Predation and Self-Defense:
Feedback and Contagion through Distressed Competition

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Abstract

Firms tend to compete on prices more aggressively when they are in financial distress; the intensified competition in turn reduces firms' profit margins, pushing them further into distress. Competitors' aggressive pricing reactions could be attributed to both predatory and self-defensive incentives. To quantify the effects of competition-distress feedback and financial contagion, as well as disentangle the predation from self-defense, we incorporate supergames of price competition into a model of long-term debt and strategic default. Incorporating distressed competition into asset pricing models can explain various market phenomena that otherwise seem puzzling. Depending on the heterogeneity in customer bases and financial conditions across firms in an industry as well as between incumbents and new entrants, firms can exhibit a rich variety of strategic interactions, including predation, self-defense, and collaboration. Finally, we provide empirical support for our model's predictions.

Keywords: Asset Pricing, Credit Spreads, Tacit Collusion, Market Power, Financial Distress, Gross Profitability Premium.
JEL: G12, L13, O33, C73

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1 Introduction

Product markets are often highly concentrated, and strategic competition among market leaders plays a vital role in determining industry profitability and dynamics (e.g. Grullon, Larkin and Michaely, 2018; Loecker and Eeckhout, 2019; Autor et al., 2019).[1] Moreover, the large market leaders account for a major fraction of fluctuation in aggregate output growth (e.g., Gabaix, 2011). On the one hand, firms' strategic behavior in imperfect product markets is highly endogenous and has important asset pricing implications. On the other hand, the competition intensity and pricing behavior are endogenously affected by firms' financial constraints and distress (see, e.g., Frésard, 2010; Koijen and Yogo, 2015; Gilchrist et al., 2017; Cookson, 2017, for recent empirical works).[2]

However, little is known about how strategic competition and financial distress dynamically interact, especially how such interaction depends on the industry structure, firms' capital structure, as well as the macroeconomic conditions. The main contribution of our paper is to investigate these questions systematically and quantitatively through the lens of a dynamic model that incorporates supergames of strategic price competition into the canonical framework of long-term bonds with default risk (see Leland, 1994).

In particular, we contribute to the literature in three ways. First, our dynamic model generates positive competition-distress feedback effects and financial contagion effects through imperfect product markets, and both of them lead to financial instability. Second, our model advances the understanding of important questions in industrial organization: when do firms aggressively cut their product prices, exhibiting predation-like behavior? How much of predation-like behavior is due to real predatory incentives rather than self-defensive incentives (e.g., Besanko, Doraszelski and Kryukov, 2014)? We provide a quantitative evaluation of real predatory incentives by decomposing the predation-like behavior in the presence of financial distress. Third, our theory also implies a novel amplification effect of competition-distress feedback on industry risk exposure through which the gross profitability premium puzzle can be explained.

Intuitively, a firm's incentive to collude with its peers in setting profit margins depends on how much its managers value the cooperation and profits in the future, following the idea of Fudenberg and Maskin (1986)'s "Folk theorem". When the industry is hit

[1] According to the U.S. Census data, the top four firms within each 4-digit SIC industry account for about 48% of the industry's total revenue (see Dou, Ji and Wu, 2020, Online Appendix B). Further, the strategic pricing competition is prevalent since the market leading position is highly persistent (e.g., Geroski and Toker, 1996; Matraves and Rondi, 2007; Sutton, 2007; Bronnenberg, Dhar and Dubé, 2009).

[2] See, e.g., Corhay, Kung and Schmid (2017) and Dou, Ji and Wu (2020) for studies on the asset pricing implications, and Bolton and Scharfstein (1990), Chevalier (1995), and Chevalier and Scharfstein (1996) for early seminal works on the effects of financial conditions on product-market behavior.

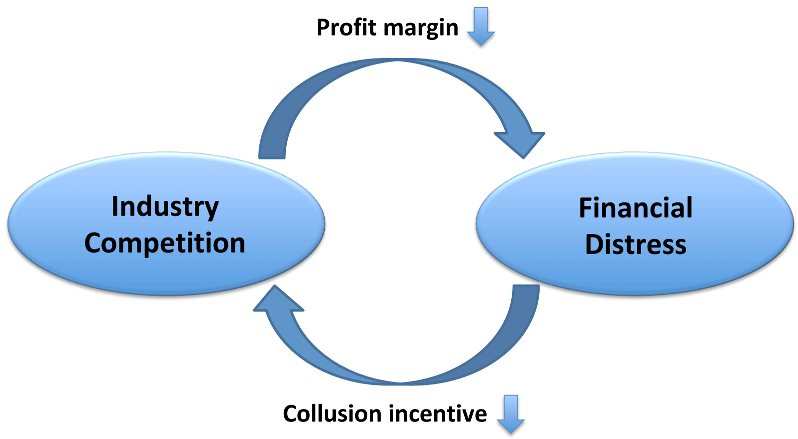


Figure 1: Positive feedback loop between industry competition and financial distress.

by adverse aggregate cash-flow shocks, all firms become more financially distressed and effectively more impatient due to the higher risk of bankruptcy. As a result, the present value of future cooperation decreases, suppressing firms' collusion incentive. When each firm's deviation motive grows, all firms in the industry understand that high collusive profit margins can no longer be sustained, and thus all of them start to undercut each other's profit margins aggressively, exhibiting predation-like behavior. As an equilibrium outcome, the industry competition is endogenously intensified and profit margins drop significantly, making firms more financially distressed. Crucially, the heightened financial distress in turn makes firms more impatient, thereby suppressing firms' collusion incentive even further. Taken together, predation-like behavior emerges following adverse aggregate cash-flow shocks because there is positive feedback loop between industry competition and financial distress (see Figure 1), which raises firms' credit risk ex ante.

In addition to the positive feedback channel above, there is another important financial contagion channel through which the dynamic interaction between strategic competition and financial distress affects industry dynamics. Suppose a market leader, labeled as A, in an industry is leveraged and hit by an adverse idiosyncratic shock, which worsens its financial condition and makes it more financially distressed. As a result, firm A becomes effectively more impatient and behaves more aggressively by undercutting its profit margins in the product market. In response, firm A's competitor, labeled as B, has to narrow the profit margin accordingly in order to protect its short-run demand and customer base, self-defending against the aggressive profit-margin undercutting of firm A. Being forced to reduce the profit margin, firm B becomes more financially distressed due to the initial idiosyncratic shock to firm A (see Figure 2). The higher

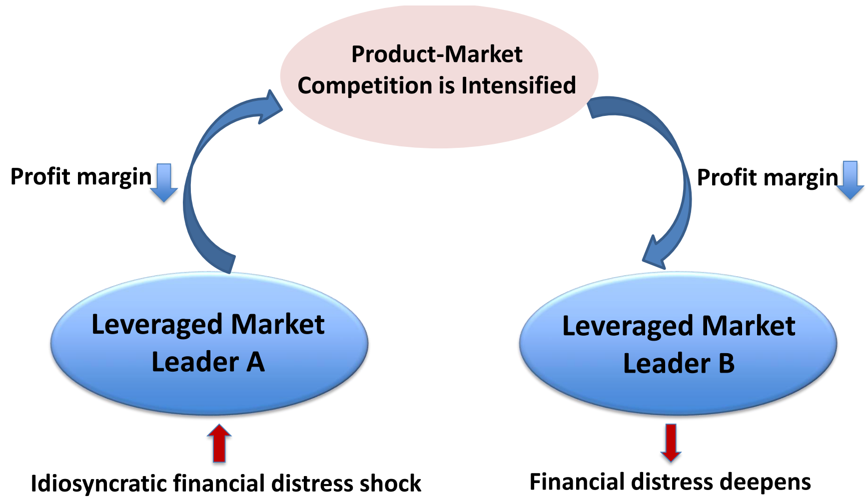


Figure 2: Financial contagion through endogenous competition in product markets.

financial distress of firm B makes it more impatient, motivating it to further undercut the profit margin, which in turn compromises firm A's initial efforts of narrowing profit margins to boost short-run demand. In fact, the predation-like behavior of firm B could be mainly due to self-defensive rather than predatory incentives, though it pushes firm A towards bankruptcy in effect; this is because firm B also becomes more financially distressed after lowering its profit margin. Therefore, similar to the competition-distress feedback channel, the contagion effect, due to either self-defensive or predatory incentives, also adversely raises firms' credit risk ex ante.

To study the quantitative effects of such competition-distress feedback and contagion, we incorporate dynamic games of price competition into an industry equilibrium model with time-varying macroeconomic conditions captured by the fluctuations in discount rates. The industry features a dynamic Bertrand duopoly with differentiated products and tacit collusion (Tirole, 1988, Chapter 6). Consumers have relative deep habits (Ravn, Schmitt-Grohe and Uribe, 2006) over firms' products, which are embodied in customer base. Therefore, firms find it valuable to maintain their customer base. Firms' cash flows are endogenously determined by their product prices and customer base. Shareholders issue consols which promise a perpetual coupon payment to debtholders.

Duopolisits can implicitly collude with each other on setting high product prices and obtaining high profit margins.[3] Knowing that the competitor will honor the collusive

[3]Collusion is pervasive among leading competitors in industries. John Connor's Private International Cartels Dataset (see Connor, 2016) shows that during 1990-2016, 953 cartels were convicted of price fixing and 296 suspected cartels were under investigation. The estimated cartel overcharges since 1990 exceed $1.5 trillion. The majority of the corporate cartelists were from Europe or North America. More importantly, besides explicit collusion, firms also engage, even more pervasively, in tacit collusion. For

profit-margin scheme, a firm can boost up its short-run revenue by undercutting profit margins to attract more customers; however, deviating from the collusive profit-margin scheme may reduce revenue in the long run if the profit-margin undercutting behavior is detected and punished by the competitor. Following the literature (e.g., Green and Porter, 1984; Brock and Scheinkman, 1985; Rotemberg and Saloner, 1986), we adopt the non-collusive Nash equilibrium as the incentive-compatible punishment for deviation. The implicit collusive profit margins depend on firms' deviation incentives: a higher collusive profit margin can only be sustained by a lower deviation incentive, which is further determined by firms' intertemporal trade-off between short- and long-run cash flows.

Our model yields several main implications. First, there exists a positive feedback loop between competition and financial distress. When firms become more financially distressed, default risk rises. The heightened default risk makes competition more fierce because firms find it more difficult to collude with each other. Intuitively, when default risk rises, the firm becomes more impatient and values its cash flows in the short run more than those in the long run. This renders the punishment for deviation less threatening, incentivizing the firm to undercut its competitor's profit margin and thus intensifying competition. The increased competition results in lower profit margins, further amplifying financial distress and default risk.

Second, our model generates financial contagion among competitors within an industry through the product market competition channel. More precisely, when one leading firm is disturbed by idiosyncratic adverse shocks and forced into financial distress, it will start to behave aggressively in the product market in hopes of gaining higher short-run cash flows to survive. However, the price-undercutting behavior of the financially distressed firm will push financially strong firm to undercut prices, narrow its profit margins, and even trigger price wars. As a result, the financial condition of the competitors in the same industry is also weakened.

Third, predation-like behavior emerges endogenously as an equilibrium outcome of collusion. Due to the competition-distress feedback and financial contagion, the financially strong firm in an industry significantly cuts its price following both adverse

example, Bourveau, She and Zaldokas (2019) show that firms can use corporate disclosure to facilitate tacit coordination. He and Huang (2017) show that institutional cross-ownership can facilitate firms in tacitly colluding and better collaborating with each other in product markets. González, Schmid and Yermack (2019) show that managers have incentives to engage in price fixing as they enjoy greater job security and higher compensation. Managers also actively use concealment strategies to limit detection of cartel membership. Byrne and de Roos (2019) provide evidence on how collusive agreements are initiated. Based on a unique dataset that contains the universe of station-level prices for an urban market, they find that market leaders use price experiments to test rivals' willingness to collude and signal their intentions, leading to price coordination and enhancing profit margins.

aggregate cash-flow shocks and adverse idiosyncratic shocks to the financially weak competitor. Such predation-like behavior could reflects both the self-defensive and predatory incentives of the financially strong firm (Besanko, Doraszelski and Kryukov, 2014). The self-defensive incentives refer to price-undercutting for the benefits of acquiring competitive advantage (i.e., pricing for efficiency), whereas the predatory incentives refer to price-undercutting for the benefits of preventing rival firms from acquiring competitive advantage (i.e., pricing for eliminating rivals). As argued by Fisher (2001), the self-defensive incentives are better described by defensive predation whereas the real predatory incentives are better described by offensive predation. We use our calibrated model to theoretically isolate and quantify a firm's predatory incentives by decomposing the equilibrium product-market pricing conditions.

Importantly, in industries with a sufficiently high entry barrier, our model can generate endogenous price wars, a phenomenon where the two firms abandon collusive agreement and switch to the non-collusive equilibrium. During the price war, the financially strong firm significantly cuts its profit margin, reflecting its strong predatory incentives. By starting a price war against its financially weak competitor, the strong firm can push its weak competitor further into financial distress, driving it out of the market and enjoying the monopoly rent in the future. However, such price-war phenomena can disappear or be substantially weakened once we allow for new entries to the industry.

Forth, we shed light on the asset pricing implications of predation-like behavior caused by endogenous competition-distress feedback. On the one hand, we show that there is an amplification effect on the industry's exposure to aggregate discount-rate shocks owing to the competition-distress feedback. On the other hand, our model implies that industries with higher gross profitability are associated with higher equity returns but lower credit spreads. In a related paper, Dou, Ji and Wu (2020) build a model with endogenous market power risk like our model, but focus on all-equity firms. They show that the gross profitability premium cross industries can be explained by the heterogeneous persistence of market leadership and the endogenous market power risk. Our paper extends their framework by allowing the interaction between strategic competition and financial distress, which amplifies the effect of endogenous market power risk studied by Dou, Ji and Wu (2020); more importantly, our model can explain the joint patterns of equity returns and credit spreads associated with gross profitability, which is generally viewed as a strengthened version of gross profitability premium puzzle.

While our contribution is mainly theoretical, we empirically test the main predictions of our model and find strong evidence that supports the theoretical implications.

Related Literature. Our paper contributes to the growing literature on feedback effects between the capital markets and real economy. Understanding the feedback effects has become particularly relevant in the light of the recent financial crisis. There are two major classes of channels for the feedback effects — the fundamental-based and information-based channels. Seminal examples of the fundamental-based channel include Bernanke and Gertler (1989) and Kiyotaki and Moore (1997), demonstrating how adverse selection or moral hazard problems cause frictions for the firms to raise external funding. Particularly, when the financing constraint is price dependent, there is an adverse feedback loop: firms are more financially constrained and thus forced to reduce real investment and hiring, and this in turn makes firms more financially constrained. Dou et al. (2020*b*) provide a recent survey for this class of macro-finance models. As emphasized by Bond, Edmans and Goldstein (2012), the fundamental-based channel is about primary financial markets, and the feedback effect between secondary financial markets and real economy is also crucial yet mainly through the information-based channel (e.g., Chen, Goldstein and Jiang, 2006; Bakke and Whited, 2010; Edmans, Goldstein and Jiang, 2012). This paper introduces a novel fundamental-based feedback channel — the feedback effect between imperfect capital markets and imperfect product markets as a result of predation incentives and predation-like behavior (i.e. self-defense incentives).

Financial contagion also takes place through two major classes of channels — the fundamental-based and information-based channels (see Goldstein, 2013). The fundamental-based channel is through real linkages between economic entities, such as common (levered) investors (e.g., Kyle and Xiong, 2001; Kodres and Pritsker, 2002; Kaminsky, Reinhart and Végh, 2003; Martin, 2013; Gârleanu, Panageas and Yu, 2015) and financial-network linkages (e.g., Allen and Gale, 2000; Acemoglu, Ozdaglar and Tahbaz-Salehi, 2015). Contagion can also work through self-fulfilling beliefs (e.g., Goldstein and Pauzner, 2004). This paper proposes a novel product-market competition channel through which financial distress becomes contagious among product-market peers.

