}{r-\mu} - \frac{F_i}{r}\right) + \left(\omega_i(1-\alpha)S + \frac{F_i}{r} - \frac{\Pi x_{im}}{r-\mu}\right)\left(\frac{x}{x_{im}}\right)^{\lambda_2} \\ &\quad + \left[\frac{(\Pi-\pi)x_{jd}}{r-\mu}\left(\frac{x}{x_{jd}}\right)^{\lambda_2}\right] \\ &= \left(\frac{\pi x}{r-\mu} - \frac{F_i}{r}\right) + C_i x^{\lambda_2} + D x_{jd}\left(\frac{x}{x_{jd}}\right)^{\lambda_2} \end{aligned} \tag{8}$$

$$\begin{aligned} E_{im}(x) &= \left(\frac{\Pi x}{r-\mu} - \frac{F_i}{r}\right) + \left(\omega_i(1-\alpha)S + \frac{F_i}{r} - \frac{\Pi x_{im}}{r-\mu}\right)\left(\frac{x}{x_{im}}\right)^{\lambda_2} \\ &= \left(\frac{\Pi x}{r-\mu} - \frac{F_i}{r}\right) + C_i x^{\lambda_2} \end{aligned} \tag{9}$$

where the exit trigger for firm i, x_{im}, is given by:

$$x_{im} = \frac{-\lambda_2(r-\mu)(\omega_i(1-\alpha)rS + F_i)}{(1-\lambda_2)r\Pi} \tag{10}$$

(iv) Total firm value for firm k is given by:

$$V_k(x) = D_k(x) + E_k(x), k \in \{i, j\} \tag{11}$$

Proof: *See Appendix A.*

Proposition 1[9] details the structure and various factors that determine the value of debt and equity claims of the firms. Debt value consists of two parts as shown in equation (2). The first part is the present value of the fixed claim of bondholders on the firm. The second component, $A_k x^{\lambda_2}$, captures the value associated with the flexibility of equityholders to choose the time of exit. From equation (3), this value depends on whether the salvage value of firm assets net of bankruptcy costs, $(1-\alpha)S$, is sufficient to cover the present value of coupon payments, $\frac{c_k}{r}$. If this is the case, then bondholders recover their claim in full when the firm exits. In other words, the debt contract is riskless and therefore, the value of debt is simply the present value of coupon payments. If, on the other hand, $(1-\alpha)S < \frac{c_k}{r}$, bondholders give up the present value of coupon payments but capture fully the salvage value after accounting for the proportional loss, α. This is represented by the bracketed term in equation (3).

[9] Proposition 1 of this paper is analogous to Proposition 2 of Lambrecht (2001). Proposition 1 generalizes Lambrecht's Proposition 2 to include operating leverage and salvage value.

As for the equity value, consider first firm j, which leaves the market first. Its equity value is composed of three parts. First, the firm generates operating revenues, πx_t. The first term captures the present value of this revenue stream discounted at the risk-adjusted rate. The firm must also pay out the present value of fixed claims coming from financial and operating leverage. This is captured by the second term. Together, these two parts comprise the value of assets in place net of fixed obligations of the firm. The final term in equation (4) characterizes the additional value associated with the flexibility of equityholders to leave the market. Analogous to the debt contract, at the exit trigger, x_{jd}, equityholders give up the present value of the assets in place and instead retrieve the salvage value of the assets.

The equity value of firm i comprises of two regions reflecting the product market structure as shown in equation (7). In the region in which firm j has not yet exited, firm i operates as duopolist. Therefore, its value comprises the same elements as those in the equity value of firm j. The duopoly equity value, however, is further enhanced by the strategic interaction. In particular, the last term in equation (8) captures the incremental benefit that accrues to firm i when firm j exits the market at x_{jd}. Once firm j leaves the market, firm i's operating revenues jump by a factor $\frac{\Pi}{\pi}$ and the strategic effect disappears in equation (9), which captures the firm i value as a monopolist.

The analysis in Proposition 1 is silent on which firm leaves the market first. In what follows, I address this issue by considering various cases based on relative strength of the firms. The analysis includes cases in which information revelation occurs with strategic exercise of options as well as those cases in which information revelation can break down. In the subsequent analysis, the uninformed firm 1 is said to strictly dominate the informed firm 2 of type k if $F_1 < F_k, k = L, H$. Conversely, type k firm 2 strictly dominates firm 1 if $F_k < F_1, k = L, H$. In the case $F_L < F_1 < F_H$, no dominance occurs *ex ante*. Given these competitive environments, each firm optimally determines when to exit the market based on its information set. In particular, the uninformed firm 1 can choose to leave either at its *duopoly exit trigger*, x_{1d} or at the *monopoly exit trigger* x_{1m}. The triggers x_{1d} and x_{1m} are given, respectively by x_{jd} and x_{im} in Proposition 1 with the appropriate firm-specific parameters. Similarly, a type k firm 2 must determine whether it exits at the duopoly trigger, x_{2d}^k or at the monopoly trigger, x_{2m}^k. Proposition 1 shows that all exit triggers are strictly increasing in the total leverage of the firm. A higher firm leverage compared to the competitor, therefore, implies that the firm exits the market sooner than the rival in a frictionless environment. In terms of the information sets, knowing rival firm leverage is equivalent to knowing the exit trigger.

Before analyzing these cases, it is crucial to define the concepts of *reservation trigger*, which plays an important role in deriving the subsequent equilibria, and *revelation strategy*. As in Lambrecht (2001), the reservation trigger is the critical threshold of the competitor that makes firm i indifferent between becoming a monopolist at this trigger and leaving first at its own duopoly threshold. Figure 1 shows firm 1 duopoly value function for various levels of duopoly exit trigger of type L firm 2. Note that the value function is increasing in the exit trigger of the competitor. Put differently, the sooner firm 2 leaves, the higher is the value of firm 1 since it has a shorter duopoly but a longer monopoly position. The existence of the reservation trigger is guaranteed by this feature and the fact that the value functions

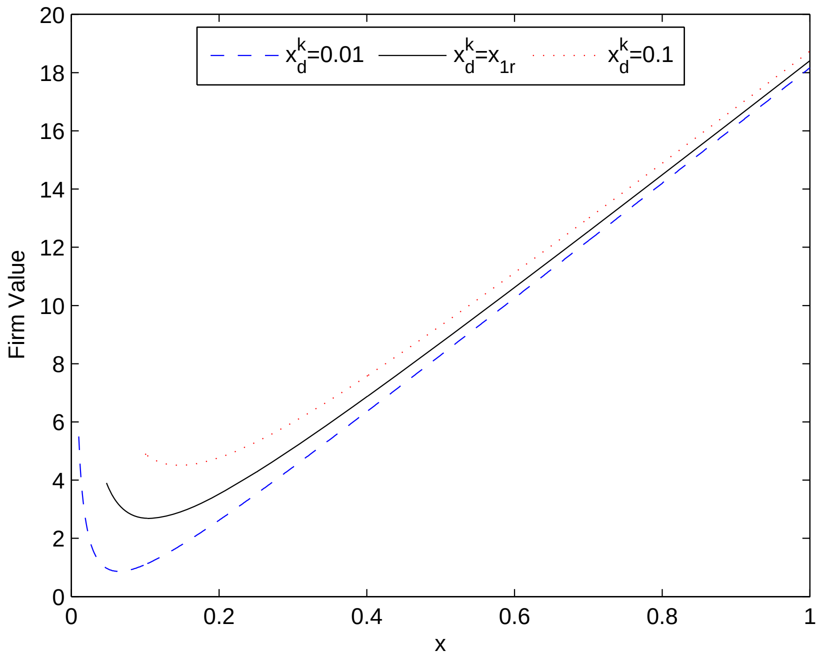

Figure 1: *Duopoly Firm 1 Value as a Function of Type L Firm 2 Duopoly Trigger. The parameters are* $\mu = 0, \sigma = 0.2, r = 0.05, \Pi = 2, \pi = 1, S = 1, f_1 = 0.1$. *The reservation trigger with this parameter set is* $x_{1r} = 0.05$

are of the same shape. Specifically, the reservation triggers for firm 1 and type k firm 2, respectively, are the critical value of competitor's duopoly threshold such that

$$E_{1d}^k(x_{1r}) = E_{1d}(x_{1d}) \tag{12}$$

$$\bar{E}_{2d}^k(x_{2r}) = E_{2d}^k(x_d^k) \tag{13}$$

In equations (12) and (13), the left-hand-side is the value of the firm that eventually becomes a monopolist at the competitor's exit trigger. The right-hand-side yields the value when leaving first at the duopoly trigger. Substituting for equations (12) and (13) from the analysis in Proposition 1, the reservation triggers can be obtained as:

$$\begin{aligned} x_{1r} &= \left\{ \frac{(\omega_1(1-\alpha)rS + F_1)(r-\mu)}{(\Pi-\pi)(1-\lambda_2)r} \left(\frac{1}{x_{1d}^{\lambda_2}} - \frac{1}{x_{1m}^{\lambda_2}} \right) \right\}^{\frac{1}{1-\lambda_2}} \\ x_r^k &= \left\{ \frac{(\omega_k(1-\alpha)rS + F_k)(r-\mu)}{(\Pi-\pi)(1-\lambda_2)r} \left(\frac{1}{(x_d^k)^{\lambda_2}} - \frac{1}{(x_m^k)^{\lambda_2}} \right) \right\}^{\frac{1}{1-\lambda_2}} \end{aligned} \tag{14}$$