Our paper contributes to the large and growing literature on the structural model of corporate debt and default (see Merton, 1974; Leland, 1994, for the seminal benchmark framework). Sundaresan (2013) provides a comprehensive review on this literature. Particularly, Fischer, Heinkel and Zechner (1989), Leland and Toft (1996), Anderson and Sundaresan (1996), Goldstein, Ju and Leland (2001), DeMarzo and Sannikov (2006), Broadie, Chernov and Sundaresan (2007), and DeMarzo and Fishman (2007), among others, study dynamic theory of capital structure. Specifically, Hackbarth, Miao and Morellec (2006), Chen, Collin-Dufresne and Goldstein (2008), Bhamra, Kuehn and Strebulaev (2010*a*,*b*), Chen (2010), and Chen et al. (2018) focus on the impact of macroeconomic conditions on firms' financing policies, credit risk, and asset prices. Further, Anderson and Carverhill (2012) and Bolton, Wang and Yang (2019) focus on the impact of financial flexibility on firms' capital structure dynamics. Existing dynamic models of capital structure and credit risk typically assume that the product market offers exogenous cash flows unrelated to firms' debt-equity positions or corporate liquidity conditions. Our model differs from those in this literature by explicitly considering an oligopoly industry in which firms' strategic price competition generates endogenous cash flows. This allows us to jointly study firms' financial decisions in the financial market and their markup-setting decisions in the product market, as well as the interactions. Like ours, Brander and Lewis (1986) and Corhay (2017) also develops a model in which firms' cash flows are determined by strategic competition in the product market. The key difference is that our model incorporates a dynamic supergame of Bertrand competition. Therefore, our model predicts that the degree of product market competition endogenously varies with macroeconomic conditions and corporate financial conditions, providing an amplification mechanism on credit risk through a competition-distress feedback channel.

Our paper is also related to the literature highlighting the importance of customer base in determining profit margins (e.g., Phelps and Winter, 1970; Rotemberg and Woodford, 1991, 1992; Ravn, Schmitt-Grohe and Uribe, 2006; van Binsbergen, 2016). In a seminal work, Ravn, Schmitt-Grohe and Uribe (2006) provide a micro-foundation for customer market based on consumers' deep habits, which can generate countercyclical markups. Our model differs from these models by focusing on oligopoly industries with endogenous leverage and default decisions – we emphasize the collusive equilibrium of dynamic strategic price competition and its interaction with firms' financial conditions.

Our paper also contributes to the emerging literature on the impact of industry competition and customer market on financial decisions and valuations. Titman (1984) and Titman and Wessels (1988) provide the first piece of theoretical insight into and empirical evidence on the impact of product market characteristics on a firm's financial decisions. Specifically, Banerjee, Dasgupta and Kim (2008) and Hoberg, Phillips and Prabhala (2014), and D'Acunto et al. (2018) empirically investigate the effect of industry competition and customer base on firms' leverage decisions. Moreover, Dumas (1989), Kovenock and Phillips (1997), Grenadier (2002), Aguerrevere (2009), Back and Paulsen (2009), Hoberg and Phillips (2010), Hackbarth and Miao (2012), Gourio and Rudanko (2014), Hackbarth, Mathews and Robinson (2014), Bustamante (2015), Dou et al. (2019), and Dou and Ji (2019) investigate the implication of industry competition and customer base on various corporate policies such as investment, cash holdings, mergers and acquisitions, and entries and exits. Finally, there is a growing literature on the implication of strategic industry competition on firms' valuation and equity returns (e.g., Aguerrevere, 2009; Opp, Parlour and Walden, 2014; Bustamante, 2015; Corhay, Kung and Schmid, 2017; Dou, Ji and Wu, 2020). Our model highlights the dynamic interaction of endogenous competition and financial distress, generating competition-distress feedback effects and financial contagion effects, which are new to the literature.

Our paper is also related to the burgeoning literature on how financial characteristics influence firms' performance and decisions in the product market. In the early seminal works, Titman (1984) and Maksimovic and Titman (1991) study how capital structure affects a firm's choice of product quality and the viability of its products' warranties. Brander and Lewis (1986) focuses on the "limited liability" effect of short-term debt financing on product competition behavior. Bolton and Scharfstein (1990) show that financial constraints give rise to rational predation behavior. Jacob (1994) focuses on the role of long-term debt and shows that the accumulated profit is important in determining product market behavior. In Allen (2000), greater debt increases the probability of bankruptcy and liquidation which is costly, and thus, higher leverage will be associated with less aggressive product market behavior subsequently. Phillips (1995) empirically investigates whether a firm's capital structure affects its own and its competitors' output and product pricing decisions. Chevalier and Scharfstein (1996) and Gilchrist et al. (2017) show both in model and data that liquidity-constrained firms tend to set higher markups to increase their short-term cash flows. Hoberg and Phillips (2016) investigate how R&D expenses affect product market competition behavior, and Hackbarth and Taub (2018) study how M&A activities affect product market competition behavior. Banerjee et al. (2019) document evidence of rival firms conducting predatory advertising and predatory pricing (i.e., decrease in profit margins) when major firms commit financial frauds. They show that this effect is particularly stronger when the fraud firm has higher leverage and when the rival firms have lower leverage. Opp, Parlour and Walden (2014) and Dou, Ji and Wu (2020) show that the time-varying discount rates affect firms' collusion incentive and thus their market power. Different from the existing works, our paper combines Brander and Lewis (1986) and Dou, Ji and Wu (2020), and then extends the hybrid to a dynamic Leland framework with long-term debt with endogenous default, customer base accumulation, and dynamic strategic competition allowing for collusive behavior.

There is an extensive industrial organization (IO) literature that attempts to rationalize predatory pricing as an equilibrium phenomenon by means of reputation effects (e.g., Kreps and Wilson, 1982), informational asymmetries (e.g., Fudenberg and Tirole, 1986), financial constraints (e.g., Bolton and Scharfstein, 1990), or learning-by-doing (e.g., Cabral and Riordan, 1994; Snider, 2008; Besanko, Doraszelski and Kryukov, 2014). To fix idea, our model forgoes these features and focuses on the interaction between predatory pricing and financial distress. Our numerical analysis nevertheless reveals the widespread existence of equilibria involving behavior that resembles conventional notions of predatory pricing in the sense that aggressive pricing in the short run is associated with reduced competition in the long run. More importantly, the full-blown price war endogenously breaks out when the predatory incentives dominate. The predation price war would happen when the financial condition is very imbalanced among the competitors and the entry threat is very weak. One of our contribution to the IO literature is to show that we can isolate a firm's predatory incentives by structurally decomposing the equilibrium pricing condition. Our structural decomposition is reminiscent of that of Besanko, Doraszelski and Kryukov (2014) but extends to the complex strategic competition-distress interactions that arise in the non-Markov (collusive) equilibrium of a supergame. Our decomposition corresponds to the common practice of antitrust authorities to question the intent behind a business strategy: Is the firm's aggressive pricing behavior primarily driven by the benefits of acquiring competitive advantage or by the benefits from preventing the rival from acquiring competitive advantage or overcoming competitive disadvantage? The predatory motive maps into the first set of benefits and the self-defensive motive into the second set.

2 The Baseline Model

We develop a dynamic industry-equilibrium model of default with long-term bonds and time-varying market prices of risk. The industry has two firms, referred to as market leaders, indexed by $i \in \{1, 2\}$ and many followers with measure zero; so each industry is essentially a duopoly. We label a generic firm by i and its competitor by j.

2.1 Product Market Structure

Industry Demand. Similar to the seminal works of Hopenhayn (1992), Pindyck (1993), and Caballero and Pindyck (1996), we focus on the industry equilibrium by specifying the industry demand $C_t = \mathcal{D}(P_t)$ as a function of the price index of the industry composite. Specifically, we assume an isoelastic industry demand curve:

$$C_t = M_t P_t^{-\epsilon}, \tag{1}$$

where M_t is an endogenous variable that captures the total customer base in the industry. The evolution of M_t is determined by the demand for the goods produced by firms in the industry as well as industry- and firm-level "taste" shocks. The coefficient ϵ captures the industry's short-run price elasticity of demand.

Firm-level Demand. The demand for the industry composite C_t consists of firm-level differentiated goods through a Dixit-Stiglitz CES aggregation. In particular, the industry composite C_t is given by,

$$C_t = \left[\sum_{i=1}^{2}\left(\frac{M_{i,t}}{M_t}\right)^{\frac{1}{\eta}} C_{i,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \text{ with } M_t = \sum_{i=1}^{2} M_{i,t}, \tag{2}$$

where $C_{i,t}$ is the demand for firm i's goods, and the parameter $\eta > 1$ captures the elasticity of substitution among goods produced by different firms in the same industry. The weight $M_{i,t}/M_t$ captures consumers' relative "taste" for purchasing firm i's goods.

Given firm i's price $P_{i,t}$ and the industry demand C_t, we obtain the demand for firm i's goods $C_{i,t}$ by solving a standard expenditure minimization problem:

$$C_{i,t} = M_{i,t}\left(\frac{P_{i,t}}{P_t}\right)^{-\eta} P_t^{-\epsilon}, \quad \text{with } P_t = \left[\sum_{i=1}^{2}\left(\frac{M_{i,t}}{M_t}\right) P_{i,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}. \tag{3}$$

Equation (3) implies that the demand for firm i's goods $C_{i,t}$ is linear and increasing in $M_{i,t}$. Therefore, from a firm's perspective, we can think of the consumers' taste $M_{i,t}$ as reflecting the firm's customer base (or customer capital) (e.g., Gourio and Rudanko, 2014; Dou, Ji and Wu, 2020). The ratio $M_{i,t}/M_t$ can be interpreted as the customer base share of firm i.

Moreover, equation (3) implies that firm i will have more influence on the industry's price index P_t when its customer base share $M_{i,t}/M_t$ is larger. When setting product prices $P_{i,t}$, firm i internalizes not only the effect of its own but also the effect of its competitor j's price on the industry's price index P_t, resulting in strategic interactions between the two firms. By contrast, in a standard monopolistic competition model with a continuum of firms, each firm is atomistic and has no influence on the industry's price index.

Endogenous Price Elasticity of Demand. The short-run price elasticity of demand for firm i's goods, taking into account of the externality, is given by

$$-\frac{\partial \ln C_{i,t}}{\partial \ln P_{i,t}} = \underbrace{\mu_{i,t}\left[-\frac{\partial \ln C_t}{\partial \ln P_t}\right]}_{\text{cross-industry}} + \underbrace{(1-\mu_{i,t})\left[-\frac{\partial \ln(C_{i,t}/C_t)}{\partial \ln(P_{i,t}/P_t)}\right]}_{\text{within-industry}} = \mu_{i,t}\epsilon + (1-\mu_{i,t})\eta,$$

where $\mu_{i,t}$ is the *(revenue) market share* of firm i and is defined as follows:

$$\mu_{i,t} = \frac{P_{i,t}C_{i,t}}{P_t C_t} = \left(\frac{P_{i,t}}{P_t}\right)^{1-\eta}\frac{M_{i,t}}{M_t}. \tag{4}$$

Equation (4) shows that the short-run price elasticity of demand is given by the average of within-industry elasticity η and cross-industry elasticity ϵ, weighted by the firm's revenue market share. That is, depending on the revenue market share $\mu_{i,t}$, the short-run price elasticity of demand of firm i lies in the interval $[\epsilon, \eta]$. On the one hand, when firm i's revenue market share $\mu_{i,t}$ becomes smaller, within-industry competition becomes more relevant, so firm i's price elasticity of demand depends more heavily on the within-industry elasticity η. In the extreme case of $\mu_{i,t} = 0$, firm i becomes atomistic and takes the industry price index P_t as given. As a result, firm i's price elasticity of demand is exactly η. On the other hand, when $\mu_{i,t}$ becomes larger, cross-industry competition becomes more relevant and thus firm i's price elasticity of demand depends more strongly on the cross-industry elasticity ϵ. In the extreme case of $\mu_{i,t} = 1$, firm i monopolizes the industry and its price elasticity of demand is exactly ϵ.

Evolution of Customer Base. Firms can attract consumers through cutting profit margins, such as lowering prices, offering discounts, or increasing marketing and advertising expenses. Cutting profit margins can have a persistent positive effect on the firm's demand due to consumption inertia, information frictions, and switching costs. To capture this idea, following Phelps and Winter (1970) and Ravn, Schmitt-Grohe and Uribe (2006), we model the evolution of firm i's customer base as

$$\mathrm{d}M_{i,t}/M_{i,t} = \left[g + \alpha\left(C_{i,t}/M_{i,t}\right)^h\right]\mathrm{d}t + \varsigma \mathrm{d}Z_t + \sigma \mathrm{d}W_{i,t}. \tag{5}$$

In equation (5), the term $\alpha\left(C_{i,t}/M_{i,t}\right)^h$ with $h \in [0,1]$ captures the endogenous accumulation of customer base. Intuitively, by setting a lower price $P_{i,t}$, firm i increases the contemporaneous demand flow rate $C_{i,t}$, thereby allowing the firm to accumulate more customer base over $[t, t+\mathrm{d}t]$. The parameter $\alpha > 0$ captures the speed of customer base accumulation. A greater α indicates that customer base accumulation is more sensitive to contemporaneous demand $C_{i,t}$. The parameter h captures the relative importance of contemporaneous demand in accumulating customer base. Consistent with the empirical evidence, the slow-moving customer base $M_{i,t}$ implies that the long-run price elasticity of demand is higher than the short-run elasticity (e.g., Rotemberg and Woodford, 1991). The constant growth term g in equation (5) captures customer base accumulation due to industry-level reasons. The standard Brownian motion Z_t captures aggregate shocks and $W_{i,t}$ captures idiosyncratic shocks to firm i's customer base. The Brownian motions Z_t, $W_{1,t}$, and $W_{2,t}$ can be interpreted as "taste shocks" and are mutually independent.

The preference towards differentiated goods, combining equations (2) and (5), is similar to *relative deep habits* (e.g., Ravn, Schmitt-Grohe and Uribe, 2006; van Binsbergen, 2016). The specification of relative deep habits is inspired by the habit formation of Abel (1990), which features *catching up with the Joneses*. The defining feature of relative deep habits is that agents form habits over individual varieties of goods as opposed to a composite consumption good. The coefficient α captures the strength of deep habits. When $\alpha = 0$, the deep habit channel is shut down. For small values of α, as suggested by the empirical results in Gilchrist et al. (2017), the firm-level customer base $M_{i,t}$ is persistent over time, which can be interpreted as consumption inertia or brand loyalty to firm i's goods (Klemperer, 1995).

Persistence of Market Leadership. The market leaders' position is sticky. Market followers in an industry are constantly challenging and trying to replace the existing market leaders, and they typically do so through distinctive innovation or rapid business expansion. The change of market leaders does not occur gradually over an extended period of time; instead, market leaders are replaced rapidly and disruptively (e.g., Christensen, 1997). For example, Apple and Samsung replaced Nokia and Motorola and became the leaders in the mobile phone industry over a very short period of time.

We assume that the change of market leadership in the industry, as a disruption to the market structure, occurs with intensity $\lambda \geq 0$.[4] Upon the disruption to the market structure, the incumbent market leaders are replaced by new market leaders who used to be followers, and the asset value of replaced firms is destroyed. Both new market leaders have a positive debt level b_0 and initial customer base M_0, which is normalized to be one without loss of generality. Technically, we can view the random event that results in a change of market leadership as restarting a new dynamic game of price competition in

[4]Significant heterogeneity exists in the persistence of market leaders' position across industries. See, for example, Baldwin (1995), Geroski and Toker (1996), Caves (1998), Matraves and Rondi (2007), Sutton (2007), Bronnenberg, Dhar and Dubé (2009), and Ino and Matsumura (2012) for empirical evidence.

the industry.

2.2 Firms' Decisions

Firms' shareholders choose profit margins and exit decisions strategically to maximize their market equity value.

Profit Margin Decision. The marginal cost for a firm to produce a flow of goods is ω with $\omega > 0$. That is, when firm i produces goods at rate $Y_{i,t}$, its total costs of production are $\omega Y_{i,t} \mathrm{d}t$ over $[t, t + \mathrm{d}t]$. In equilibrium, the firm finds it optimal to choose $P_{i,t} > \omega$ and the market clears for each differentiated good, i.e., $Y_{i,t} = C_{i,t}$. Denote by $\theta_{i,t}$ and θ_t the firm-level and industry-level profit margins, defined as follows:

$$\theta_{i,t} \equiv \frac{P_{i,t} - \omega}{P_{i,t}} \quad \text{and} \quad \theta_t \equiv \frac{P_t - \omega}{P_t}. \tag{6}$$

It directly follows from equation (3) that the relation between $\theta_{i,t}$ and θ_t is

$$1 - \theta_t = \left[\sum_{j=1}^{2} \left(\frac{M_{i,t}}{M_t} \right) (1 - \theta_{i,t})^{\eta - 1} \right]^{\frac{1}{\eta - 1}}. \tag{7}$$

Firm i's operating profits per customer base depend on both its own and its competitor's profit margin decisions:

$$\Pi_i(\theta_{i,t}, \theta_{j,t}) \equiv (P_{i,t} - \omega) \, C_{i,t} / M_{i,t} = \omega^{1-\epsilon} \theta_{i,t} \, (1 - \theta_{i,t})^{\eta - 1} \, (1 - \theta_t)^{\epsilon - \eta}. \tag{8}$$

Equation (8) shows that the (local) profit rate of firm i depends on its competitor j's profit margin $\theta_{j,t}$ through the industry's profit margin θ_t. This reflects the externality of firm j's decisions. For example, holding firm i's profit margin fixed, if firm j cuts its profit margin $\theta_{j,t}$, the industry's profit margin θ_t will drop, which will reduce the demand for firm i's goods $C_{i,t}$ (see equation 3), and in turn firm i's profits $\Pi_i(\theta_{i,t}, \theta_{j,t})$. Therefore, when the competitor j sets a lower profit margin $\theta_{j,t}$, firm i will also be motivated to lower its own profit margin $\theta_{i,t}$ in order to maintain the demand for its goods. As a result, the two firms' profit-margin setting decisions exhibit strategic complementarity in equilibrium.

Default and Exit Decision. Firms are financed by debt and equity, and they issue long-term debt to take advantage of the tax shield. The corporate tax rate is τ. We assume that firms do not hold cash reserves. A levered firm first uses its cash flow to make interest payments, then pays taxes, and distributes the rest to equity-holders as dividends. Shareholders have limited liability and the option to default. When internally generated cash cannot cover the interest expenses, the firm can costlessly issue equity to cover the shortfalls.[5] If equity-holders are no longer willing to inject more capital, the firm defaults and exits. In other words, if the equity value falls to zero, shareholders will default and exit. Upon shareholders' defaulting on the debt, the firm is liquidated and its debtholders would obtain a fraction ν of the abandonment value (unlevered asset value).

Debt is modeled as a consol bond, which promises perpetual coupon payments at rate b_i. This is a standard assumption in the literature (Leland, 1994; Duffie and Lando, 2001), which helps maintain a time-homogeneous setting. Thus, firm i's flow of earnings after interest expenses and taxes over $[t, t + \mathrm{d}t]$ is $(1 - \tau) \left[\Pi_i(\theta_{i,t}, \theta_{j,t})M_{i,t} - b_i\right] \mathrm{d}t$.

To maintain tractability, we assume that a new firm enters the industry only after an incumbent firm defaults and exits. This is a standard assumption in the literature of industrial organization on predatory pricing (e.g., Besanko, Doraszelski and Kryukov, 2014). Intuitively, this assumption implies that we always focus on the competition between the two top leaders in the industry. In particular, upon an incumbent firm i's exiting, a new entrant firm with initial customer base $M_{new} = \kappa M_{j,t} > 0$ and coupon rate b_{new} will enter the market, where b_{new} is chosen so that the initial debt-asset ratio, the market value of debt divided by the market value of assets, is set to be ℓ_{new}. The parameter $\kappa > 0$ captures the relative size of the new entrant firm and the non-exiting incumbent firm j.

2.3 Stochastic Discount Factor

Given our focus is on the feedback effect between industry competition and financial distress, we directly specify the stochastic discount factor (SDF), denoted by Λ_t, for tractability. The SDF evolves as follows:

$$\frac{\mathrm{d}\Lambda_t}{\Lambda_t} = -r_f \mathrm{d}t - \gamma_t \mathrm{d}Z_t - \zeta \mathrm{d}Z_{\gamma,t}, \tag{9}$$

where Z_t and $Z_{\gamma,t}$ are independent standard Brown motions, the equilibrium risk-free rate is r_f, and the time-varying market price of risk γ_t evolves as follows:

$$\mathrm{d}\gamma_t = -\varphi(\gamma_t - \overline{\gamma})\mathrm{d}t - \pi \mathrm{d}Z_{\gamma,t} \quad \text{with} \quad \varphi, \overline{\gamma}, \pi > 0. \tag{10}$$

[5] The costless issuance of equity is a simplification assumption widely adopted in credit risk models (e.g., Leland, 1994; Hackbarth, Miao and Morellec, 2006; Chen, 2010). Incorporating the costly equity issuance and endogenous cashholding, as in Bolton, Chen and Wang (2011, 2013) and Dou et al. (2019), is interesting for future research.

Our specification of time-varying discount rate γ_t follows the literature on cross-sectional return predictability (e.g., Lettau and Wachter, 2007; Belo and Lin, 2012; Dou, Ji and Wu, 2020). We assume $\zeta > 0$ to capture the well-documented countercyclical price of risk. The primitive economic mechanism driving the countercyclical price of risk can be, for example, time-varying risk aversion, as in Campbell and Cochrane (1999). Therefore, our model is similar to Chen, Collin-Dufresne and Goldstein (2008), who show that the strongly countercyclical risk prices generated by the habit formation model (Campbell and Cochrane, 1999), combined with exogenously imposed countercyclical asset value default boundaries, can generate high credit spreads. However, by contrast, default boundaries are highly endogenous in our model due to the endogenous time-varying competition intensity.

It is worth pointing out that the Poisson shocks resulting in changes of market leadership are not priced in the SDF. This is because the economy comprises a continuum of industries, and any industry-specific change of market leadership is an idiosyncratic event to the fully diversified representative investor.

2.4 Nash Equilibrium: Collusion and Equity Value

We now solve the dynamic games with strategic profit margin and default decisions based on the SDF specified in equations (9) and (10). The discount rate γ_t is the only aggregate state variable. Economic downturns in our model are characterized by those states with a high γ_t.

Subgame Perfect Nash Equilibrium. The two firms in an industry play a supergame (Friedman, 1971), in which the stage games of setting profit margins are played continuously and repeated infinitely with exogenous and endogenous state variables varying over time. Formally, a subgame perfect Nash equilibrium for the dynamic game consists of a collection of profit-margin strategies that constitute a Nash equilibrium for every history of the game. We do not consider all such equilibria; instead, we only focus on those which allow for collusive arrangements enforced by punishment schemes. All strategies are allowed to depend upon both "payoff-relevant" states $x_t = \{M_{1,t}, M_{2,t}, \gamma_t\}$ in state space $\mathcal{X}$, as in Maskin and Tirole (1988*a*,*b*), and a set of indicator functions that track whether any firm has previously deviated from a collusive profit-margin agreement, as in Fershtman and Pakes (2000, Page 212).[6] Thus, the industry's state is the vector of firms' payoff-relevant states $x_t = \{M_{1,t}, M_{2,t}, \gamma_t\}$.

[6]For notational simplicity, we omit the indicator states of historical deviations.

In particular, there exists a non-collusive equilibrium, which is the repetition of the one-shot Nash equilibrium and thus is Markov perfect. Meanwhile, multiple subgame perfect collusive equilibria also exist in which profit-margin strategies are sustained by conditional punishment strategies.[7]

Non-Collusive Equilibrium with Endogenous Default Boundaries. The non-collusive equilibrium is characterized by profit-margin scheme $\Theta^N(\cdot) = (\theta_1^N(\cdot), \theta_2^N(\cdot))$, which is a pair of functions defined in state space $\mathcal{X}$, such that each firm i chooses profit margin $\theta_{i,t} \equiv \theta_i(x_t)$ to maximize equity value $V_{i,t}^N \equiv V_i^N(x_t)$, under the assumption that its competitor j will set the one-shot Nash-equilibrium profit margin $\theta_{j,t}^N \equiv \theta_j^N(x_t)$. Following the recursive formulation in dynamic games for characterizing the Nash equilibrium (e.g., Pakes and McGuire, 1994; Ericson and Pakes, 1995; Maskin and Tirole, 2001), optimization problems can be formulated recursively by Hamilton-Jacobi-Bellman (HJB) equations:

$$0 = \max_{\theta_{i,t}} \Lambda_t \left[(1-\tau)[\Pi_i(\theta_{i,t}, \theta_{j,t}^N)M_{i,t} - b_i] - \lambda V_{i,t}^N\right] \mathrm{d}t + \underbrace{\mathbb{E}_t\left[\mathrm{d}(\Lambda_t V_{i,t}^N)\right]}_{\text{if not disrupted}}, \quad \text{for } i = 1, 2. \tag{11}$$

The solutions to the coupled HJB equations give the non-collusive-equilibrium profit margin $\theta_{i,t}^N \equiv \theta^N(x_{i,t})$ with $i = 1, 2$.

Firm i's endogenous default boundary in the non-collusive equilibrium, which is in terms of its customer base, is denoted by $\underline{M}_{i,t}^N \equiv \underline{M}_i^N(M_{j,t}, \gamma_t)$. At the optimal default boundary, the equity value of firm i is equal to zero (the value matching condition) and the boundary is optimal in terms of maximizing the equity value (the smooth pasting condition):

$$V_i^N(x_t)\Big|_{M_{i,t}=\underline{M}_{i,t}^N} = 0 \quad \text{and} \quad \frac{\partial}{\partial M_{i,t}} V_i^N(x_t)\Big|_{M_{i,t}=\underline{M}_{i,t}^N} = 0, \quad \text{respectively.} \tag{12}$$

The boundary condition at $M_{i,t} = +\infty$ is given by Appendix A.1.

Collusive Equilibrium with Endogenous Default Boundaries. In the collusive equilibrium, firms (tacitly) collude in setting higher profit margins, with any deviation triggering a switch to the non-collusive Nash equilibrium. The collusion is "tacit" in the sense that it can be enforced without relying on legal contracts. Each firm is deterred from breaking

[7] In the industrial organization and macroeconomics literature, this equilibrium is called the collusive equilibrium or collusion (see, e.g., Green and Porter, 1984; Rotemberg and Saloner, 1986). Game theorists generally call it the equilibrium of repeated game (see Fudenberg and Tirole, 1991) in order to distinguish it from the one-shot Nash equilibrium (i.e., our non-collusive equilibrium).

the collusion agreement because doing so could provoke fierce non-collusive competition.

Consider a generic collusive equilibrium in which the two firms follow a collusive profit-margin scheme. Both firms can costlessly observe the other's profit margin, so that deviation can be detected and punished. The assumption of perfect information follows the literature.[8] In particular, if one firm deviates from the collusive profit-margin scheme, then with probability $\xi \mathrm{d}t$ over $[t, t+\mathrm{d}t]$ the other firm will implement a punishment strategy in which it will forever set the non-collusive profit margin. Entering the non-collusive equilibrium is considered as the punishment for the deviating firm, because the industry will switch from the collusive to the non-collusive equilibrium featuring the lowest profit margin.[9] We use the idiosyncratic Poisson process $N_{i,t}$ to characterize whether a firm can successfully implement a punishment strategy. One interpretation of $N_{i,t}$ is that, with $1 - \xi \mathrm{d}t$ probability over $[t, t+\mathrm{d}t]$, the deviator can persuade its competitor not to enter the non-collusive Nash equilibrium over $[t, t+\mathrm{d}t]$.[10] Thus, the punishment intensity ξ can be viewed as a parameter governing the credibility of the punishment for deviating behavior. A higher ξ leads to a lower deviation incentive.

Formally, the set of incentive-compatible collusion agreements, denoted by $\mathcal{C}$, consists of all continuous profit-margin schemes $\Theta^C(\cdot) \equiv (\theta_1^C(\cdot), \theta_2^C(\cdot))$, such that the following participation constraints (PC) and incentive compatibility (IC) constraints are satisfied:

$$V_i^N(x) \leq V_i^C(x), \quad \text{for all } x \in \mathcal{X} \text{ and } i = 1,2; \qquad \text{(PC constraints)} \qquad (13)$$

$$V_i^D(x) \leq V_i^C(x), \quad \text{for all } x \in \mathcal{X} \text{ and } i = 1,2. \qquad \text{(IC constraints)} \qquad (14)$$

Here, $V_i^N(x)$ is firm i's equity value in the non-collusive equilibrium, $V_i^D(x)$ is firm i's equity value if it chooses to deviate from the collusion, and $V_i^C(x)$ is firm i's equity value in the collusive equilibrium, pinned down recursively according to

$$0 = \Lambda_t \left\{ (1-\tau)[\Pi_i(\theta_{i,t}^C, \theta_{j,t}^C) M_{i,t} - b_i] - \lambda V_{i,t}^C \right\} \mathrm{d}t + \mathbb{E}_t \left[\mathrm{d}(\Lambda_t V_{i,t}^C) \right], \qquad (15)$$

subject to the PC and IC constraints in equations (13) and (14), where $\theta_{i,t}^C \equiv \theta_i^C(x_t)$

[8] A few examples include Rotemberg and Saloner (1986), Haltiwanger and Harrington (1991), Staiger and Wolak (1992), and Bagwell and Staiger (1997).

[9] We adopt the non-collusive equilibrium as the incentive-compatible punishment for deviation, which follows the literature (see, e.g., Green and Porter, 1984; Rotemberg and Saloner, 1986). We can extend the setup to allow for finite-period punishment. The quantitative implications are not altered significantly provided that the punishment lasts long enough.

[10] Ex-post renegotiations can occur because the non-collusive equilibrium is not renegotiation-proof or "immune to collective rethinking" (see Farrell and Maskin, 1989). The strategy we consider is essentially a probabilistic punishment strategy. This "inertia assumption" also solves the technical issue of continuous-time dynamic games about indeterminacy of outcomes (see, e.g., Simon and Stinchcombe, 1989; Bergin and MacLeod, 1993).

with $i = 1, 2$ are the collusive profit margins. Obviously, the equilibrium recursive relation in equation (15) only holds within the non-default region, characterized by $M_{i,t} > \underline{M}_{i,t}^{C} \equiv \underline{M}_{i}^{C}(M_{j,t}, \gamma_t)$ where $\underline{M}_{i,t}^{C}$ is firm i's default boundary in the collusive equilibrium. The value matching and smooth pasting conditions for the optimal default boundary are

$$V_i^C(x_t)\Big|_{M_{i,t}=\underline{M}_{i,t}^{C}} = 0 \text{ and } \frac{\partial}{\partial M_{i,t}} V_i^C(x_t)\Big|_{M_{i,t}=\underline{M}_{i,t}^{C}} = 0, \text{ respectively.} \tag{16}$$

The boundary condition at $M_{i,t} = +\infty$ is identical to that in the non-collusive equilibrium, because when $M_{i,t} = +\infty$, firm i is essentially an industry monopoly and there is no benefit from colluding with firm j whose customer base share is zero.

Equilibrium Deviation Values. Let $V_{i,t}^{D} \equiv V_i^D(x_{i,t})$ be firm j's highest equity value if it deviates from implicit collusion. The highest deviation value evolves as follows:

$$0 = \max_{\theta_{i,t}} \Lambda_t \left\{ (1-\tau)[\Pi_i(\theta_{i,t}, \theta_{j,t}^{C}) M_{i,t} - b_i] - \xi \left(V_{i,t}^{D} - V_{i,t}^{N} \right) - \lambda V_{i,t}^{D} \right\} \mathrm{d}t + \underbrace{\mathbb{E}_t \left[\mathrm{d}(\Lambda_t V_{i,t}^{D}) \right]}_{\text{if not disrupted}}, \tag{17}$$

for $i = 1, 2$. The equilibrium recursive relation characterized by equation (17) only holds within non-default region, characterized by $M_{i,t} > \underline{M}_{i,t}^{D} \equiv \underline{M}_{i}^{D}(M_{j,t}, \gamma_t)$ where $\underline{M}_{i,t}^{D}$ is firm i's default boundary if it chooses to deviate from the collusion. The value matching and smooth pasting conditions for the optimal default boundary are

$$V_i^D(x_t)\Big|_{M_{i,t}=\underline{M}_{i,t}^{D}} = 0 \text{ and } \frac{\partial}{\partial M_{i,t}} V_i^D(x_t)\Big|_{M_{i,t}=\underline{M}_{i,t}^{D}} = 0, \text{ respectively.} \tag{18}$$

The boundary condition at $M_{i,t} = +\infty$ is identical to that in the non-collusive equilibrium as discussed above.