As in Lambrecht (2001), the reservation trigger can be perceived as the point until which firm i is willing to incur losses to reap off monopoly benefits when the competitor leaves the market. Furthermore, substituting for the exit triggers in equation (14), it turns out that the reservation trigger is linearly increasing in the firm's total leverage. The reservation trigger can be written generically as:

$$\begin{aligned} x_{ir} &= \frac{(r-\mu)}{(1-\lambda_2)r} \left[\frac{\pi^{\lambda_2} - \Pi^{\lambda_2}}{(-\lambda_2)^{\lambda_2}(\Pi-\pi)} \right]^{\frac{1}{1-\lambda_2}} (\omega_i(1-\alpha)rS + F_i) \\ &= \frac{(r-\mu)}{(1-\lambda_2)r} \Omega(\omega_i(1-\alpha)rS + F_i) \end{aligned} \tag{15}$$

Equation (15) allows us to make a natural order among reservation triggers. This simplifies the derivation of the equilibrium. In addition, the reservation trigger has the feature that it is between the duopoly and monopoly thresholds, $x_{im} \leqslant x_{ir} \leqslant x_{id}, i = 1, 2$.

I now turn to the discussion of the *revelation strategy*. The revelation strategy for the uninformed firm 1 aims to induce the rival firm to truthfully reveal its type through its actions. Since the action space for firm 2 involves exiting at either the duopoly or the monopoly triggers, the revelation strategy leads a type H firm 2 to exit at x_{2d}^H, implying that the exercise (or the lack thereof) of the exit option dissipates the information asymmetry in the product markets. Note that firm 1 can devise a revelation strategy using the reservation trigger. Since the reservation trigger measures a firm's willingness to endure losses in order to become a monopolist, a lower reservation trigger can serve as a credible threat mechanism and force the H type firm to truthfully reveal its type.

Having defined the concepts of the reservation trigger and the revelation strategy, Proposition 2 establishes one of the main results of the paper in the non-dominance case: that information revelation in product markets can follow from strategic exercise of real options.

Proposition 2 (Information Revelation): *Suppose $F_L < F_1 < F_H$ and $x_{1d} < x_{2r}^H$. Then the unique separating perfect Bayesian equilibrium (PBE) involves type L firm 2 leaving the market at its monopoly trigger and type H firm 2 exiting when x_t hits x_{2d}^H. Firm 1 plays the revelation strategy in which it observes the firm 2 action at x_{2d}^H. Firm 1 leaves the market either at its duopoly trigger if firm 2 has not exited at x_{2d}^H or exits at the monopoly trigger if firm 2 has exited at x_{2d}^H.*

Proof: *See Appendix A.*

The significance of Proposition 2 stems from the fact that real options exercises carry information. This information can be crucial so as to resolve information asymmetry and to determine the outcome of product market competition. Three remarks are in order here. First, although information revelation ensures that the stronger firm in terms of total leverage outlives the competitor, it does capture the possibility that the exit is due to high debt rather than operating inefficiency. Suppose that firm 1 faces a type L firm 2 and that $f_1 < f_L$. Firm 1 leaves the market due to relatively high financial leverage if $c_1 - c_2 > f_L - f_1$.

Second, it is important to realize that Proposition 2 claims the separating PBE is unique. The uniqueness of the PBE arises from the observation that the firms play their dominant strategies given the parameter assumptions in Proposition 2. In particular, a type H firm has no incentive to pool with the type L firm since the duopoly trigger of firm 1 is below its reservation trigger, x_{2r}^{H}. Hence, even if firm 1 is misled to believe that the competitor is an L type firm, the exit at x_{1d} would lead to unjustified losses beyond the indifference point of the H type firm.

Finally, note that a full solution to the game describes what firms will do for each possible parameter set, in particular, also when $x_{1d} \geq x_{2r}^{H}$. Following the strategy outlined in Proposition 2 when $x_{1d} \geq x_{2r}^{H}$ for the uninformed firm 1 gives the high-leverage firm 2 the incentive to stay in the market beyond its duopoly exit trigger. To see this, suppose that the state variable hits x_{2d}^{H}. By staying until $x_{2d}^{H} - \epsilon$, $\epsilon > 0$, the inefficient firm leads firm 1 to believe that it faces a low-leverage rival and therefore, it leaves the market at x_{1d}. Since $x_{1d} \geq x_{2r}^{H}$, the high-leverage firm is willing to incur these losses since it will eventually become a monopolist. Hence, the equilibrium of Proposition 2 breaks down when $x_{1d} \geq x_{2r}^{H}$. On the other hand, since the parameters of the game are known at the outset, firm 1 knows whether or not $x_{1d} \geq x_{2r}^{H}$. The fact that the game is played in triggers implies firm 1 could devise another revelation strategy. If the expected payoff from the revelation strategy is greater than that from exiting at the duopoly trigger, firm 1 will adopt the revelation strategy. The revelation strategy when $x_{1d} \geq x_{2r}^{H}$ involves waiting until just after the reservation trigger of type H firm 2, $x_{2r}^{H} - \epsilon$. If firm 1 commits[10] to this strategy, the best response of a type H firm 2 would be to leave at the duopoly trigger. A type L firm

[10] Firm 1 can credibly commit to the strategy since $x_{1r} < x_{2r}^{H}$.

2 would wait until firm 1 leaves since $x_{2r}^L < x_{1r}$. Note, however, that firm 1's commitment to this strategy depends crucially on the beliefs it holds as to the type of the rival upon observing no exit at the trigger x_{2d}^H. Denote by r the conditional probability that firm 1 faces an L type rival given no exit has occurred at x_{2d}^H. If firm 1 exits first at the duopoly trigger, its expected equity value would be given by $E_{1d}(x)$ as specified in equation (4). On the other hand, the revelation strategy yields an expected value of $rE_{1d}(x; x_{2r}^H) + (1-r)E_{1d}^H(x)$. In this formulation, $E_{1d}(x; x_{2r}^H)$ denotes the firm 1 value when equityholders exit at the reservation trigger of the H type rival, x_{2r}^H, while $E_{1d}^H(x)$ is the value to equityholders when the rival firm turns out to be an H type firm and exits at $x_{2d}^H - \epsilon, \epsilon > 0$. The latter is given by equation (8). The next proposition shows that if the expected value from the duopoly strategy exceeds that from the revelation strategy, there exists indeed an equilibrium in which the high-leverage firm induces the uninformed firm 1 to exit the market prematurely by taking advantage of the information asymmetry.

Proposition 3: *Suppose $F_L < F_1 < F_H$ and $x_{1d} \geq x_{2r}^H$. If firm 1's prior on an L type rival, p, satisfies*

$$p \geq \frac{E_{1d}^H(x) - E_{1d}(x)}{E_{1d}^H(x) - E_{1d}(x; x_{2r}^H)} \tag{16}$$

then there exists a PBE in which firm 1 leaves the market first at its duopoly trigger x_{1d}.

Proof: *See Appendix A.*

Proposition 3 is another central result of the paper. For the result in Proposition 3 to prevail, the uninformed firm's prior about an L type rival must be sufficiently high. When this is the case, firm 1 prefers to leave the market first at its duopoly trigger. The distortionary effect of information asymmetry may occur in a number of competitive settings and industry characteristics. For instance, one may expect information asymmetry to be particularly high in R&D intensive industries in which firms may want to conceal private information in order to gain competitive advantage over the rival. Information about a new entrant may also be scarce for an incumbent firm.

The proposition shows a more efficient, low-debt firm can be driven out of the market. In a sense, this result entails the evidence in Khanna and Tice (2005) that a more efficient firm with high debt can be driven out of the market earlier than a relatively less efficient rival with lower financial leverage. At the same time, it is more general than the evidence in Khanna and Tice (2005) since it shows that information asymmetry can cause the exit of the stronger firm in the market.