More Discussions. Several points are worth mentioning. First, the equity value in the collusive equilibrium may be equal to that in the non-collusive equilibrium, i.e., the PC constraints (13) are binding. When one firm's PC constraint starts to bind, the two firms switch to the non collusive equilibrium. The endogenous switch to the non-collusive equilibrium captures endogenous price wars, which we illustrate in Subsection 3.6. We assume that once the two firms switch to the non-collusive equilibrium, they will stay there forever.[11] The endogenous equilibrium switching is our model's key difference from that of Dou, Ji and Wu (2020), in which firms finance only by issuing equity and never suffer from financial distress. In their model, the PC constraints for profit-margin collusion are always not binding since higher profit margins always lead to higher equity value without default or exit.

Second, there exist infinitely many elements in $\mathcal{C}$ and hence infinitely many collusive equilibria. We focus on a subset of $\mathcal{C}$, denoted by $\overline{\mathcal{C}}$, consisting of all profit-margin schemes $\Theta_i^C(\cdot)$ such that the IC constraints (14) are binding state by state, i.e., $V_i^D(x_t) = V_i^C(x_t)$ for all $x_t \in \mathcal{X}$ and $i = 1, 2$.[12] It is obvious that the subset $\overline{\mathcal{C}}$ is nonempty since it contains the profit-margin scheme in the non-collusive Nash equilibrium. We further narrow our focus to the "Pareto-efficient frontier" of $\overline{\mathcal{C}}$, denoted by $\overline{\mathcal{C}}_p$, consisting of all pairs of $\Theta_i^C(\cdot)$ such that there does not exist another pair $\widetilde{\Theta}^C(\cdot) \in \overline{\mathcal{C}}$ with $\widetilde{\theta}_i(x_t) \geq \theta_i^C(x_t)$ for all $x_t \in \mathcal{X}$ and $i = 1, 2$, and with strict inequality holding for some x_t and i.[13] Our numerical algorithm follows a method similar to that of Abreu, Pearce and Stacchetti (1990*a*).[14] Deviation never occurs on the equilibrium path. Using the one-shot deviation principle (Fudenberg and Tirole, 1991), it is clear that the collusive equilibrium characterized above is a subgame perfect Nash equilibrium.

2.5 Debt Value

We start by determining the value of corporate debt. Debt value equals the sum of the present value of the cash flows that accrue to debtholders until the default time or the replacement time by market followers, whichever is earlier, and the change in this present value that arises in default or replacement. Since the latter component depends on the firm's abandonment value, we start by deriving this value below.

We set the abandonment value to be zero for disruption-driven exits because being replaced by market followers reflects economic distress. We set the abandonment value to be a fraction ν of the value of unlevered assets $A_i^C(x_t)$ for default-driven exits, which

[11] The firm that proposes to switch to the non-collusive equilibrium is essentially deviating, and thus we assume they will not return to the collusive equilibrium to be consistent with our specification of punishment strategies.

[12] Such equilibrium refinement in a general equilibrium framework is in spirit similar to Abreu (1988), Alvarez and Jermann (2000, 2001), and Opp, Parlour and Walden (2014).

[13] It can be shown that the "Pareto-efficient frontier" is nonempty based on the fundamental theorem of the existence of Pareto-efficient allocations (see, e.g., Mas-Colell, Whinston and Green, 1995), as $\overline{\mathcal{C}}$ is nonempty and compact, and the order we are considering is complete, transitive, and continuous.

[14] Alternative methods include Cronshaw and Luenberger (1994), Pakes and McGuire (1994), and Judd, Yeltekin and Conklin (2003), which contain similar ingredients to those of our solution method. Proving the uniqueness of the equilibrium under our selection criterion is beyond the scope of the paper. We use different initial points in our numerical algorithm and find robust convergence to the same equilibrium.

are caused by financial distress. This assumption follows the literature on dynamic debt models (e.g., Mello and Parsons, 1992; Leland, 1994; Hackbarth, Miao and Morellec, 2006). The unlevered-asset value $A_i^C(x_t)$ is the value of an all-equity firm. In the collusive equilibrium, the unlevered asset value $A_i^C(x_t)$ is determined similarly by equations (11) – (18) except for setting $b_i = 0$ and removing the default boundary conditions (12), (16), and (18).

The value of debt in the collusive equilibrium, denoted by $D_{i,t}^C = D_i^C(x_t)$, can be characterized as follows. In the non-default region (i.e., $M_{i,t} > \underline{M}_{i,t}^C$), the debt value is given by the following HJB equation:

$$0 = \Lambda_t \left(b_i - \lambda D_{i,t}^C\right) \mathrm{d}t + \mathbb{E}_t \left[\mathrm{d}(\Lambda_t D_{i,t}^C)\right], \quad \text{for } i = 1, 2, \tag{19}$$

with boundary conditions:

$$D_i^C(x_t)\Big|_{M_{i,t}=\underline{M}_{i,t}^C} = \nu A_i^C(x_t)\Big|_{M_{i,t}=\underline{M}_{i,t}^C} \quad \text{and} \quad \lim_{M_{i,t}\to+\infty} D_i^C(x_t) = b_i/r_f, \quad \text{for } i = 1, 2. \tag{20}$$

The first condition in equation (20) is the liquidation payoff to the debtholders at the default boundary, and the second condition in equation (20) captures the asymptotic behavior of debt value when customer base $M_{i,t}$ approach to infinity, which is basically the value of a default-free consol bond with constant coupon rate b_i.

3 Predation-Like Behavior

One of the core implications of our model is that the predation-like behavior in the product market can be rationalized as an equilibrium phenomenon owing to the interaction between endogenous competition and financial distress. The predation-like behavior refers to firms' aggressive price-cutting behavior, and it could be driven by both self-defensive and predatory incentives (Besanko, Doraszelski and Kryukov, 2014). The self-defensive incentives refer to price-undercutting for the benefits of acquiring competitive advantage (i.e., pricing for efficiency), whereas the predatory incentives refer to price-undercutting for the benefits of preventing rival firms from acquiring competitive advantage (i.e., pricing for eliminating rivals). As argued by Fisher (2001), the self-defensive incentives are better described by defensive predation whereas the real predatory incentives are better described by offensive predation.

In this section, we calibrate our duopoly model to address the following three interrelated questions about predation-like behavior. First, when does predation-like behavior arise? We show that predation-like behavior can emerge routinely in response to aggregate and idiosyncratic shocks without requiring extreme or unusual parameterizations. In Subsection 3.2, we show that there is a positive feedback loop between competition and financial distress as increased competition leads to more financial distress, which in turn motivates both firms to compete more fiercely. Predation-like behavior emerges when aggregate shocks make the industry more financially distressed, as both firms significantly cut their prices. In Subsection 3.3, we show there is financial contagion in the industry. For example, a negative idiosyncratic shock hitting one firm may incentivize the other firm to cut prices, exhibiting predation-like behavior, which in turn increases both firms' default risk.

Second, how much of predation-like behavior is attributed to predatory rather than self-defensive incentives? In Subsection 3.4, we use our calibrated model to theoretically isolate and quantify a firm's predatory incentives by decomposing the equilibrium product-market pricing conditions.

Third, what is the asset pricing implications of predation-like behavior caused by endogenous competition-distress feedback? In Subsection 3.5, we show that on the one hand, there is an amplification effect on the industry's exposure to aggregate discount-rate shocks owing to the competition-distress feedback. On the other hand, we shed light on the implications of the interaction between the competition-distress feedback and the persistence of market leadership across industries. The model implies that in the industries where market leaders have higher turnover rates, firms' profit margins are lower and less sensitive to discount rate shocks. As a result, in such industries, shareholders are less exposed to aggregate discount rate shocks. However, debtholders are more exposed to aggregate discount rate shocks due to higher default risk.

Finally, in Subsection 3.6, we show that in industries with a sufficiently high entry barrier, our model can generate endogenous price wars, a phenomenon where the two firms abandon collusive agreement and switch to the non-collusive equilibrium. During the price war, the financially strong firm significantly cuts its profit margin with the intention to drive its financially weak competitor out of the market.

3.1 Calibration and Parameter Choice

The risk-free rate is $r_f = 2\%$. We set the persistence of the market price of risk to be $\varphi = 0.13$ as in Campbell and Cochrane (1999) and $\pi = 0.12$ as in Lettau and Wachter (2007). The within-industry elasticity of substitution is set at $\eta = 15$ and the industry's price elasticity of demand at $\epsilon = 2$, which are broadly consistent with the values of Atkeson and Burstein (2008). We set the corporate tax rate $\tau = 27\%$ and the drift term under physical measure $g = 1.8\%$ as in He and Milbradt (2014). We set the bond recovery

Table 1: Calibration and parameter choice.

Panel A: Externally Determined Parameters					
Parameter	Symbol	Value	Parameter	Symbol	Value
Risk-free rate	r_f	2%	Persistence of market price of risk	φ	0.13
Volatility of market price of risk	π	0.12	Within-industry elasticity	η	15
Industry's price elasticity	ϵ	2	Corporate tax rate	τ	0.27
Mean growth rate of customer base	g	1.89%	Bond recovery rate	ν	0.41
Debt-asset ratio of new entrant	l_{new}	0.4	Customer base of new entrant	κ	0.3
Market disruption rate	λ	0	Initial customer base	M_0	1
Customer base accumulation rate	α	0.01	Customer base adjustment friction	h	0.44
Panel B: Internally Calibrated Parameters					
Parameter	Symbol	Value	Moments	Data	Model
Initial coupon rate	b_0	10	Average debt-asset ratio	0.34	0.35
Volatility of idiosyncratic shocks	σ	25%	10-year default rate (Baa rated)	4.9%	5.0%
Marginal cost of production	ω	2	Average net profitability	3.9%	3.6%
Punishment rate	ξ	0.09	Average gross profit margin	31.4%	26.5%
Market price of risk for Z_t	$\overline{\gamma}$	0.15	Average risk premium ($\mathbb{E}(r - r_f)$)	6.7%	6.7%
Volatility of aggregate shocks	ς	0.04	Sharpe ratio ($\mathbb{E}(r - r_f)/\sigma(r - r_f)$)	0.40	0.42
Market price of risk for $Z_{\gamma,t}$	ζ	0.45	Credit spread for Baa-rated bonds	138bps	143bps

rate at $\nu = 0.41$ based on the mean recovery rate of Baa-rated bonds estimated by Chen (2010). This is fairly close to the estimated average recovery rate of debt in bankruptcy for large, public, non-financial U.S. firms from $1996 - 2014$ (see Dou et al., 2020*a*). The initial debt-asset ratio of new entrant is set at $l_{new} = 0.4$. We set the initial customer base of new entrant to be a fraction $\kappa = 0.3$ of the non-exiting firm's customer base. The market disruption rate is set to be $\lambda = 0$ in our baseline calibration, we study the comparative statics of κ and λ below.

The parameters α and h determine the stickiness of customer base with respect to short-run demand. The parameter α determines the overall incentive to invest in customer base. A higher α implies that firms have more incentive to set lower markups to accumulate customer base. Thus, we set $\alpha = 0.01$ to capture the stickiness of the customer base, emphasized by Gilchrist et al. (2017). The parameter h determines the extent to which firms' profit margin respond to their financial distress and customer bases. We thus set $h = 0.44$ following Dou and Ji (2019).

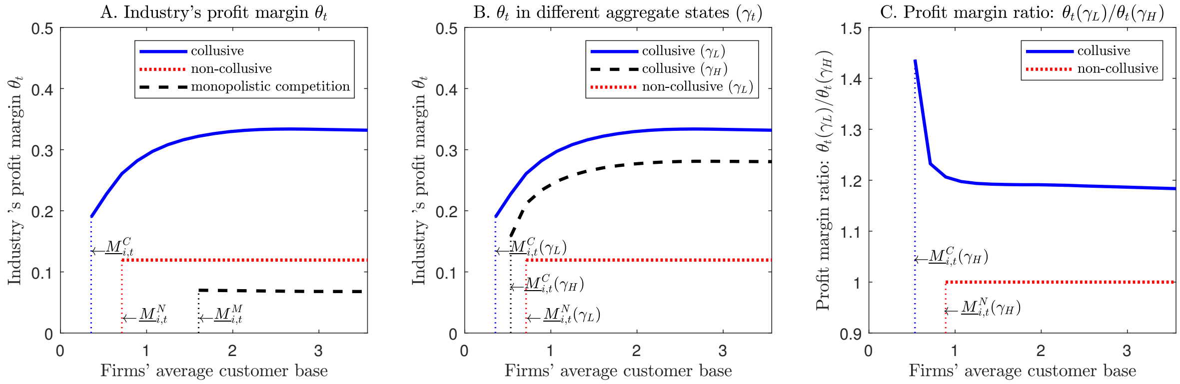
The remaining parameters are calibrated by matching relevant moments in Panel B of Table 1. We assume that the two firms in the industry initially have the same coupon rate b_0 and customer base M_0. The initial customer base M_0 is normalized to be 1 and we set $b_0 = 10$ to generate an average debt-asset ratio of 0.35. The volatility of idiosyncratic shocks is $\sigma = 25\%$ which generates a 10-year default rate of 5%. The marginal cost of production $\omega = 2$ is determined to match the average net profitability. We set the punishment rate $\xi = 0.09$ so that the average gross profit margin is consistent with the data. Duffee (1998) reports that the average credit spread between a Baa-rated 10-year bond in the industrial sector and the Treasury is 138 bps. We set $\zeta = 0.45$, $\overline{\gamma} = 0.15$, and $\varsigma = 4\%$ so that the average equity premium is 6.7%, the Sharpe ratio is 0.42, and the credit spread is 143 bps.

3.2 Feedback between Competition and Distress

Predation-like behavior can emerge when the industry is hit by aggregate shocks. In this subsection, we show that there is a positive feedback loop between competition and financial distress: heightened competition leads to increased financial distress, which in turn incentivizes firms to compete more fiercely by undercutting profit margins aggressively. Thus, when the industry becomes financially distressed due to negative aggregate shocks to customer base, both firms will compete more fiercely and undercut their profit margins, exhibiting predation-like behavior. Moreover, we show that when the discount rate rises, competition intensity increases more in financially distressed industries, owing to the feedback mechanism.

Feedback and Predation-Like Behavior. To fix ideas, consider a duopoly industry with two identical firms.[15] Panel A of Figure 3 plots the industry's profit margin as a function of firms' average customer base. The industry has higher profit margins in the collusive equilibrium (the blue solid line) than in the non-collusive equilibrium (the red dotted line). Moreover, compared to an industry of monopolistic competition with a continuum of firms (the black dashed line), firms in the duopoly industry have higher profit margins. Intuitively, firms' profit margins reflect the competition intensity they face in the product market. Higher competition intensity effectively means a higher price elasticity of demand, which results in lower equilibrium profit margins. The lower profit margins in turn increase the probability of default. As shown by the vertical lines in the figure, firms' default boundary in the collusive equilibrium are lower than that in the non-collusive equilibrium of the duopoly industry, which are lower than that in the industry of monopolistic competition (i.e., $\underline{M}_{i,t}^{M} > \underline{M}_{i,t}^{N} > \underline{M}_{i,t}^{C}$). This implies that financial

[15]We consider identical firms for illustration purposes because it implies that the industry's profit margin and financial distress is the same as each firm's profit margin and financial distress. The feedback mechanism also exists when firms are assymmetric.