Turning to the cases of strict dominance, Proposition 4 establishes that as long as there is strict dominance between firms, information revelation always takes place.

Proposition 4: (i) *When $F_1 < F_k, k = L, H$, the unique perfect Bayesian equilibrium involves firm 2 of type $k = L, H$ leaving the market first. Type k firm equity value and the exit trigger are given by equations (4) and (5), respectively. The equity value of firm 1 is given by:*

$$E_1 = \begin{cases} pE_{1d}^L(x) + qE_{1d}^H(x), & if \;\; t < \tau_H \\ E_{1d}^L(x), & t \in [\tau_H, \tau_L] \\ E_{1m}(x), & otherwise \end{cases} \tag{17}$$

where $\tau_k, k = L, H$ is the adapted stopping time at which type k firm 2 exits. Firm 1 exit trigger is as in equation (10).

(ii) When $F_k < F_1, k = L, H$, the unique perfect Bayesian equilibrium involves firm 2 of type $k = L, H$ leaving the market last. Type k firm equity value and the exit trigger are given by equations (7) and (10), respectively. Firm 1 equity value and exit trigger are given by equations (4) and (5), respectively.

Proof: *See Appendix A.*

Similar to the previous results, Proposition 4 shows that total leverage determines the order of exit in product markets. As opposed to Proposition 3, however, it argues that information asymmetry cannot be taken advantage of and that it is immaterial to the outcome of competition. So long as there is strict dominance between firms, the state variable and the exercise of real options reveal private information. Similar to Proposition 2, the exit in strict dominance cases might result either from operating inefficiency or relatively high debt.

2.3 Capital Structure and Information Revelation

The previous subsection discussed how information revelation can occur and break down in product markets with strategic exercise of real options. The focus of this subsection is how firms can make use of their capital structure to reveal their private information. The analysis up to this section considered cases in which the relations among total leverages of firms were strict inequalities.

However, it may be the case that the total leverage of firm 1, F_1, is equal to that of type H firm 2, F_H. When this is the case, the reservation triggers of firm 1 and type H firm 2 are equal. Neither firm, therefore, can credibly threaten the rival by staying until their respective reservation triggers. The uninformed firm 1 would then compare its expected payoff from exiting at its duopoly trigger to that from exiting at its monopoly trigger. If parameters are such that the expected payoff from the monopoly strategy exceeds that from the duopoly strategy, firm 1 would then stay in the market until its monopoly trigger. This would, in turn, give the L type rival to separate itself from an H type firm.

How does capital structure reveal information? Since the competitive environment is determined by the firm-specific and market-wide characteristics known to both firms at the outset of the game,[11] a type L firm 2 knows the best response function of the uninformed firm 1. An L-type firm, therefore, can signal its type by issuing bonds *ex ante* that promise a total coupon payment of $(c_2 + b_L)dt$. Recall that in the previous subsection, the only heterogeneity across both types of firms was the operating leverage. The debt contract of Section 2.2 promised a constant coupon of $c_2 dt$ for both types. Therefore, b_L denotes the amount of coupon paid by the L type firm to separate itself from an H type firm. An L type firm can signal its type by setting b_L such that an H type firm has no incentive to mimic. Specifically, b_L should be set such that, when mimicked, an H type firm optimally leaves at its duopoly trigger. This requires that

$$x_{1r} < \bar{x}_{2r}^{H} \tag{18}$$

where $\bar{x}_{2r}^{H}$ is the reservation trigger of an H type firm if it mimics an L type firm. Condition (18) restores the competitive advantage of firm 1 over an H type firm. In particular, firm 1 can again use the information revelation strategy outlined in Proposition 2.

[11] Recall, however, that the uninformed firm knows distribution of its rival's operating leverage.

A second requirement for a separating debt contract is that an L type firm does not lose its competitive advantage over firm 1. Proposition 4 showed that this will be the case so long as the reservation trigger of an L type firm is below that of firm 1:

$$\bar{x}_r^L \leq x_{1r} \tag{19}$$

where $\bar{x}_r^L$ is the reservation trigger of an L type firm when the firm issues a debt contract with coupon $c_2 + b_L$. Combining conditions (18) and (19) yields the Proposition 5.

Proposition 5: *A separating debt contract issued ex ante by an L type firm must satisfy:*

$$(\omega_1 - \bar{\omega}_H)(1-\alpha)rS < b_L \leq (\omega_1 - \bar{\omega}_L)(1-\alpha)rS + (f_1 - f_L) + (c_1 - c_2) \tag{20}$$

Proof: *The proof follows from straightforward substitution for x_{1d}, $\bar{x}_{2r}^H$ and $\bar{x}_{2r}^L$.*

Proposition 5 suggests that operating efficiency increases debt capacity of the firm allowing it to issue more debt *ex ante*: note that the upper bound on b_L is increasing in the difference of operating leverages of firm 1 and type L firm 2. Put differently, this result shows how product market competition can constrain the use of debt for other corporate purposes. A small magnitude of this difference might imply that the firm faces a tradeoff between addressing the free cash flow problem and maintaining its competitive position in the product markets.

3 Economic Implications and Risk Analysis

This section aims to assess the significance of the results proposed in Section 2 and to derive economic implications. Three broad questions are addressed through simulations. First, how do firm values respond to changes in crucial parameters of the model? Of particular interest is the effect of information asymmetry on the value of the uninformed firm. Second, I investigate the relation between operating and financial leverage and analyze corresponding empirical predictions. Finally, I define and show the risk implications of the model. The parameter values used in the analysis are given in Appendix B.

3.1 Implications for Firm Value

Figure 2 illustrates the impact of information asymmetry on the value of the uninformed firm 1 for various values of the probability of an L type rival. Panel A of Figure 2 conditions on an L type firm. The graph is divided into four regions separated by the exit triggers $x_{1m} < x_{2d}^L < x_{2d}^H$. The firm values are are identical in the regions in which $x_t < x_{2d}^H$. This is because all information asymmetry is resolved below x_{2d}^H. However, for $x_t \geq x_{2d}^H$, the uninformed firm 1 value is an expectation over types. Several observations are salient in Panel A. First, the figure exhibits a nonmonotonic relation between firm value and the *extent of information asymmetry*. The extent of information asymmetry is greatest at $p = 0.5$. Note that firm value when $p = 0.5$ is between those when $p = 1$ and $p = 0.2$. Second, when $p = 1$, that is, when firm 1 knows the rival's type is L, firm 1 value is continuous as shown by the dotted line in the figure. On the other hand, when there is information asymmetry, firm 1 value jumps at the exit trigger of an H type firm, x_{2d}^H. The size of the jump increases in the probability

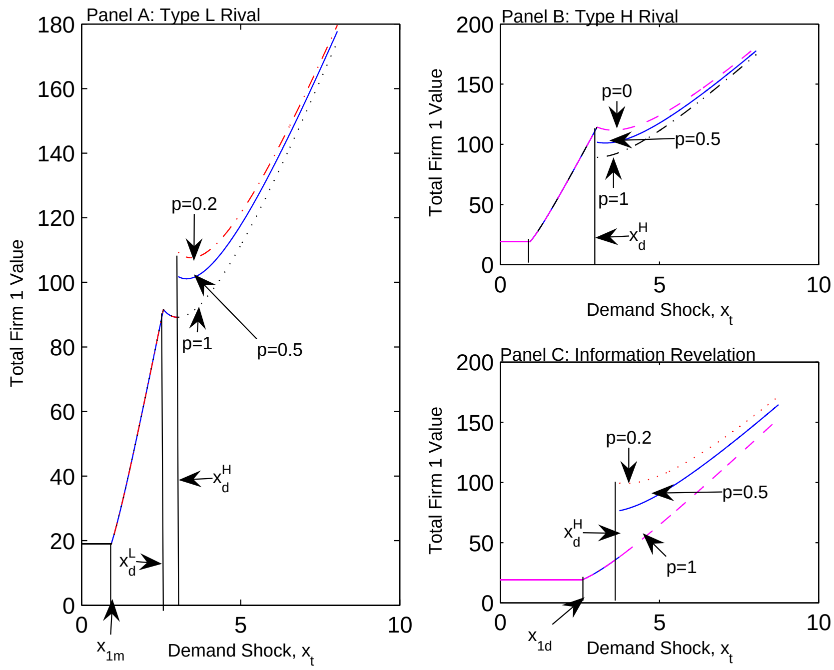

Figure 2: ***Effect of Information Asymmetry on Uninformed Firm Value. Panels A and B show the case $F_1 < F_k, k \in \{L, H\}$. Panel C shows information revelation conditional on type L rival.***

of an H type firm, $1 - p$. By attaching a higher probability to an H type rival, firm 1 weighs the prospect of becoming a monopolist at an earlier date, x_{2d}^H, relatively high. As firm 1 finds out that the rival is type L at x_{2d}^H, the adjustment to firm value becomes more drastic. For instance, when $p = 0.5$, the adjustment to firm value is about 11% whereas when $p = 0.2$, the adjustment is as high as 22%. If one interprets p as the common prior of firm 1 about the rival's type, this observation shows the significance and value of information held by competitors in product markets. Finally, note that for large values of x_t, the value functions close in on each other since, at this range, firm 1 is far from the duopoly exit trigger x_{2d}^H and the probability of becoming a monopolist soon is relatively low. The pattern of adjustment is reversed when one conditions on an H type firm. Panel B of Figure 2

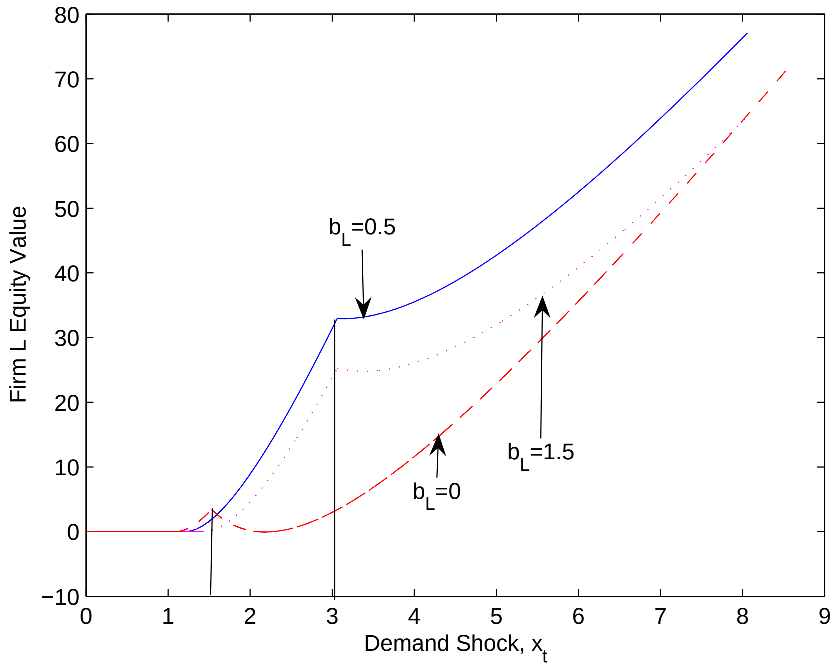

Figure 3: *Type L Firm 2 Equity Value with and without Signaling. The parameters are* $\mu = -0.01, \sigma = 0.2, r = 0.05, \alpha = 0.05, \Pi = 2, \pi = 1, S = 20, f_1 = 2, c_1 = 5, f_L = 1, c_L = 4, f_H = 2, c_H = 5$.

depicts this case. Analogous to Panel A, the graph is divided into three regions separated by x_{2d}^H where information asymmetry is resolved and x_{1m} where firm 1 optimally leaves the market. In this case, $p = 0$ corresponds to the perfect information setting in which firm 1 knows that the rival is a highly leveraged firm. This is shown by long dashed lines in the figure. When $p = 0$, firm 1 value is continuous. However, when there is information asymmetry, firm 1 value experiences an upward adjustment at x_{2d}^H as it finds out the rival's type. This is because, before x_{2d}^H is hit, firm 1 value takes into consideration the likelihood that the rival might be a low leveraged firm. The value adjustment at x_{2d}^H is upward since the firm becomes a monopolist at an earlier time relative to the case in which the rival is a low leveraged firm. In other words, firm 1 receives either good or bad news when x_{2d}^H is hit. In the case of Panel B, the news is good since the rival turns out to be a high-leverage firm. As in Panel A, the adjustment to value in Panel B is significant. When $p = 0.5$, the jump in value is approximately 13%. A similar pattern is observed in Panel C of Figure 2 when $F_1 \in (F_L, F_H)$ and $x_{1d} < x_{2r}^H$ so that the revelation strategy as outlined in Proposition 2 can be used. The figure conditions on the *ex post* realization of an L type rival. The graph with the dashed lines shows the perfect information case in which $p = 1$. In that case, firm 1 value is continuous and given simply by its duopoly value without any strategic interaction terms.[12] When there is information asymmetry, firm 1 learns the rival's type at $x_{2d}^H = 2.90$ and firm value is adjusted accordingly. As with Panels A and B, the adjustment at x_{2d}^H is significant.

Proposition 5 derives the conditions for the debt contract that reveals firm type when the uninformed firm's total leverage is equivalent to that of the highly levered firm 2 and the uninformed firm's expected value from following the monopoly strategy is higher than that from exiting at the duopoly trigger. Figure 3 assesses the significance of the debt contract suggested by Proposition 5. Type L firm 2 equity value without signaling is shown by the dashed curve in the figure. The dotted and the solid curves show the equity value of the signaling firm with two different levels of coupon. As expected, signaling increases the equity value of the type L firm. This arises mainly from the fact that the type L firm becomes a monopolist at an earlier date when it reveals its type. Given the parameter set of Figure 3, type L firm 2 becomes a monpolist when the shock process hits 3 rather than 1.5 without signaling. In addition, the increase in the equity value is more significant when b_L is chosen closer to the lower bound in Proposition 5. For instance,

[12]Refer to Proposition 1, equation (4).

choosing $b_L = 0.5$ rather than $b_L = 1.5$ leads to a 40% higher value at the exit of firm 1 at x_{1d}.

3.2 Firm Leverage and Exit

The model developed in the paper defines firm leverage broadly as the sum of financial leverage and operating leverage. Operating leverage, at the same time, is the proxy for firm efficiency. In particular, it can be thought of as a measure indicating how well the firm manages its supply chain and networks or as a measure of production costs. Although all these relate to real decisions of the firm as opposed to financial decisions, they represent a fixed outlay for the firm as long as it operates. Therefore, it is analogous to financial leverage.

In addition, operating leverage is often a consequence of the technology choice of the firm. A change in technology can prove to be a difficult decision: it may involve a large, irreversible lump-sum investment cost as well as adjustment costs and may require ongoing R&D activities prior to the switch. Compared to a firm's financial leverage, therefore, changes in operating leverage are more costly and likely to be infrequent.[13] Recall also that total firm leverage determines the competitive strength of the firm. That is, firm i outlasts firm j so long as $c_i + f_i = F_i < F_j = c_j + f_j$. Therefore, particularly in concentrated industries in which firms may have incentives to induce the exit of their rivals, a firm's financial leverage choice is constrained both by its technology choice and the leverage of its rivals. To see this, suppose that $f_j < f_i$. If it turns out that $c_j - c_i > f_i - f_j$, a more efficient firm will be driven out of the market due to excessive leverage since

[13]This is not to say that changes in financial leverage can be carried out easily at no cost. See, among others, Fischer, Heinkel, and Zechner (1989) for a transaction-cost-based explanation.

$F_i < F_j$. Equivalently, for firm j to attain or maintain a competitive edge over the rival, the portion of total leverage accounted for by debt, c_j/F_j, must be bounded by $F_i/F_j - f_j/F_j$.

Several testable implications emerge out of this. First, changes in a firm's technology and/or innovations that increase firm efficiency are expected to precipitate a rise in financial leverage. Similarly, the financial leverage of a firm is expected to increase subsequent to a major competitor's exit or contraction. This hypothesis is the result of two effects following a rival's exit. First, the firm's financial leverage is no longer constrained by the rival firm's leverage. Second, due to the exit of the rival, the firm can experience an increase in its profitability, which, in turn, can lead to a rise in financial leverage. At the industry level, the model predicts that firms' financial leverage moves together as increases (decreases) in the rival firms' debt relaxes (tightens) the constraint on other firms' financial leverage, *ceteris paribus*. Another policy implication is that firms with relatively high debt levels are expected to invest more in measures that can increase firm efficiency. This effect should be stronger in concentrated industries: as Zingales (1998) and Khanna and Tice (2005) point out, in concentrated industries with less levered rivals, predatory pricing can be observed. The effect should also be observed more strongly for firms that are financially constrained and unable to renegotiate the debt contract.

3.3 Implications for Firm Risk

In a previous paper, Carlson, Fisher, and Giammarino (2004) develop a model in which a time-varying risk structure can be tied to the size and book-to-market factors through operating leverage and the real options of the firm.