Note: We consider a duopoly industry with two identical firms (i.e., $M_{i,t} = M_{j,t}$). The blue solid and red dotted lines in panel A plots the duopoly industry's profit margin θ_t as a function of firms' average customer base, where θ_t is defined in equation (6). The black dashed line plots the profit margin of an industry of monopolistic competition where a continuum of firms exists. We use $\gamma_t = \overline{\gamma}$ in panel A. Panel B plots the same duopoly industry's profit margin θ_t for different aggregate states γ_t. The blue solid and black dashed lines represent a low $\gamma_t \equiv \gamma_L$ and a high $\gamma_t \equiv \gamma_H$ in the collusive equilibrium. The red dotted dash-dotted line represents the non-collusive equilibrium with γ_L. In panel B, we set $\gamma_L = \overline{\gamma}$ and $\gamma_H = \overline{\gamma} + 2\text{std}(\gamma_t)$. Panel C plots the percentage change in profit margin when the aggregate state changes from γ_H to γ_L, i.e., $\theta_t(\gamma_L)/\theta_t(\gamma_H)$. The blue solid and red-dotted lines represent collusive and non-collusive equilibria respectively. In all panels, the vertical dotted lines represent firms' default boundaries in respective cases.

Figure 3: Positive feedback loop between competition and financial distress.

distress becomes deepened with increased competition intensity, because undercutting profit margins erodes firms' cash flows.

In the rest of this section, we focus on the collusive equilibrium where interesting dynamics of strategic competition are present. The blue solid line in panel A shows that the profit margin decreases when the industry becomes more financially distressed (i.e., when firms' average customer base decreases). This indicates that financial distress leads to more competition and lower equilibrium profit margins. Intuitively, the incentive to collude on higher profit margins depends on how much firms value future cash flows relative to their contemporaneous cash flows. By deviating from collusive profit-margin-setting schemes, firms can obtain higher contemporaneous cash flows; however, firms run into the risk of losing future cash flows because once the deviation is punished by the other firm, the non-collusive equilibrium will be implemented. When firms are closer to the default boundary, they are more likely to exit the market in the near future due to the higher probability of default. As a result, firms become effectively more impatient and value their cash flows in the short run more than those in the long run. This motivates firms to undercut their competitors' profit margins. Thus, if the two firms were to maintain the collusive equilibrium, the mutually agreed profit margins must fall when firms are more distressed to ensure that deviation does not occur in equilibrium (i.e., the IC constraints are satisfied). Thus, increased financial distress would generate lower profit margins and intensify competition. Our idea echoes and formalizes the important generic insight of Maskin and Tirole (1988*a*) and Fershtman and Pakes (2000): the tacit collusion among oligopolists arises in industries where each firm expects others to remain in the market for a long time; but if firms are more likely to exit the market in the future, the incentive for collusive behavior becomes weaker. Taken together, panel A of Figure 3 implies a positive feedback loop between competition and financial distress.[16] Such a feedback loop amplifies default risks because firms would find their profit margins lower exactly when they are more distressed. We discuss the asset pricing implications of this feedback mechanism in Subsection 3.5.1.

Predation-like behavior emerges when aggregate shocks makes the industry more financially distressed. Specifically, negative shocks to the industry (i.e., $\mathrm{d}Z_t$ in equation 5) reduce both firms' customer base, moving the equilibrium profit margin to the left along the blue solid line in panel A. Both firms cut their profit margins and compete more fiercely, resulting in lower profit margin for the industry. Thus, from either firm's perspective, the other firm's profit-margin undercutting exhibits predation-like behavior. To be more specific, if firm i were to keep its profit margin unchanged the industry becomes more distressed, its competitor, firm j, will deviate from the collusive equilibrium by significantly undercutting the profit margin due to the intuitions above. To prevent firm j from deviating, firm i has to cut its own profit margin, which itself is an optimal response to increased financial distress. Therefore, although both firms exhibit predation-like behavior when the industry is more distressed, the purpose of profit-margin undercutting reflects more about their self-defensive than predatory incentives. In Subsection 3.4, we demonstrate how our model can be used to isolate and quantify firms' predatory incentives.

Profit-Margin Exposure to Discount-Rate Shocks. Dou, Ji and Wu (2020) show that high discount rates lead to high competition intensity in industries. We make a further point by showing that high discount rates lead to a larger increase in competition intensity of financially distressed industries, owing to the positive feedback loop between competition and financial distress. In other words, our model implies that the profit margin of more financially distressed industries is more exposed to discount-rate shocks (i.e., $\mathrm{d}Z_{\gamma,t}$ in equation 10).

[16]By contrast, there is no feedback look in the non-collusive equilibrium or (the red dotted line in panel A) or in the industry of monopolistic competition (the black dashed line in panel A). In these two cases, the industry's profit margin is flat regardless of the average customer base of firms within the industry. This is because in both cases, the intensity of competition is exogenously determined by the price elasticity of demand. Thus, by definition, there is no feedback effect from financial distress on competition intensity.

To illustrate this idea, panel B of Figure 3 plots the duopoly industry's profit margin in the collusive equilibrium in the state with a low discount rate γ_L (the blue solid line) and a high discount rate γ_H (the black dashed line). It is shown that the industry's profit margin is lower when the discount rate is higher.[17] This is because a higher discount rate γ_H makes firms more impatient and focus more on short-term cash flows. As a result, future punishment becomes less threatening and higher profit margins are more difficult to be sustained.[18] The blue solid line in panel C plots the ratio of profit margins across the two states (i.e., γ_L and γ_H) in the collusive equilibrium. It is shown that percentage change in profit margin increases monotonically when the industry becomes more financially distressed. In particular, when the industry is close to the default boundary, the profit margin increases by as large as 44% in responding to a higher discount rate whereas the profit margin increases by about 18% when the industry is far away from the default boundary.

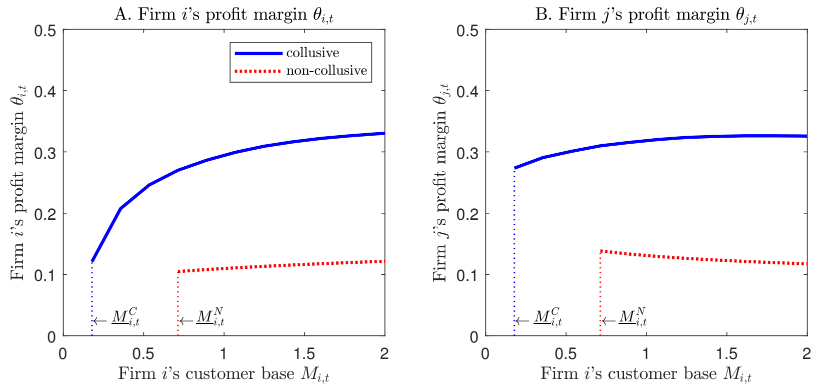
3.3 Financial Contagion

Predation-like behavior can also emerge when firms are hit by idiosyncratic shocks. In this subsection, we show that there is financial contagion among firms within the same industry: negative idiosyncratic shocks hitting one firm may increase both firms' default risk. This financial contagion effect originates from the predation-like behavior, as both firms cut their profit margins when any firm is driven into financial distress by idiosyncratic shocks.

To elaborate on the predation-like behavior, Figure 4 plots the two firms' profit margins as a function of firm i's customer base $M_{i,t}$, given firm j's customer base fixed at $M_{j,t} = 2$. The blue solid line in panel A shows that firm i reduces its profit margin when it becomes more financially distressed (i.e., $M_{i,t}$ decreases) due to negative idiosyncratic shocks (i.e., $dW_{i,t}$ in equation 5). Moreover, its financially strong competitor, firm j, also lowers its profit margin (see the blue solid line in panel B), exhibiting predation-like behavior, even though firm j's customer base $M_{j,t}$ remains unchanged. In fact, like the response of

[17] Kawakami and Yoshihiro (1997) and Wiseman (2017) show that in a market with exits but no entries, firms may have less incentive to collude with each other when the discount rate is lower, and instead they enter into a price war until only one firm in the industry is alive. This is not the case under our baseline calibration because we assume that new firms enter the industry when existing firms exit after default.

[18] By contrast, in the non-collusive equilibrium, profit margins remain almost unchanged when the discount rate rises (see the red-dotted line) because competition intensity is exogenously determined by the price elasticity of demand, which does not vary with γ_t. For clarity, we only draw the non-collusive profit margin in the state with a low discount rate γ_L in panel B of Figure 3, which is slightly different from the profit margin in the state with a high discount rate γ_H, reflecting the change in firms' incentive in accumulating customer base. If we set $\alpha = 0$ in equation (5), profit margins in the non-collusive equilibrium will stay constant when γ_t changes.



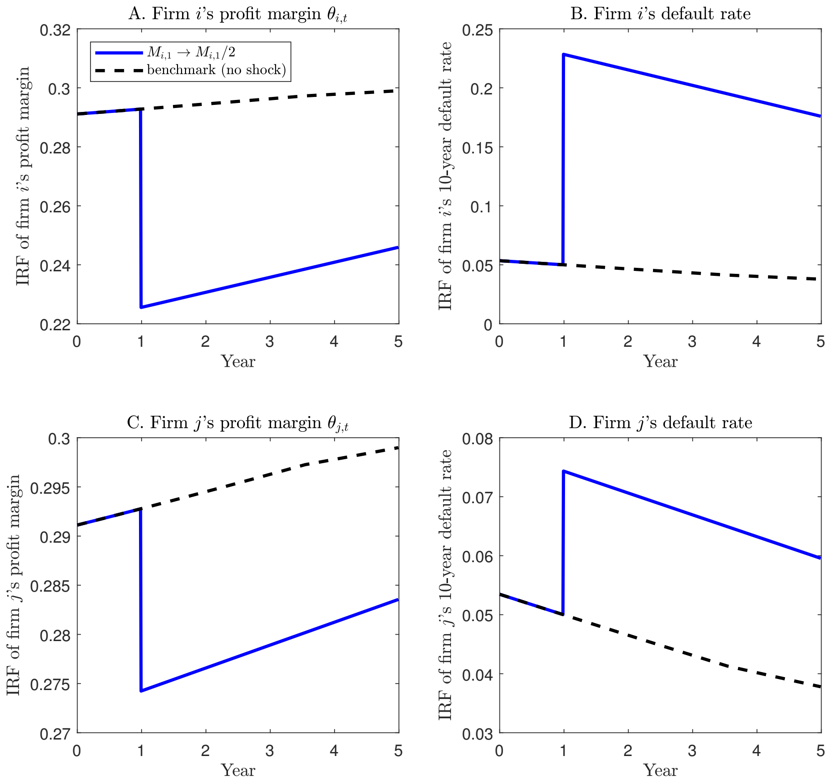
Note: Panel A plots firm i's profit margin θ_i as a function of its own customer base $M_{i,t}$; and panel B plots firm j's profit margin as a function of firm i's customer base $M_{i,t}$. The blue solid and red dotted lines represent the collusive equilibrium and the non-collusive equilibrium in our calibrated industry. The vertical dotted lines represent default boundaries of firm i in respective cases. In both panels, we use $\gamma_t = \overline{\gamma}$ and $M_{j,t} = 2$.

Figure 4: Predation-like behavior after idiosyncratic shocks.

profit margins to aggregate shocks discussed in Subsection 3.2, firm j's profit-margin undercutting reflects both about its self-defensive and predatory incentives. Intuitively, on the one hand, firm j may have the predatory incentives to drive its financially weak competitor, firm i, into default so as to capture a potentially larger market share. On the other hand, firm j also has the self-defensive incentive because it knows that the financially weak firm i will cut its profit margin to steal customer base (see the blue solid line in panel A). The intention of setting a lower profit margin is partly to prevent its financially weak competitor from stealing demand.[19]

Firms' predation-like behavior caused by idiosyncratic shocks and financial distress imply that there is financial contagion among firms within the same industry. To illustrate the contagious effect, Figure 5 plots the two firms' impulse response functions (IRF) of profit margins and 10-year default rate after a negative shock to firm i's customer base. In panels A and B, the blue solid lines plot the IRF of firm i's profit margin and default rate when its customer base is reduced unexpectedly by 50% at $t = 1$. The black dashed lines represent the benchmark case without the shock. Consistent with panel A of Figure 4, firm i's profit margin decreased dramatically after hit by the idiosyncratic shock (panel

[19]By contrast, in the non-collusive equilibrium, firm i's profit margin increases with its own customer base $M_{i,t}$ (see the red dotted line in panel A) and firm j's profit margin decreases with its competitor firm i's customer base $M_{i,t}$ (see the red dotted line in panel B). In other words, both firms' non-collusive profit margins are increasing in their own customer base and deceasing in their competitor's customer base. This is because non-collusive profit margins are one-shot Nash equilibrium outcomes. When customer base is sticky (i.e., small α), firms' non-collusive profit margins simply reflect the short-run price elasticity of demand they face. As shown by equation (4), a firm's short-run price elasticity of demand decreases with its customer base share, and thus a larger customer base share leads to a lower elasticity and a higher non-collusive profit margin.

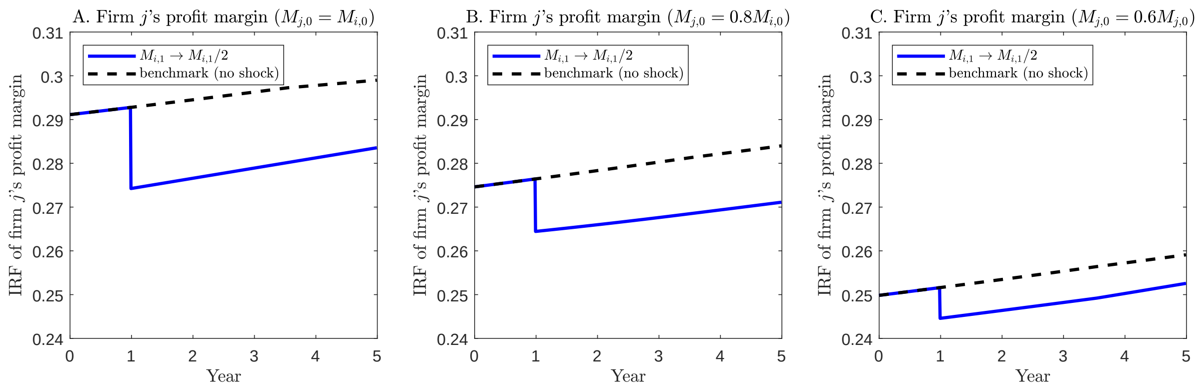


Note: This figure illustrate the IRF of profit margins and default rates after a negative idiosyncratic shock to firm i's customer base. The black dashed lines in all panels plot the benchmark case without aggregate or idiosyncratic shocks for both firms. The blue solid lines in all panels plot the IRF when there is an unexpected idiosyncratic shock at $t = 1$, which reduces firm i's customer base by 50%, from $M_{i,1}$ to $M_{i,1}/2$. Panels A and B plot the profit margin and 10-year default rate of firm i in the collusive equilibrium. Panels C and D plot those of firm j in the collusive equilibrium. In all panels, we set $M_{i,0} = M_{j,0} = 1$ and $\gamma_t = \overline{\gamma}$.

Figure 5: Financial contagion between the two firms in the same industry.

A) due to the competition-distress feedback. The lower profit margin and customer base significantly increase firm i's default rate (panel B). In panels C and D, the blue solid lines plot the IRF of firm j's profit margin and default rate in response to the shock on firm i's customer base. Although firm j is not hit by any shocks, its profit margin also decreases when firm i is hit by the shock, exhibiting predation-like behavior as discussed above. Importantly, firm j's default rate increases by 2.5% when its competitor, firm i, becomes more financially distressed at the impact of the shock, indicating the existence of financial contagion within the industry.

In Figure 6, we study how the distribution of customer base between the two firms in the industry affect the strategic profit-margin setting behavior. In particular, we consider industries with different initial distribution of customer base in panels A, B, and C. For the same shock to firm i's customer base at $t = 1$, the negative impact on firm j's profit



Note: This figure illustrate the IRF of firm j's profit margins after a negative idiosyncratic shock to firm i's customer base. We consider three industries with different initial customer base share, i.e., $M_{j,0} = M_{i,0}$ in panel A, $M_{j,0} = 0.8M_{i,0}$ in panel B, and $M_{j,0} = 0.6M_{i,0}$ in panel C. The black dashed lines in all panels plot the benchmark case without aggregate or idiosyncratic shocks for both firms. The blue solid lines in all panels plot the IRF when there is an unexpected idiosyncratic shock at $t = 1$, which reduces firm i's customer base by 50%, from $M_{i,1}$ to $M_{i,1}/2$. In all panels, we set $M_{i,0} = 1$ and $\gamma_t = \overline{\gamma}$. We adjust firm j's coupon rate b_j so that it has the same initial financial leverage across the three panels.