The aim of this section is to analyze the dynamic risk structure of firms. The main emphasis is on how information asymmetry and information revelation impact the risk dynamics of the uninformed firm. I also investigate the role of signaling on risk dynamics of the signaling firm. As will be seen, the risk dynamics will not only reflect the book-to-market and size effects but also the impact of information asymmetry and product market competition.

Firm risk is defined as in previous research by Carlson, Fisher, and Giammarino (2004) and Carlson, Dockner, Fisher, and Giammarino (2009). It measures the sensitivity of firm value with respect to changing demand conditions in the product markets. More formally, firm risk, β, is defined as:

$$\beta_i^t = \frac{\partial V_i(x)}{\partial x} \frac{x}{V_i(x)} \tag{21}$$

where $V_i(x) = E_i(x) + D_i(x), i = 1, 2$ is the total firm value.

Note that, in this formulation, market conditions as measured by the movements in stochastic demand acts as the main risk factor. As opposed to most models in the literature pioneered by Berk, Green, and Naik (1999),[14] the model presented in this paper considers financially leveraged firms. This structure allows one to depict a fuller characterization of a firm's time-varying risk dynamics or cost of capital. To see this, define firm i's equity and debt betas as:

$$\beta_i^e = \frac{\partial E_i(x)}{\partial x} \frac{x}{E_i(x)} \tag{22}$$

[14]See Introduction for a discussion of this literature.

and

$$\beta_i^d = \frac{\partial D_i(x)}{\partial x} \frac{x}{D_i(x)} \tag{23}$$

Simple manipulation of the expression for β_i^t using equations (22) and (23) yields:

$$\begin{aligned} \beta_i^t &= \frac{E}{D+E}\beta_i^e + \frac{D}{D+E}\beta_i^d \\ &= w_e \beta_i^e + w_d \beta_i^d \end{aligned} \tag{24}$$

Equation (24) relates total firm risk or its *asset beta* to its two main components represented by the two groups of claimholders. Specifically, firm i's asset beta changes as the market risks of its equityholders (β_i^e) and debtholders (β_i^d) change, weighted by their respective fractions held in the firm.

For expositional purposes, Proposition 6 derives the risk dynamics of only the uninformed firm 1 when it strictly dominates the rival firm of either type. Since the functional form of firm β is similar in all cases, Proposition 6 reflects risk dynamics in all the other cases as well.

Proposition 6: *Suppose $F_1 < F_k, k = L, H$ and let β_1^t and β_1^e denote firm 1 total and equity risk, respectively. Then*
(i) firm 1 total risk and equity risk, conditional on type L competitor, is given by:

$$\begin{aligned} \beta_1^t(x) = 1 + \frac{f_1/r}{V_1(x)} - (1-\lambda_2)\frac{A}{V_1(x)}x^{\lambda_2} - (1-\lambda_2)\frac{C}{V_1(x)}x^{\lambda_2} \\ -(1-\lambda_2)\frac{D}{V_1(x)}\left[p x_{2d}^L \left(\frac{x}{x_{2d}^L}\right)^{\lambda_2} + q x_{2d}^H \left(\frac{x}{x_{2d}^H}\right)^{\lambda_2} \right] \end{aligned} \tag{25}$$

$$\beta_1^e(x) = 1 + \frac{F_1/r}{E_1(x)} - (1-\lambda_2)\frac{C}{E_1(x)}x^{\lambda_2}$$
$$-(1-\lambda_2)\frac{D}{E_1(x)}\left[px_{2d}^L\left(\frac{x}{x_{2d}^L}\right)^{\lambda_2} + qx_{2d}^H\left(\frac{x}{x_{2d}^H}\right)^{\lambda_2}\right] \tag{26}$$

in the region $x_t \geq x_{2d}^H$. In the region $x_t \in [x_{2d}^L, x_{2d}^H]$, firm 1 risk is:

$$\beta_1^t(x) = 1 + \frac{f_1/r}{V_1(x)} - (1-\lambda_2)\frac{A}{V_1(x)}x^{\lambda_2} - (1-\lambda_2)\frac{C}{V_1(x)}x^{\lambda_2}$$
$$-(1-\lambda_2)\frac{D}{V_1(x)}x_{2d}^L\left(\frac{x}{x_{2d}^L}\right)^{\lambda_2} \tag{27}$$

$$\beta_1^e(x) = 1 + \frac{F_1/r}{E_1(x)} - (1-\lambda_2)\frac{C}{E_1(x)}x^{\lambda_2}$$
$$-(1-\lambda_2)\frac{D}{E_1(x)}x_{2d}^L\left(\frac{x}{x_{2d}^L}\right)^{\lambda_2} \tag{28}$$

When firm 1 operates as a monopolist in the region $x_t \in [x_{1m}, x_{2d}^L]$, its risk is given by:

$$\beta_1^t(x) = 1 + \frac{f_1/r}{V_1(x)} - (1-\lambda_2)\frac{A}{V_1(x)}x^{\lambda_2} - (1-\lambda_2)\frac{C}{V_1(x)}x^{\lambda_2} \tag{29}$$

$$\beta_1^e(x) = 1 + \frac{F_1/r}{E_1(x)} - (1-\lambda_2)\frac{C}{E_1(x)}x^{\lambda_2} \tag{30}$$

(ii) firm 1 total risk and equity risk, conditional on type H rival, are given by equations (25) and (26) in the region $x_t \geq x_{2d}^H$ and equations (29) and (30) in the region $x_t \in [x_{1m}, x_{2d}^H]$.

Proof: *The proof follows from taking derivatives of value functions provided in Proposition 1.*

Proposisiton 6 highlights the major factors that determine the dynamic risk structure of firms. It also shows how information asymmetry and learning change risk dynamics. The first component in all equations is called the *revenue beta*, which is normalized to 1. The second component in equations (25)-(30) reflects the contribution from firm leverage. Operating leverage is positively related to total firm risk as well as equity risk. On the other hand, financial leverage is risk-increasing only for equity risk. As in Carlson, Fisher, and Giammarino (2004), this component captures the book-to-market effect. The terms that follow the first two components pertain to the effect of the exit option held by the firm. The third term in total firm risk, $\beta_1^t(x)$, shows the impact of the exit option through debt value. Recall, from equation (3), that $A \leq 0$. If $A < 0$, then the the impact of the exit option on firm value is risk increasing through debt value. On the other hand, when $A = 0$, total firm risk is unaffected by movements in demand conditions. Note that $A = 0$ when the salvage value of the firm is sufficiently high so that debtholders fully recover their claim. Since debtholders retrieve the full claim in the event of exit by equityholders, debt value is not affected by movements in product market conditions. Note also that this effect is absent altogether in equity risk, $\beta_1^e(x)$. As in Carlson, Dockner, Fisher, and Giammarino (2009), both firm's own exit option and the competitor's exit option reduce risk. In other words, competition reduces both firm and equity risk by alleviating the effects of a demand shock. Although lower demand reduces the revenues generated by a particular firm, it also increases the likelihood that the competitor will leave the market, thereby mildening the effect of the negative shock.

The effect of information asymmetry and option exercise can be seen in Proposition 6 as well as Figure 4. Panels A (B) in Figure 4 illustrates total firm 1 risk conditional on a type L (H) rival. Equations (25) and (26) show that firm 1's risk is affected by the extent of information asymmetry. Before rival firm type is revealed through the option exercise at x_{2d}^H, firm 1 weighs the possibility that the rival can be of either type. As in the analysis

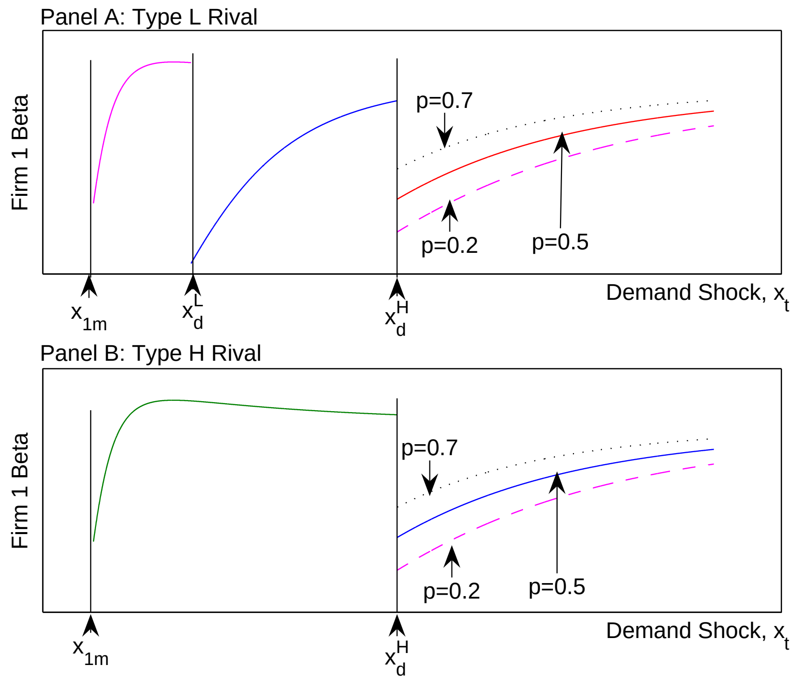

Figure 4: ***Firm 1 Risk When*** $F_1 < F_L < F_H$. ***The parameters are*** $\mu = 0.01, \sigma = 0.2, r = 0.05, \alpha = 0.05, \Pi = 2, \pi = 1, S = 20, f_1 = 1, c_1 = 1, f_L = 2, c_L = 0.5, f_H = 4, c_H = 3$.