Figure 6: Financial contagion in industries with different distribution of customer base.

margin is the largest when the two firms' customer base is comparable (panel A), and the impact becomes smaller when their customer base is more different (panels B and C). Intuitively, when the two firms have similar customer base, both firms have large influence on the industry's price index through equation (3). This generates stronger strategic concerns in profit-margin decisions as both firms know that the industry's price index is sensitive not only to their own profit margins but also to their competitor's profit margins. As a result, a change in one firm's financial condition would generate a larger impact on the other firm's profit margins. By contrast, when the two firms' customer base is more different, both firms would have less strategic concerns. On the one hand, the small firm knows that it has less impact on the industry's price index, and thus it optimally chooses not to respond much to the big firm's financial conditions. On the other hand, the big firm knows that the small firm has less impact on the industry's price index, and thus it does not care too much about how the small firm behaves. Therefore, in industries with more unbalanced distribution of customer base, both the small and the big firms' profit margins reflect more about their own financial conditions rather than their competitors' financial conditions due to less strategic concerns.

3.4 Isolating the Predatory Incentive

As discussed in Subsections 3.2 and 3.3, firms cut profit margins and exhibit predation-like behavior in response to negative aggregate and idiosyncratic shocks to customer base.

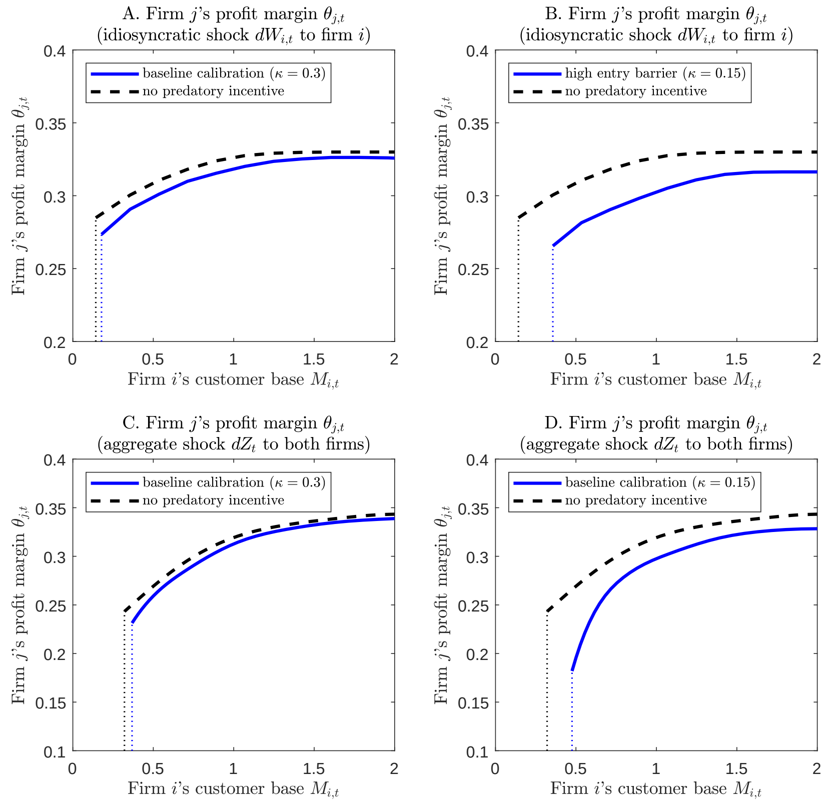
The predation-like behavior of the financially strong firm reflects both its self-defensive and predatory incentives. In this subsection, we use the model to isolate firms' predatory incentives from their predation-like behavior. To this end, we compare the financially strong firm's profit margin in our baseline model (the blue solid lines in Figure 7) to that in a counterfactual scenario (the black dashed lines in Figure 7) where the new entrant has the same amount of customer base as the financially distressed firm that exits the industry, i.e., $M_{new} = M_{i,t}$ when firm i defaults at t.[20] In this counterfactual scenario, by definition, the financially strong firm would not have any predatory incentives because driving its financially weak competitor out of the market does not increase its monopoly power or profitability in the future.

Panels A and B of Figure 7 quantify the predatory incentives arising from idiosyncratic shocks. Specifically, we consider an experiment where the initial customer base of both firms are set at $M_{i,0} = M_{j,0} = 2$. Then, we hold firm j's customer base fixed and introduce a sequence of negative idiosyncratic shocks to firm i, which gradually reduce its customer base until it hits the default boundary. Panel A shows that the financially strong firm j cuts its profit margin more significantly in our baseline industry (the blue solid line) than in the counterfactual scenario (the black dashed line) when firm i becomes more financially distressed due to idiosyncratic shocks (i.e., lower $M_{i,t}$). The difference between the two curves quantifies firm j's real predatory incentives.[21] As a further illustration, in panel B, we consider an industry with higher entry barrier by assuming that the new entrant has a smaller size than that in our baseline industry (i.e., reducing κ from 0.3 to 0.15). This implies that the financially strong firm j would have more predatory incentives because it can capture a larger market share by successfully driving its weak competitor i into default. Comparing the difference betwen the blue solid and black dashed lines in panels A and B, it is clear that firm j has higher predatory incentives in the latter industry. In particular, when firm i is close to its default boundary, firm j is willing to forgo 4% of its profit margin to drive firm i into default.

Panels C and D of Figure 7 quantify the predatory incentives arising from aggregate shocks. Specifically, we set the initial customer base of both firms at $M_{i,0} = 2$ and $M_{j,0} = 3$ so that firm j is the financially stronger than firm i. Then, we introduce a sequence of negative aggregate shocks, which gradually reduce both firms' customer base until the

[20]We assume that the new entrant chooses its initial coupon rate b_{new} to keep the initial debt ratio at l_{new}. This ensures that the new entrant does not default immediately even though it has the same amount of customer base as the exiting firm.

[21]The predatory incentives of firm j quantified by the difference between the two curves also reflect the feedback effect from firm i's profit margin. Intuitively, when firm j lowers its profit margin due to pure predatory incentives, firm i will respond by setting a lower profit margin due to strategic complementarity. This in turn will further lower firm j's profit margin.



Note: In panels A and B, we set the initial customer base of both firms at $M_{i,0} = M_{j,0} = 2$. Then, we hold firm j's customer base fixed and introduce a sequence of negative idiosyncratic shocks to firm i, which gradually reduce its customer base until it hits the default boundary. The blue solid line traces out how firm j's profit margin $\theta_{j,t}$ varies with firm i's customer base $M_{i,t}$ over time in the industry with a low entry barrier ($\kappa = 0.3$, panel A) and the industry with a high entry barrier ($\kappa = 0.15$, panel B). The black dashed line represents the industry in which firms have no predatory incentives (i.e., the new entrant has the same amount of customer base as the exiting firm). In panels C and D, we set the initial customer base of both firms at $M_{i,0} = 2$ and $M_{j,0} = 3$. Then, we introduce a sequence of negative aggregate shocks, which gradually reduce both firms' customer base until the smaller firm (i.e., firm i) hits the default boundary. The curves in panels C and D trace out how firm j's profit margin $\theta_{j,t}$ varies with firm i's customer base $M_{i,t}$ over time in different industries. In all panels, the vertical dotted lines represent default boundaries of firm i in respective cases and we set $\gamma_t = \overline{\gamma}$.

Figure 7: Isolating the real predatory incentives.

smaller firm (i.e., firm i) hits the default boundary. The predatory incentives of firm j is quantified by the difference between the blue solid and black dashed lines, and similarly, we find that predatory incentives are larger in the industry with a higher entry barrier.

3.5 Asset Pricing Implications

The predation-like behavior caused by endogenous competition-distress feedback has two asset pricing implications. First, we show that industries' exposure to discount-rate shocks is amplified due to the competition-distress feedback. Second, we show that our model can explain the joint patterns on the relationship between gross profitability and industries' equity returns and credit spreads. Industries with more persistent leadership are associated with higher profitability, and in such industries, shareholders are less exposed to discount-rate shocks, but debtholders are more exposed to these shocks. This relationship is more pronounced among financially distressed industries, due to the competition-distress feedback.

3.5.1 Amplification Effect on Industry Risk Exposure

Figure 3 implies that a higher discount rate depresses the industry's value not only through the standard discounting effect but also by reducing profit margins due to higher competition. The endogenously intensified competition is further amplified by the feedback loop between competition and financial distress, dramatically increasing the industry's exposure to discount-rate shocks. In particular, the intensified competition in the aggregate states of high discount rates lowers firms' cash flows, which raises the default risk of levered firms. The rising default risk makes financially distressed firms compete more aggressively, which further reduces profit margins and increases the default risk across firms.

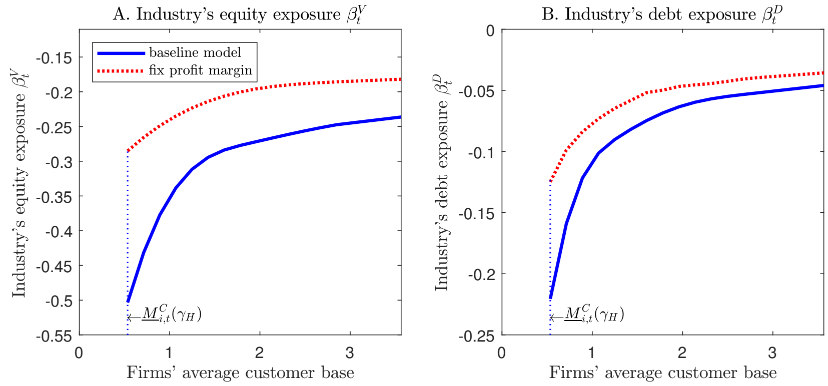
To illustrate this amplification effect, consider the same duopoly industry in Subsection 3.2. Figure 8 plots the industry-level beta of equity (β_t^V) and debt (β_t^D) with respect to discount-rate shocks, calculated as the value-weighted firm-level beta:

$$\beta_t^V = \sum_{i=1}^{2} w_{i,t}^V \beta_{i,t}^V, \text{ where } \beta_{i,t}^V = \frac{V_{i,t}^C(\gamma_H)}{V_{i,t}^C(\gamma_L)} - 1 \text{ and } w_{i,t}^V = \frac{V_{i,t}^C(\gamma_L)}{\sum_{j=1}^2 V_{j,t}^C(\gamma_L)}, \tag{21}$$

$$\beta_t^D = \sum_{i=1}^{2} w_{i,t}^D \beta_{i,t}^D, \text{ where } \beta_{i,t}^D = \frac{D_{i,t}^C(\gamma_H)}{D_{i,t}^C(\gamma_L)} - 1 \text{ and } w_{i,t}^D = \frac{D_{i,t}^C(\gamma_L)}{\sum_{j=1}^2 D_{j,t}^C(\gamma_L)}, \tag{22}$$

for all $M_{i,t}, M_{j,t} > 0$.

The blue solid lines in panels A and B plot the industry's beta of equity and debt when from the discount rate increases from γ_L to γ_H. As a benchmark, the red dotted lines plot the industry's beta in a counterfactual experiment where profit margins remain fixed when the discount rate increases. Our baseline model implies that the industry's equity and debt are much more exposed to discount-rate shocks because profit margins negatively comove with the discount rate. This implication is consistent with that of Dou, Ji and Wu (2020) whose model focuses on all-equity industries (i.e., all firms in the industry are unlevered). Different from Dou, Ji and Wu (2020), our model further implies



Note: We consider a duopoly industry with two identical firms (i.e., $M_{i,t} = M_{j,t}$). Panel A plots the industry's equity exposure (defined in equation 21) as a function of firms' average customer base; and panel B plots industry's debt exposure (defined in equation 22). The blue solid line represents the collusive equilibrium of our baseline model and the red dotted line represents the counterfactual case where industries profit margins remain unchanged when the discount rate rises. The vertical dotted lines represent firms' default boundary in the state of γ_H. In both panels, we use $\gamma_L = \overline{\gamma}$ and $\gamma_H = \overline{\gamma} + 2\text{std}(\gamma_t)$.

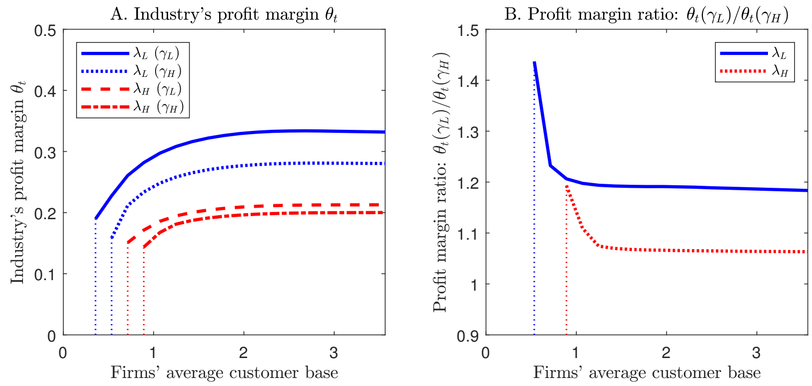
Figure 8: Amplification effect of competition-distress feedback on industry risk exposure.

that the magnitude of the amplification effect, as measured by the distance between the blue solid and red dotted lines, is larger when the industry is more financially distressed. This is due to the positive feedback loop between competition and distress (see panel C of Figure 3).

3.5.2 Profitability and the Exposure of Equity and Debt

We study the model's implications in the cross-section of industries with different turnover rates of market leaders. Our model provide an interpretation for the empirical patterns that equity returns are higher but credit spreads are lower in industries with higher gross profitability. In addition, our model implies that such patterns are more pronounced among financially distressed industries because of the competition-distress feedback.

To fix the idea, consider duopoly industries with identical firms as in Subsection 3.2. For comparison, we focus on two industries with different leadership turnover rates, λ_L and λ_H. Panel A of Figure 9 plots the two industries' profit margins in the aggregate state with a high (γ_H) and a low discount rate (γ_L). Profit margins are much higher in the industry with a low leadership turnover rate (λ_L). Moreover, in this industry, profit margins drop more substantially in response to an increase in the discount rate from γ_L to γ_H. Panel B makes this point clearer by comparing the profit margin ratios across the two aggregate states, i.e., $\theta_t(\gamma_L)/\theta_t(\gamma_H)$, in the two industries. In both industries, profit margin ratios are higher when firms within the industry are more financially distressed, reflecting the competition-distress feedback. Importantly, the sensitivity of profit margins



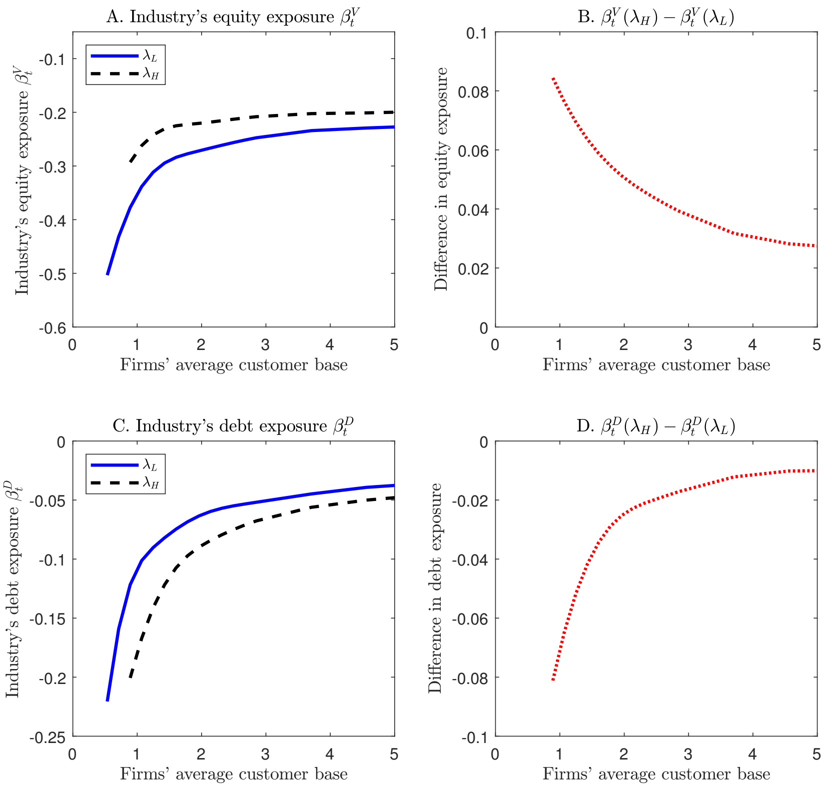
Note: We consider duopoly industry with two identical firms (i.e., $M_{i,t} = M_{j,t}$). Panel A plots the industry's profit margin θ_t as a function of firms' average customer base, where θ_t is defined in equation (6). The blue solid and dotted lines represent the industry with λ_L in the states of γ_L and γ_H respectively. The red dashed and dash-dotted lines represent the industry with λ_H in the states of γ_L and γ_H respectively. Panel B plots the percentage change in profit margin when the aggregate state changes from γ_H to γ_L, i.e., $\theta_t(\gamma_L)/\theta_t(\gamma_H)$. The blue solid and red-dotted lines represent the industry with λ_L and the one with λ_H respectively. In all panels, the vertical dotted lines represent firms' default boundaries in respective cases. We use $\lambda_L = 0$, $\lambda_H = 0.15$, $\gamma_L = \overline{\gamma}$ and $\gamma_H = \overline{\gamma} + 2\text{std}(\gamma_t)$.