of value functions in Section 3.1, the relation between firm risk and the *extent* of information asymmetry is not monotonic. Recall that the extent of information asymmetry is greatest when $p = 0.5$. Both panels of Figure 4 show that if firm 1 has a prior attaching a higher probability to an L-type firm, the size of the jump in firm risk decreases.

Figure 4 also shows that firm risk decreases as demand conditions worsen when $x_t \geq x_{2d}^H$. At x_{2d}^H, firm 1 finds out rival firm type and firm risk jumps. Since Panel A assumes a type L rival, firm 1 continues to operate as a duopolist as long as x_t hits the duopoly exit trigger of the L-type rival, x_{2d}^L. Firm risk in this region follows a similar pattern to that before x_t hits x_{2d}^H. When type L firm leaves the market at x_{2d}^L, there is another upward jump

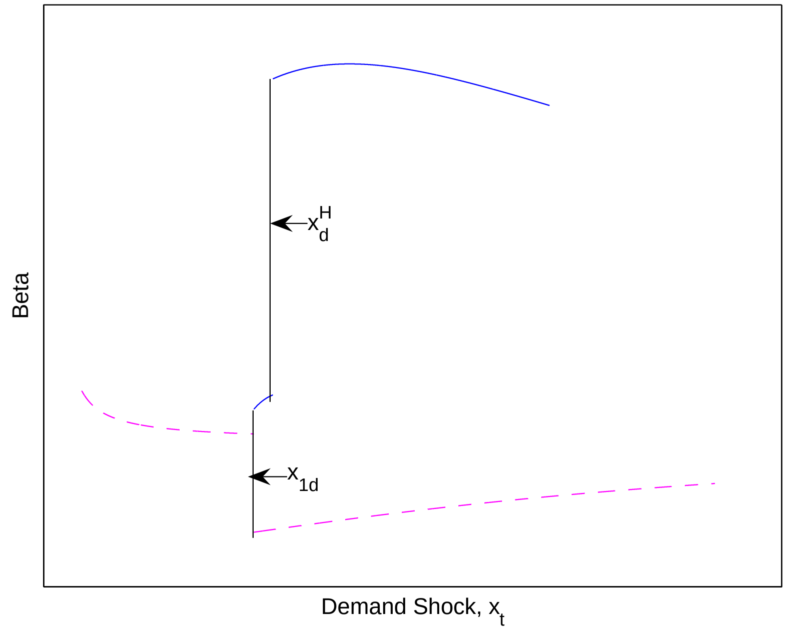

Figure 5: *Firm 1 and Firm L Risk When* $F_L < F_1 < F_H$ *and* $x_{1d} < x_{2r}^H$.

in firm risk. The same observations can be made in Panel B when firm 1 faces an H-type rival. In sum, option exercise manifests itself as jumps in firm risk.

Figure 5 compares firm 1 risk with that of type L firm risk when information revelation takes place in the no-dominance case. The solid curves depict the risk structure of firm 1 while the dashed curves indicate that of type L firm 2. Recall from Proposition 2 that firm 1 learns rival type through the revelation strategy at the duopoly exit trigger of the high-leverage firm, x_{2d}^H. Accordingly, firm 1 risk jumps at x_{2d}^H. As in Figure 4, rival action or inaction leads to a change in firm 1 risk. Type L firm 2 risk, on the other hand, follows a similar pattern observed in Figure 4. As the state variable approaches the exit trigger of firm 1, firm 2 risk declines. At the exit trigger

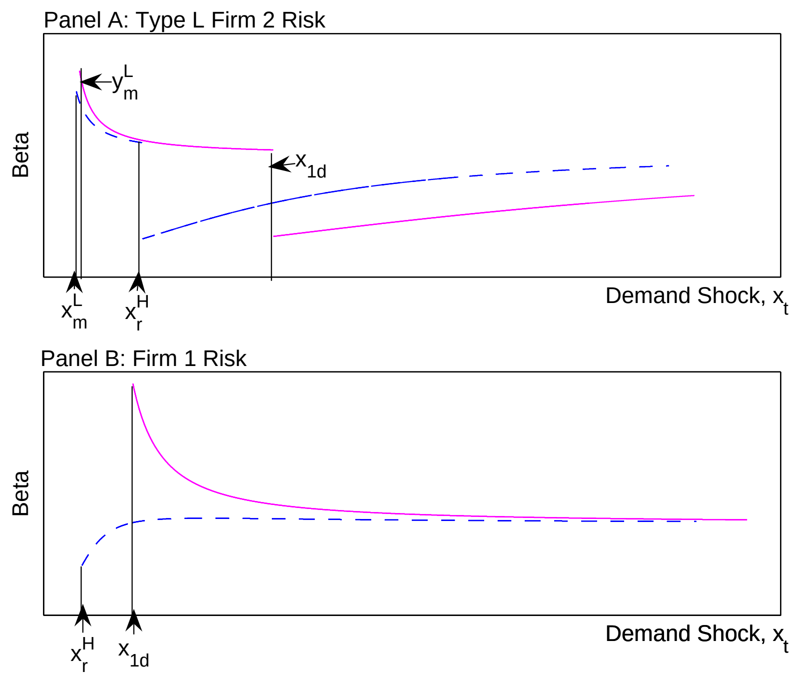

Figure 6: *Firm 1 and Firm L Risk with and without Signaling.*

of firm 1, firm 2 risk jumps upward.

Panels A and B of Figure 6 explore the risk structure of type L firm 2 and firm 1 in the signaling case, respectively. Recall that signaling takes place when $F_1 = F_H$ and expected firm 1 value from waiting in the market beyond its duopoly exit trigger exceeds that from leaving the market at x_{1d}. The dashed curves in both panels depict risk structure without signaling. In this case, type L firm 2 becomes a monopolist only at x_{2r}^H as opposed to x_{1d}. The risk dynamics are similar with and without signaling. Firm risk decreases as the state variable approaches the exit trigger and jumps at the trigger. Turning to firm 1 risk, one observes that for large values of demand shock, x_t, firm risk is similar with and without the signaling contract of type L firm. However, as the state variable approaches the respective exit triggers, firm risks diverge.

4 Conclusion

The empirical literature has shown the importance of the interaction between the capital structure choice and efficiency for a firm's product market behavior and the contraction and exit decisions. The evidence also suggests that aggregate factors such as business cycles and industry features play a crucial role as their impact differs across firms. This paper develops a model that brings all these features together and analyzes the product market competition with asymmetric information. The model illustrates how firm-specific factors such as the debt, the efficiency and the quality of information held about the rivals affect the exit decision in various competitive environments. The relative position of a firm in terms of debt and efficiency is an important determinant of the exit decision.

The model explains the role information asymmetry in the product markets. It shows that information asymmetry not only affects the outcome of the product market competition but also contributes significantly to the firm value and the risk dynamics. In particular, product market behavior carries valuable information that can potentially change investors' beliefs about a firm's future stream of cash flows. This, in turn, implies that the cross-section of average stock returns are sensitive to the competitors' product market policies.

Consistent with the empirical literature, the model predicts that a firm's total leverage is positively related to the probability of exit. The model distinguishes between the financial and the operating leverage. This distinction allows one to link the exit decision explicitly to its drivers. Specifically, the model shows that a relatively high level of debt can lead a firm to shut down sooner. This result is consistent with the evidence in Khanna and Tice (2005) and Zingales (1998). An important consequence of this result is that the rival firms' leverage imposes a constraint on a firm's capital structure choice. Furthermore, the model also generates a number of other predictions. First, it predicts that the incumbent firms' debt is expected to increase following the exit or the contraction of the rival firms. Second, the firms' debt levels are expected to move together over time as the rival firms' changes in their debt either tightens or relaxes the constraint on a firm's capital structure choice.