Figure 9: Implications of leadership turnover rates on profit margins.

to discount-rate shocks is much larger in the industry with λ_L (the blue solid line). Intuitively, a higher rate of market leadership turnover has a similar effect to that of a higher discount rate. It motivates firms to compete more aggressively to generate more profits now rather than in the future, which dampens the collusion incentive, resulting in both lower levels and lower sensitivity of profit margins to aggregate discount-rate shocks.

In industries with lower turnover rates of market leadership, shareholders are more exposed to discount-rate shocks because of the larger fluctuations in profit margins and cash flows. Panel A of Figure 10 compares the equity beta (defined in equation 21) of the two industries. The industry with λ_L is more exposed to the discount-rate shocks than the industry with λ_H. Moreover, panel B Figure 10 shows that the difference in equity beta is particularly large when firms within the industry are financially distressed thanks to the competition-distress feedback.

However, our model implies that debtholders are less exposed to discount-rate shocks in industries with lower turnover rates of market leadership. This is because these industries have higher profit margins, which imply that debt holders face lower default risk (see the default boundaries in panel A of Figure 9). Panel B of Figure 10 shows that the debt beta (defined in equation 21) in the industry with λ_L is less negative (the blue solid line), which is opposite to the pattern of equity beta (the blue solid line in panel A of Figure 10). Moreover, panel D shows that similar to equity beta, the difference in



Note: We consider duopoly industry with two identical firms (i.e., $M_{i,t} = M_{j,t}$). Panel A plots the industry's equity exposure (defined in equation 21). The blue solid and black dashed lines represent the industry with λ_L and λ_H respectively. We adjust the coupon rate b_0 in the industry with λ_H so that it has the same average debt ratio as the industry with λ_L. Panel B plots the difference in equity exposure of the two industries, i.e., $\beta_i^V(\lambda_H) - \beta_i^V(\lambda_L)$. Panel C plots the industry's debt exposure (defined in equation 22) and panel D plots the difference in debt exposure of the two industries. In all panels, the vertical dotted lines represent firms' default boundaries in respective cases. We use $\lambda_L = 0$, $\lambda_H = 0.15$, $\gamma_L = \overline{\gamma}$ and $\gamma_H = \overline{\gamma} + 2\text{std}(\gamma_t)$.

Figure 10: Implications of leadership turnover rate on industry risk exposure.

debt beta between the two industries is larger when firms within the industry are more financially distressed.

Taken together, our model implies that in industries with higher gross profitability (i.e., lower λ), shareholders are more exposed but debtholders are less exposed to aggregate discount-rate shocks. Thus, our model provides one explanation for the joint patterns on the cross-industry relation between gross profitability, equity returns, and credit spreads, which is generally viewed as a strengthened version of gross profitability premium.[22] Further, our model implies that this relation would be more pronounced among financially distressed industries. We provide empirical evidence supporting these predictions in

[22] Dou, Ji and Wu (2020) focus on all-equity firms and thus their model does not have any prediction on the relation between gross profitability and credit spreads, or how they interact with financial distress.

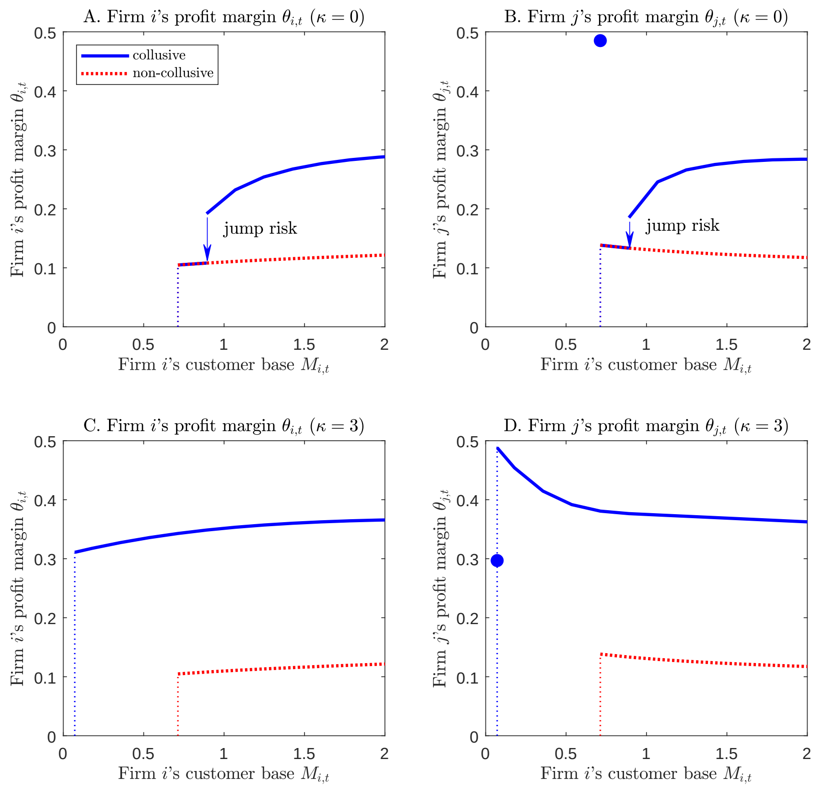
Section 4.

3.6 Endogenous Price Wars

In our model, when one firm defaults, a new entrant with initial customer base $M_{new} = \kappa M_{j,t}$ immediately enters the market. A smaller value of κ implies that the industry has a lower level of entry barrier. In this subsection, we show that when the industry's entry barrier is sufficiently high, the financially strong firm would wage a price war against its financially weak competitor, reflecting the strong firm's high real predatory incentives.

To make a stark comparison, we consider an industry with no entries by setting $\kappa = 0$. Panels A and B of 11 plot the two firms' profit margins as a function of firm i's customer base $M_{i,t}$ holding firm j's customer base fixed at $M_{j,t} = 2$. In this industry with no entries, profit margins are lower compared to the baseline industry in Figure 4 due to the lack of collusion. Intuitively, both firms know that by driving their competitor out of the market, they can monopolize the industry and enjoy much higher profit margins in the future. Thus, they have less incentive to collude with each other ex-ante. Even more dramatically, the two firms abandons collusion when firm i's customer base $M_{i,t}$ drops below 0.85 and becomes financially distressed. The collusive profit margins suddenly jump downward at $M_{i,t} = 0.85$ and become equal to the non-collusive profit margins for $M_{i,t} < 0.85$. In Appendix A.4, we show that it is the financially strong firm, firm j in this example, that wants to drive its financially weak competitor i into default by waging the price war. The downward jump in firm j's profit margins reflects its high real predatory incentives.

What would happen if the size of entrants is larger than the incumbent firm? In panels C and D of Figure 11, we consider an industry with large new entrants by setting $\kappa = 3$. In this industry, the two firms collude on much higher profit margins compared to the baseline industry in Figure 4. This is because both firms worry about losing market power to the large new entrants, and they thus collaborate with each other on maintaining higher profit margins in order to reduce the default risk. In particular, panel D shows that when firm i's customer base decreases, firm j is willing to sacrifice its demand by significantly increasing its profit margin, with the intention to help increase firm i's cash flows.



Note: In panels A and B, we consider an industry with no entry ($\kappa = 0$) and plot the two firms' profit margins as a function of firm i's customer base $M_{i,t}$. In panels C and D, we consider an industry with large new entrants ($\kappa = 3$). In all panels, the blue solid and red dash-dotted lines represent the collusive equilibrium and the non-collusive equilibrium. The blue dots in panels B and D represent the profit margin that firm j would set immediately after firm i defaults and exits the market. We set $\gamma_t = \overline{\gamma}$ and $M_{j,t} = 2$.

Figure 11: Illustration of endogenous price wars and jump risks in cash flows.

4 Empirical Evidence

4.1 Data Description

In the empirical section, we take firm-level accounting data from Compustat, stock return data from CRSP, credit spread data, and the fluidity data from Hoberg, Phillips and Prabhala (2014). The credit spread dataset we use spans from 1973 to 2018, with cross sectional coverage of 400 to 750 firms. We exclude all financial firms and utility firms (SIC codes between 6,000 and 6,999 and between 4,900 and 4,999, respectively). Following the literature (e.g., Frésard, 2010), at least 10 firms are required in each industry-year to ensure that the industry-level variables, such as industry-level profit margin and returns, are well-behaved. The firm-level financial distress measure is constructed as in Campbell, Hilscher and Szilagyi (2008). Industry-level fundamental variables—profit

Table 2: Financial distress and profit margins' loading on discount rates

	(1)	(2)	(3)	(4)	(5)	(6)
			$\Delta \ln(1 + \text{PM}_{i,t})$			
Distress quintiles	Q1 (L)	Q2	Q3	Q4	Q5 (H)	$5 - 1$
ΔDiscount rate$_t$	-0.002	-0.022	0.007	-0.063	-0.095	-0.093**
	[-0.12]	[-1.48]	[0.51]	[-1.29]	[-1.59]	[-2.07]
Observations	47	47	47	47	47	47
R-square	0.000	0.021	0.001	0.050	0.064	0.060

Note: This table reports results from the annual time-series regressions: $\Delta \ln(1 + \text{PM}_{i,t}) = a_i + b_i \Delta\text{Discount rate}_t + \epsilon_{i,t}$ with $i = 1, \cdots, 5$. Here industries are sorted into 5 quintiles based on the industry-level financial distress measure. $\Delta \ln(1 + \text{PM}_{i,t}) \equiv \ln(1 + \text{PM}_{i,t}) - \ln(1 + \text{PM}_{i,t-1})$, where $\ln(1 + \text{PM}_{i,t})$ is the logged one plus simple average profit margins of the industries in the ith quintile. Discount rate$_t$ is calculated by fitting a time series regression of forward 12-month stock market return on the smoothed EP ratio, and then take the fitted value at the end of year t. ΔDiscount rate$_t$ is the AR1 residual of the discount rate at year t. The sample of this table spans the period from 1972 to 2018. The exposure of profit margins to discount rates, b_i, is reported in the table. We omit the coefficients for the constant terms a_i in the table for brevity. The standard errors are robust to heteroskedasticity and autocorrelation. We include t-statistics in square brackets. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

margin, distress, operating leverage, idiosyncratic shocks, fluidity—are aggregated based on averaging firm-level fundamental variables weighted by sales. Industry-level stock return is weighted by market capitalization. Industry-level credit spreads are weighted by the bonds' par value. When organizing the cross section of accounting data, we first map fiscal year to calendar year and when applicable, map to market data starting from the June of the next year, following the practice of Fama and French (1993). The central aggregate shocks in our theory is the discount rate shock, which drives the competition intensity across all industries. The empirical proxy for discount rates is based on the smoothed earning-price ratio motivated by the return predictability studies (e.g., Campbell and Shiller, 1988, 1998; Campbell and Thompson, 2008), and is obtained from Robert Shiller's website.

4.2 Empirical Results

We provide empirical evidence to support the main theoretical implications. First, we provide empirical support for the financial feedback and contagion effect using profit margin data in Section 4.2.1.

4.2.1 Profit Margin Implications

Profit Margins' Exposure to Discount Rates. Table 2 reports the loadings of the change in industry profit margin on the shock to the discount rate. Industries are sorted into five groups based on industry-level financial distress level. Average profit margin and its change are then computed for each group. The loading of industry-level profit margins on discount rates is estimated for each group using time-series regressions. The table shows that industries with higher financial distress level have more negative exposure to shocks in discount rates than those with lower financial distress level, consistent with the model implications (see Figure 3). The estimated relationship between financial distress and exposure to discount rates is (almost) strictly monotonic, and the difference in loadings between group 5 (high financial distress) and group 1 (low financial distress) is statistically significant. The economic scale of the difference is also large. The coefficient of -0.095 in column 5 of the table means that 1% increase in discount rate shock corresponds to 0.095% decrease in profit margin change, for the most financially distressed industries in the cross section.

Feedback between Industry Profit Margin and Financial Distress. Table 3 shows the feedback between industry profit margin and financial distress. The first two columns show that when the industry is distressed this year, it is likely to have lower profit margin in the next year. The next two columns show that when the profit margin of the industry is low, it is likely to have high level distress in the next year. The last two columns show that when the current competition level in the industry is high, the industry is likely to be more distressed in the next year. These results confirm the basic channels of the model. Here, profit margin and distress are in fractional unit, while fluidity are in the original unit as in Hoberg, Phillips and Prabhala (2014). The coefficient of -4.274 in the first column means that a 1% increase in distress this year corresponds to a 4.274% decrease in the profit margin of the industry in the next year. The standard deviation of the fluidity measure is about 0.65 and that for the aggregate distress measure is about 0.00044. Hence, a coefficient of 0.0004 in the 5th column means a 1 standard deviation increase fluidity corresponds to 0.65 standard deviation increase in distress level the next year.

Financial Contagion through Product-Market Competition. Table 4 tests our model's prediction on the financial contagion effect among the market leaders with an industry. The model predicts that the adverse idiosyncratic shock to a financially distressed big player within an industry will lead to more aggressive price setting behavior with decreased profit margin; in the imperfect product market, other big players within the

Table 3: Feedback between industry profit margin and distress

	(1)	(2)	(3)	(4)
	All Firms		Top 6	
	$\log(1+\text{PM}_{i,t})$	$\text{Distress}_{i,t}$	$\log(1+\text{PM}_{i,t})$	$\text{Distress}_{i,t}$
$\text{Distress}_{i,t}$	-9.415^{***}		-7.018^{***}	
	$[-5.65]$		$[-4.39]$	
$\log(1+\text{PM}_{i,t})$		-0.009^{***}		-0.022^{***}
		$[-3.44]$		$[-4.71]$
$\text{Distress}_{i,t-1}$		0.083		0.056
		[1.34]		[1.17]
$\log(1+\text{PM}_{i,t-1})$	0.419^{***}		0.399^{***}	
	[6.04]		[7.58]	
Observations	4,754	4,754	4,754	4,754
R-square	0.467	0.255	0.490	0.215

Note: This table reports results from the following industry-annual level panel regressions: $\text{PM}_{i,t} = a_1 + b_{11}\text{PM}_{i,t-1} + b_{12}\text{Distress}_{i,t} + \sum_t \delta_{1,t} FE_t + \sum_i \rho_{1,i} FE_i + \epsilon_{i,t}$, and $\text{Distress}_{i,t} = a_2 + b_{21}\text{Distress}_{i,t-1} + b_{22}\text{PM}_{i,t} + \sum_t \delta_t FE_t + \sum_i \rho_i FE_i + \epsilon_{i,t}$. The variables $\log(1+PM_{i,t})$ and $Distress_{i,t}$ are the logged one plus average profit margin and the average distress of the industry of firm i in year t. Industry level profit margins are winsorized from below at the 1st percentile to deal with extreme negative values that are potentially below negative one. The variables FE_t and FE_i are time and industry fixed effect. Average within an industry is weighted by sales. All variables are in fractional unit. The sample of this table spans the period from 1972 to 2018. The standard errors are robust to heteroskedasticity and autocorrelation. We compute t-statistics using Driscoll-Kraay standard errors with 5 lags, and include t-statistics in square brackets. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

same industry will conduct predation-like behavior by pushing down their profit margins (see Panel A and Panel D of Figure 5). Such predation-like behavior can be mainly driven by predatory incentives or self-defensive motives (see Panel C and Panel E of Figure 5). Additionally, the model predicts that the financial contagion effect is greater in more balanced industries, i.e., the market leaders are of more balanced market shares (see Figure 6). To see the financial contagion effect in the data, in each year we split the top firms of each industry into 3 groups, tertile-sorting based on their financial distress level. Group L (the first tertile) contains the financially healthy firms (i.e., the firms whose financial distress measure is in the lowest tertile), and group H (the third tertile) contains the financially distressed ones (i.e. the firms whose financial distress measure is in the highest tertile). We then construct idiosyncratic shocks to each group of firms. Three

Table 4: Financial contagion effect among market leaders and heterogeneity across industries by market share imbalance.