The model can be extended along several dimensions. A first step can be to incorporate the product market pricing. In the reduced form model of this paper, it is not clear how information asymmetry affects the pricing decisions. Such an extension would also generate empirical predictions that can be compared with the existing evidence in the literature. Second, the model has the potential to investigate the impact of other firm-specific features. Heterogeneous salvage values, for instance, would allow one to model how the possibility of fire sales relate to the exit decisions. The model assumes that a firm's ability to control its costs is the proxy for its efficiency. An alternative view of efficiency focuses on the firm's ability to generate cash flows from its asset base. Such alternative proxies can easily be incorporated into the model. Third, the distributional assumptions on the information asymmetry can be relaxed or information asymmetry can be assumed to be reciprocal. However, the qualitative results of the model are unlikely to change as a consequence. Finally, the capital structure choice in the model is a static decision of the firm. An interesting extension would be to characterize the changes in capital structure and link it to the product market competition.

Appendix

Appendix A. Proofs of Propositions

Proof of Proposition 1: To derive debt and equity values, I first value a generic contingent claim, $\phi(x)$, that promises its holder a net cash flow of $g(x)$. Then I relate this value to debt and equity values.

Assuming complete markets, the no-arbitrage condition yields:

$$r\phi dt = gdt + \mathbb{E}(d\phi) \tag{31}$$

Using Itô's lemma and taking expectations,

$$\frac{1}{2}\sigma^2 x^2 \phi^{''} + \mu x \phi^{'} - r\phi + g = 0 \tag{32}$$

The general solution to 32 is of the form:

$$\phi(x) = A_0 + A_1 x^{\lambda_1} + A_2 x^{\lambda_2} \tag{33}$$

where λ_1 and λ_2 are the roots of the following characteristic equation obtained by plugging in the conjectured solution into the 32:

$$\left.\begin{aligned} \lambda_1 &= \frac{1}{2} - \frac{\mu}{\sigma^2} + \sqrt{\left(\frac{1}{2} - \frac{\mu}{\sigma^2}\right)^2 + \frac{2r}{\sigma^2}} > 1 \\ \lambda_2 &= \frac{1}{2} - \frac{\mu}{\sigma^2} - \sqrt{\left(\frac{1}{2} - \frac{\mu}{\sigma^2}\right)^2 + \frac{2r}{\sigma^2}} < 0 \end{aligned}\right\} \tag{34}$$

In equation (33), A_0, A_1 and A_2 are constants to be determined from the boundary conditions.

To value debt, $D_k(x)$, note that the debt contract promises a constant payment of $c_k dt$ until the firm exits the market. Hence, $g(x) = c_k$. To obtain the coefficients in equation (33), impose the following boundary conditions:

$$\left.\begin{aligned} &\lim_{x\to\infty} D_k(x) = \frac{c_k}{r} \\ &D_k(x_k) = min[(1-\alpha)S, \tfrac{c_k}{r}] \end{aligned}\right\} \tag{35}$$

where $x_k, k = i, j$ is the trigger at which equityholders leave the market. Note that this trigger is exogenous from the perspective of debtholders. The first of the boundary conditions tells that as x_t tends to infinity, the value of debt approaches the present value of coupon payments discounted at the risk-free rate since for large x_t, the probability of an eventual exit diminishes. The second boundary condition regulates the behavior of debt value when the firm exits the market. Using these boundary conditions yields the debt value in equations (2) and (3).

Before deriving equity value, it is useful to obtain an expression for the portion of salvage value equityholders retain upon exit. The second boundary condition in (35) indicates that if $min[(1-\alpha)S, \frac{c_k}{r}] = \frac{c_k}{r}$, then the resale value of assets is sufficiently high so that equityholders retrieve the value $(1-\alpha)S - \frac{c_k}{r}$, which, in turn, implies $\omega_k(c_k) = (1-\alpha) - \frac{c_k}{rS}$. If, on the other hand, $min[(1-\alpha)S, \frac{c_k}{r}] = (1-\alpha)S$, then the salvage value accrues to debtholders and equityholders receive nothing upon exit. In this case, $\omega_k(c_k) = 0$.

Now consider the equity value of the firm that leaves the market first, firm j. In this case, $g(x) = \pi x - F_j$. To solve the differential in (32), impose the following boundary conditions:

$$\left.\begin{array}{l} \lim_{x\to\infty} E_j(x) = \dfrac{\pi x}{r-\mu} - \dfrac{F_j}{r} \\ E_j(x_{jd}) = \omega_j(1-\alpha)S \\ \dfrac{\partial E_j(x_{jd})}{\partial x} = 0 \end{array}\right\} \tag{36}$$

The first of the boundary conditions is similar to that described for the debt value. The second boundary condition is the so-called value-matching condition which states that at the point of exit, equity value is simply equal to the salvage value recovered by equityholders. The third condition is the smooth-pasting condition that ensures the optimality of the exit trigger. Solving equation (32) subject to the boundary conditions in (36) gives the equity value in (4) and the exit trigger in (5).

To derive $E_{id}(x)$ in equation (8), impose the following boundary conditions:

$$\lim_{x\to\infty} E_{id}(x) = \frac{\pi x}{r-\mu} - \frac{F_i}{r} \tag{37}$$

$$E_{id}(x_{jd}) = E_{im}(x_{jd}) \tag{38}$$

Note that in equation (38), the duopoly equity value of firm i is partly determined by the action its rival takes. This is captured by the second boundary condition. At x_{jd}, firm j leaves the market, which entitles firm i to monopoly profits. Hence, the second boundary condition ensures that equity value is continuous by equating $E_{id}(x)$ to $E_{im}(x)$ at x_{jd}. After firm

j has exited the market, firm i becomes a monopolist and its value satisfies again equation (32) with the following boundary conditions:

$$\lim_{x\to\infty} E_{im}(x) = \frac{\Pi x}{r-\mu} - \frac{F_i}{r} \tag{39}$$
$$E_{im}(x_{im}) = \omega_i S \tag{40}$$
$$\frac{\partial E_i(x_{im})}{\partial x} = 0 \tag{41}$$

Solving equations (32), (38) and (41) delivers the third part of Proposition 1.

Proof of Proposition 2: Before deriving the perfect Bayesian equilibrium (PBE), it is useful to describe the game in more detail. The game can be modelled as a dynamic game of incomplete information in which the informed firm 2 sends a signal to the uninformed firm 1 by either exiting or staying in the market at the duopoly exit trigger of an H type firm, x_{2d}^H. In the sequel, let $M = \{m_{2L}, m_{2H}\}$ denote the set of signals sent by the type L and type H firm 2, respectively. Hence, the set $M = \{ne, e\}$, for instance, corresponds to a setting in which a type L firm does not exit at x_{2d}^H but an type H firm does.

Firm 1's strategy space maps the signal sent by firm 2 to its action space. Let $A = \{a_{ne}, a_e\}$ denote the action taken by firm 1 upon observing no exit (a_{ne}) and exit (a_e) at the duopoly trigger x_{2d}^H. Once firm 1 observes rival firm behavior at x_{2d}^H, it chooses whether to exit at its duopoly trigger, x_{1d}, or the monopoly trigger, x_{1m}.

The next step is to define the conditional probabilities firm 1 uses upon observing firm 2's signal. Let r denote the probability that the rival firm is type L given that no exit has occurred at x_{2d}^H. Similarly, s denotes the conditional probability of an L type rival when firm 2 exits at x_{2d}^H.

Let $\tau_H = inf\left\{\ t : x_t = x_{2d}^H\right\}$ be an adapted stopping time denoting the time at which the state variable first hits x_{2d}^H. Consider the following strategy for firm 1: (a) wait until $x_{\tau_H} = x_{2d}^H$, (b) if at $x_{\tau_H} = x_{2d}^H$, firm 2 has not exited, leave the market at x_{1d}, (c) otherwise exit the market at x_{1m}. In other words, firm 1 plays $A = \{x_{1d}, x_{1m}\}$. I now determine firms' best responses to each other under this scheme and argue that these best responses constitute the dominant strategies for each firm.

(1) First, consider type H firm 2. Since $F_1 < F_H$, by the strict monotonicity of the reservation triggers in the fixed costs, firm 1 can make a credible threat to type H firm 2 by holding on until $x_{1r} < x_{2r}^H$. Note also that type H firm 2 cannot mimic type L firm 2 since this requires that type H firm 2 wait credibly at least until x_{1d}. But $x_{1d} < x_{2r}^H$ by assumption. Hence, type H firm 2 would always leave the market at its duopoly trigger, x_{2d}^H. In other words, playing x_{2d}^H is a dominant strategy for the H type firm.[15]

Now, consider type L firm 2. Since we have $x_{2r}^L < x_{1r}$ no matter what strategy firm 1 follows, the best response of type L firm 2 would be to leave the market at its monopoly trigger, x_{2m}^L. Hence, exiting at x_{2m}^L is a dominant strategy for a type L firm 2. Note that the ongoing discussion implies the types play a separating strategy and hence, $r = 1$ and $s = 0$.

(2) We now argue that the above profile outlined for firm 1 is the best response to firm 2 strategies. Observe that for $x_t > x_{2d}^H$, firm 1 does not commit itself to any strategy. Suppose now that $x_{\tau_H} = x_{2d}^H$. Since regardless of firm 1 strategy, type H(L) firm 2 will leave the market at its duopoly (monopoly) trigger, firm 1 finds out firm 2 type by observing firm 2 action at x_{2d}^H. If firm 2 has exited, firm 1 finds out that the competitor is of type H and leaves the market at x_{1m} by Proposition 1. If no exit has occurred at this point, firm 1 deduces that the competitor is of type L and thus exits at x_{1d}. Not only is $\{x_{1d}, x_{1m}\}$ the best response to firm 2 strategies but it is also the dominant strategy for firm 1. To see why, note that if the rival firm exits at x_{2d}^H, playing x_{1m} dominates x_{1d} by Proposition 1. If firm 2 has not exited at x_{2d}^H, playing x_{1d} dominates playing x_{1m} since by assumption $x_{1d} < x_{2r}^H$ and only an L type firm would remain in the market for $x_t < x_{2r}^H$. In this case, since an L type firm plays its dominant strategy of x_{2m}^L, firm 1 would exit at $x_{1d}, \forall r \in [0, 1]$.

Hence, the firms play their respective dominant strategies and the set $\{\{ne, e\}, \{x_{1d}, x_{1m}\}, r = 1, s = 0\}$ constitute a PBE.

Proof of Proposition 3: The structure of the game is similar to the one described for Proposition 2. Note, however, that although the signal space remains the same as in Proposition 2, the action space for firm 1 now depends on the signal sent by firm 2. If firm 1 has observed exit at x_d^H, its decision is to choose whether to exit at x_{1d} or at x_{1m}. On the other hand, if firm 1 observes no exit behavior at x_d^H, it decides whether to exit when x_t hits x_{1d}, or to wait until x_r^H in order to reveal rival firm type. As in Proposition 2, however, if firm 2 exits at x_{2d}^H, playing x_{1m} is the dominant strategy for firm 1. Therefore, in the sequel, I only consider firm 1 strategies of the form $\{a_{ne}, x_{1m}\}$.

Consider the case in which firm 2 has not exited at x_{2d}^H. We ask whether there exists a belief, r, that justifies firm 1's exit at the duopoly trigger x_{1d}, thereby leading a type H firm 2 to become a monopolist.[16]

Consider the strategy $\{x_{1d}, x_{1m}\}$ for firm 1. The expected payoff from this strategy is $E_{1d}(x)$ given in equation (4) since an L type rival would play

[15] It might happen that an H type firm trembles and does not leave at x_{2d}^H. But in this case, the dominant strategy for the H type firm would be to leave the market at $x_{2d}^H - \epsilon, \epsilon > 0$.

[16] Recall that the working assumption is $x_{2r}^H \leq x_{1d}$. Therefore, it pays the H type firm to hold on to the market until firm exits at x_{1d} to capture monopoly rents.

its dominating strategy of leaving at x_{2m}^L and an H type competitor would prefer to stay in the market beyond x_{1d} since $x_{1d} \geq x_{2r}^H$ by assumption.

Now consider the strategy $\{x_{2r}^H, x_{1m}\}$. If firm 1 faces an L type rival, firm 2 would not exit at x_{2r}^H and firm 1 would exit the market at x_{2r}^H as a duopolist. Hence its value would be $E_{1d}(x; x_{2r}^H)$ where the value function is as given in equation (4) but with the exit trigger x_{1d} replaced with x_{2r}^H. On the other hand, an H type rival would exit by $x_{2d}^H - \epsilon, \epsilon > 0$ to cut its losses. This yields the value $E_{1d}^H(x)$ given in equation (8). Hence, the expected equity value from this strategy is:

$$rE_{1d}(x; x_{2r}^H) + (1-r)E_{1d}^H(x) \tag{42}$$

Given the above expected values, firm 1 would perefer to leave at x_{1d} if $E_{1d}(x)$ is greater than the expression in (42). Manipulating this expression then yields:

$$r \geq \frac{E_{1d}^H(x) - E_{1d}(x)}{E_{1d}^H(x) - E_{1d}(x; x_{2r}^H)} \tag{43}$$

If firm 1 plays the above strategy, the best response of an L type firm 2 is to play its dominant strategy of x_{2m}^L while an H type firm plays x_{2m}^H since $x_{2r}^H \leq x_{1d}$ by assumption. This implies that firm 1's updated beliefs about an L type firm after observing no exit at x_{2d}^H, r, is given by the anterior probability p. Hence, the profile $\{\{ne, ne\}, \{x_{1d}, x_{1m}\}, r = p\}$ would constitute a pooling PBE if p satisfies equation (16).

Proof of Proposition 4: To prove part (i) of the proposition, distinguish between three cases depending on whether firm 2 types play separating or pooling strategies.

(1) Suppose that both types play x_d^k, $k = L, H$, that is, both types exit at their respective duopoly triggers. Since $x_{1m} \leqslant x_{1r} \leqslant x_{1d} < x_d^k$, $k = L, H$, firm 1 prefers to stay until its monopoly trigger. That is, exiting at the monopoly trigger, x_{1m}, is the best response of firm 1. This is easy to see. Once firm 2 leaves the market at its duopoly trigger, firm 1 becomes the monopolist. Proposition 1 shows that when firm 1 is a monopolist, it maximizes its value if it waits until x_{1m}. Now suppose that firm 1 indeed stays until x_{1m}. As argued above, firm 2 would be willing to incur losses until x_r^k to become a monopolist. However, by the strict monotonicity of reservation triggers in the firm leverage, firm 1 can make a credible threat to firm 2 by holding on to the market until x_{1r}. Given this, firm 2 would cut its losses and exit at the duopoly threshold. Hence the above profile constitues a fixed point and is therefore an PBE.

(2) Assume now that both types of firm 2 play x_m^k. It is evident that if $x_{1r} < x_m^k$ and/or $x_{1d} < x_r^k$, firm 2 would never play x_m^k, since firm 1 in either case can hold on to the market longer than its competitor. However, even if $x_{1m} < x_r^k < x_{1d}$, [17] by the strict monotonicity of x_{ir} in F_i, we have $x_{1r} < x_r^k$, $k = L, H$. That is, firm 1 can again hold out longer than firm 2 to reap off monopoly profits. Hence, the best response of firm 1 is to stay until x_{1m}. But since the best response of type k firm 2 is to exit at x_d^k, there cannot be any equilibrium with firm 1 leaving first when both types of firm 2 play x_m^k.

(3) It could also be that type L firm plays x_{2m}^L and type H plays x_{2d}^H and vice versa. However, the arguments in (2) establish that as long as $x_{1r} < x_r^k$, firm 1 can always outlast firm 2 no matter what type it is. Therefore, there cannot be any equilibrium involving firm 1 leaving first when types play separating strategies.

It is straightforward to prove part (ii) of the proposition using the same arguments as in part (i). The proof again rests on the strict monotonicity of the reservation triggers in the fixed costs.

[17] That is, firm 2 could hold out until the duopoly trigger of firm 1 if it could become the monopolist.

Appendix B. Parameter Values

Table 1: *Parameter Values for Figures 2-6*

Parameter	Figure 2		Figure 3	Figure 4	Figure 5	Figure 6
	Panel A&B	Panel C				
μ	0.01	0.01	-0.01	0.01	-0.01	0.01
σ	0.20	0.20	0.20	0.20	0.40	0.30
r	0.05	0.05	0.05	0.05	0.05	0.05
α	0.05	0.05	0.05	0.05	0.05	0.05
Π	2	2	2	2	5	5
π	1	1	1	1	1	1
S	20	20	20	20	20	20
f_1	2	3.5	2	1	2	2
c_1	2	2	4	1	3.5	5
f_L	1.5	2	1	2	1	1
f_H	2.5	3	2	4	2	3
c_2	4	3	4	3	4	4

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