		(1)	(2)	(3)	(4)	(5)
		$\log(1+PM^{(L)}_{i,t})$				
Market share imbalance tertiles		All	1 (B)	2	3 (I)	$3-1$
$\text{IdioShock}^{(H)}_{i,t}$	Method 1:	0.030***	0.051***	0.027*	0.023**	-0.028*
		[3.36]	[4.16]	[1.96]	[2.16]	[-1.94]
	Method 2:	0.033***	0.055***	0.029*	0.024	-0.031*
		[3.33]	[4.86]	[1.94]	[1.65]	[-1.81]
	Method 3:	0.031***	0.053**	0.031**	0.018	-0.035*
		[3.29]	[4.38]	[2.06]	[1.42]	[-1.86]

Note: This table reports results from the following industry-year level panel regressions: $\log(1+PM^{(L)}_{i,t}) = b_H\text{IdioShock}^{(H)}_{i,t} + b_L\text{IdioShock}^{(L)}_{i,t} + \sum_{j=1}^{5}\gamma_j \log(1+PM^{(L)}_{i,t-j}) + \delta_t + \rho_i + \epsilon_{i,t}$. The idiosyncratic shocks to each group of market leaders are constructed using three methods: (i) method 1 is firm's sales growth subtracting the cross sectional average sales growth; (ii) method 2 is time series regression residual of firm's sales growth on the cross sectional average sales growth; and (iii) method 3 is time series regression residual of firm's sales growth on the first PC extracted from a panel of industry level sales growth. The financial contagion coefficient, denoted by b_H, is reported in the first four columns. Column 1 shows b_H estimates based on the whole sample, column 2 shows b_H estimates based on the subsample 1 containing the most balanced industries in terms of market shares, column 3 shows b_H estimates based on the subsample 2 containing the moderately balanced or imbalanced industries, column 4 shows b_H estimates based on the subsample 3 containing the most imbalanced industries, and column 5 shows the difference of the columns 2 and 4. Results in this table are based on the market leaders within each SIC-4 industry, defined as the top 6 firms. Data in this regression ranges from 1976 to 2018. The standard errors are robust to heteroskedasticity and autocorrelation. We compute t-statistics using Driscoll-Kraay standard errors with 5 lags, and include t-statistics in square brackets. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

methods of constructing the idiosyncratic shocks are adopted for robustness, and the details are described in Appendix C. We run the following industry-annual level panel regression:

$$\log(1+PM^{(L)}_{i,t}) = b_H\text{IdioShock}^{(H)}_{i,t} + b_L\text{IdioShock}^{(L)}_{i,t} + \sum_{j=1}^{5}\gamma_j \log(1+PM^{(L)}_{i,t-j}) + \delta_t + \rho_i + \epsilon_{i,t}. \tag{23}$$

Here the coefficient b_H captures the effect of group H (financially distressed) firms' idiosyncratic shock on the profit margin of group L (financially healthy) firms, hence captures the financial contagion effect. We emphasize that group L (financially healthy) firms' own idiosyncratic shock $\text{IdioShock}^{(L)}_{i,t}$, group L (financially healthy) firms' past profit margins $\sum_{j=1}^{5}\gamma_j \log(1+PM^{(L)}_{i,t-j})$, the time fixed effects, and the industry fixed effects are controlled for in the regression.

The first column, titled "All", of Table 4 shows that the financial contagion effect is strong and robust to the choice of the specific measure for idiosyncratic shocks. A coefficient of 0.035 means a 100% increase in idiosyncratic shock to the group H (financially distressed) firms' sales (note all idiosyncratic shocks are constructed based on sales) corresponds to a 3.5% increase in profit margins of the group L (financially healthy) firms in the same industry and year. Additionally, the model makes an unique prediction that such financial contagion effect should be significantly greater when the market shares of the distressed and healthy firms are more balanced.

To test this theoretical prediction in data, we split the aforementioned panel regression into three subsamples based on an imbalance measure, defined as the absolute value of the log sales ratio of the group L (financially healthy) firms over the group H (financially distressed) ones. For example, when the group L (financially healthy) and group H (financially distressed) firms are of equal size (i.e. they have the same sales), the absolute value would achieve zero — the theoretical minimum. By contrast, when the group L (financially healthy) firms are much larger or smaller than the group H (financially distressed) firms, the absolute value would be a large positive number. The subsample 1 contains balanced industries whose imbalance measure lies in the first tertile in a particular year, and the subsample 3 contains imbalanced industries whose imbalance measure lies in the third tertile in a particular year.

Columns 2 – 4 of table 4 report the financial contagion coefficient b_H for the three subsamples. The financial contagion effect is the largest in subsample 1 containing the most balanced industries and the smallest in subsample 3 containing the most imbalanced industries. The difference between the estimated coefficients in subsample 1 and 3 is statistically significant, consistent with the model's prediction (see Figure 6).

Financial Contagion and Entry Threats. Table 5 tests our model's prediction on how industry's entry bar affects the financial contagion effect among the market leaders. The model predicts that the financial contagion effect is *greater* in more balanced industries in industries with *higher* entry costs. Entry costs of each industry-year is computed as the median of the trailing five year average of the net total property, plant, and equipment within the industry-year. The key idea behind the empirical measure is that sunk entry costs mainly arise from construction costs of business premises (e.g., Sutton, 1991; Karuna, 2007; Barseghyan and DiCecio, 2011). It is very intuitive: the potential challengers among the market followers need to incur higher setup costs to compete with and displace the existing market leaders if it requires higher business premises to be market leaders in this industry.

To test this theoretical prediction in data, we split the panel regression into three

Table 5: Financial contagion effect among market leaders and heterogeneity across industries by entry costs.

		(1)	(2)	(3)	(4)	(5)
		$\log(1+PM_{i,t}^{(L)})$				
Entry cost tertile		All	1 (Low)	2	3 (High)	$3-1$
$\text{IdioShock}_{i,t}^{(H)}$	Method 1:	0.031***	0.031**	0.020***	0.061***	0.030
		[3.36]	[2.02]	[2.93]	[3.40]	[1.52]
	Method 2:	0.033***	0.020*	0.024**	0.073***	0.053***
		[3.34]	[1.72]	[2.30]	[3.82]	[2.84]
	Method 3:	0.031***	0.014	0.023**	0.076***	0.061***
		[3.28]	[1.28]	[2.52]	[3.71]	[3.02]

Note: This table reports results from the following industry-year level panel regressions: $\log(1+PM_{i,t}^{(L)}) = a + b_H \text{IdioShock}_{i,t}^{(H)} + b_L \text{IdioShock}_{i,t}^{(L)} + \sum_{j=1}^{5} \gamma_j \log(1+PM_{i,t-j}^{(L)}) + \sum_t \delta_t FE_t + \sum_i \rho_i FE_i + \epsilon_{i,t}$. The idiosyncratic shocks to each group of market leaders are constructed using three methods: (i) method 1 is firm's sales growth subtracting the cross sectional average sales growth; (ii) method 2 is time series regression residual of firm's sales growth on the cross sectional average sales growth; and (iii) method 3 is time series regression residual of firm's sales growth on the first PC extracted from a panel of industry level sales growth. The financial contagion coefficient, denoted by b_H, is reported in the first four columns. Column 1 shows b_H estimates based on the whole sample, column 2 shows b_H estimates based on the subsample 1 containing the most balanced industries in terms of market shares, column 3 shows b_H estimates based on the subsample 2 containing the moderately balanced or imbalanced industries, column 4 shows b_H estimates based on the subsample 3 containing the most imbalanced industries, and column 5 shows the difference of the columns 2 and 4. Results in this table are based on the market leaders within each SIC-4 industry, defined as the top 6 firms. Data in this regression ranges from 1976 to 2018. The standard errors are robust to heteroskedasticity and autocorrelation. We compute t-statistics using Driscoll-Kraay standard errors with 5 lags, and include t-statistics in square brackets. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

subsamples based on the entry cost measure. The subsample 1 contains the industries whose entry cost measure lies in the first tertile in a particular year, and the subsample 3 contains the industries whose entry cost measure lies in the third tertile in a particular year.

Columns 2 – 4 of table 5 report the financial contagion coefficient b_H for the three subsamples. The financial contagion effect is the largest in subsample 1 containing the industries with the lowest entry costs and the smallest in subsample 3 containing the industries with the highest entry costs. The difference between the estimated coefficients in subsample 1 and 3 is statistically significant, consistent with the model's prediction.

Profit Margin Volatility and Market Concentration. Here we test the model's prediction that more concentrated industries tend to have lower volatility in profit margin in the future. We measure each industry's concentration level with the Herfindahl-Hirschman Index (HHI). As a crude way to make sure that this measure behaves well, we require at least 6 firms in each industry-year. The first row of the table shows that firms in more

Table 6: Profit margin volatility across industries

	(1)	(2)
	$PMVol_{i,t+1}$	
	All Firms	Top 6
$HHI_{i,t}$	-0.035^{***}	-0.026^{**}
	[-2.78]	[-2.49]
$PMVol_{i,t}$	0.246^{***}	0.191^{***}
	[8.13]	[6.67]
$Distress_{i,t}$	5.187^{***}	4.030^{***}
	[5.76]	[4.03]
$OL_{i,t}$	-0.002	-0.009^{***}
	[-0.59]	[-2.79]
Observations	148,615	29,594
R-square	0.173	0.175

Note: This table reports results from the following firm-year level panel regressions: $PMVol_{i,t+1} = a + b_1 HHI_{i,t} + b_2 PMVol_{i,t} + b_3 Distress_{i,t} + b_4 OL_{i,t} + \sum_t \delta_t FE_t + \sum_i \rho_i FE_i + \epsilon_{i,t}$. Here, $PMVol_{i,t+1}$ is the volatility of logged one plus the quarterly winsorized profit margin for firm i over year $t+1$. The variables $HHI_{i,t}$, $Distress_{i,t}$, and $OL_{i,t}$ are the Herfindahl-Hirschman Index (HHI) for the industry of firm i, the average financial distress level for the industry of firm i, and the average operating leverage for the industry of firm i in year t. FE_t and FE_i are time and industry fixed effect. The computation of the HHI requires at least 6 firms in each industry-year, and it is based on all firms in the industry for Column 1 and top 6 firms for Column 2. Average within an industry is weighted by sales. The regression is weighted by the firm's sale in year t. For each firm i, we compute its quarterly profit margin, and then winsorize at the 5th and 95th percentile values on the panel. This winsorization step is necessary as firm level profit margin can attain very extreme values. We then compute each firm's profit margin volatility over the next four quarters, and regress it on the industry's HHI. All other variables are in fractional unit. The standard errors are robust to heteroskedasticity and autocorrelation. We compute t-statistics using Driscoll-Kraay standard errors with 5 lags, and include t-statistics in square brackets. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

concentrated industries (i.e., the industries with a higher HHI), the volatility of profit margins in the next 12 months is lower. Here both profit margin volatility and HHI are in fractional units. A coefficient of -0.043 means a 0.15 (about the standard deviation of the HHI measure) increase in HHI corresponds to an about 65% decrease in profit margin volatility.

4.2.2 Asset Pricing Implications

Stock Returns, Credit Spreads, and Gross Profitability. Table 7 shows the relationship between profitability, defined in Novy-Marx (2013), and stock returns and credit spreads. Panel A shows that when an industry has high profitability, firms in it have higher stock

Table 7: Excess Returns, Credit Spreads, and Gross Profitability

	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A: Excess Returns			
	Q1(Low)	Q2	Q3	Q4	Q5 (High)	$5-1$
α	0.007***	0.010***	0.010***	0.009***	0.011***	0.003**
	[3.79]	[5.22]	[4.32]	[4.12]	[6.02]	[2.36]
N	671	671	671	671	671	671
			Panel B: Credit Spreads			
	Q1(Low)	Q2	Q3	Q4	Q5 (High)	$5-1$
α	0.005***	0.004***	0.004***	0.003***	0.003***	-0.002***
	[7.60]	[7.01]	[7.93]	[8.09]	[10.92]	[-4.47]
N	545	545	545	545	545	545

Note: This table reports results from the following monthly time-series regressions: $Spread_{i,t} = \alpha_i + \epsilon_{i,t}$ and $Ret_{i,t} = \alpha_i + \epsilon_{i,t}$. Here, the cross section of industries are sorted into 5 bins based on industry level gross profitability, defined as in Novy-Marx (2013). $Ret_{i,t}$ is the market value weighted returns among the stocks in the bin i. $Spread_{i,t}$ is the par value weighted average credit spread among firms within bin i. Annual accounting data of year t are mapped to credit spread and return data from Q2 of year t+1 to Q1 of year t+2, as in Fama and French (1993) and Novy-Marx (2013). The coefficient α equals the time series mean of the bin's return and credit spread. Returns are in fractional unit, and credit spreads are in annualized fractional unit. For the credit spread regression, t-statistics robust to autocorrelation are reported in square brackets.

returns relative to those in the low profitability industries. This confirms the profitability puzzle in Novy-Marx (2013) at the industry level. Panel B shows that when an industry has high profitability, firms in it have lower credit spread relative to those in the low profitability industries.

Credit Spreads' Exposure to Discount Rates. Table 8 reports the loadings of firms' credit spread on the discount rate. Here industries are sorted into five groups based on the industry-level financial distress level. Average credit spread is then computed for each group, and each group's loading on the discount rate is estimated using a time-series regression. The table shows that credit spreads have positive loadings on the discount rate, which means that corporate bond prices are on average pro-cyclical. Importantly, the credit spread loadings become more positive as the financial distress level increases, and thus, the corporate bond price loadings on the discount rate become more negative as the financial distress level increases, consistent with the model's implication shown in Panel B of Figure 8. The difference in loadings for group 1 and 5 is statistically significant.

Table 8: Financial Distress and Credit Spread's Loading on Discount Rates

	(1)	(2)	(3)	(4)
		Panel A: All firms		
		ΔCredit spread$_{i,t}$		
Distress tertiles	T1(L)	T2	T3 (H)	$3-1$
ΔDiscount rate$_t$	0.019	0.044**	0.024**	0.004*
	[1.61]	[2.40]	[1.93]	[1.73]
N	180	180	180	180
		Panel B: Top 6 firms		
		ΔCredit spread$_{i,t}$		
Distress tertiles	T1(L)	T2	T3 (H)	$3-1$
ΔDiscount rate$_t$	0.018*	0.026	0.037**	0.019*
	[1.90]	[1.53]	[2.47]	[1.78]
N	180	180	180	180

Note: This table reports results from the following quarterly time-series regressions: $\Delta\text{Credit spread}_{i,t} = \alpha_i + \beta_i \Delta\text{Discount rate}_t + \epsilon_{i,t}$. Here the cross section of industries are sorted into 3 bins based on industry financial distress level. $\Delta\text{Credit spread}_{i,t} \equiv \text{Credit spread}_{i,t} - \text{Credit spread}_{i,t-1}$, where Credit spread$_{i,t}$ is the par-value-weighted average credit spread among firms within ith bin. Discount rate$_t$ is calculated by fitting a time series regression of forward 12-month stock market return on the smoothed EP ratio, and then take the fitted value at the end of year t. ΔDiscount rate$_t$ is the AR1 residual of the discount rate at year t. Top 6 firms are determined by sales. Annual accounting data of year t are mapped to credit spread data from quarter 2 of year $t+1$ to quarter 1 of year $t+2$, as in Fama and French (1993). Each group's credit spread loadings, β_i, are reported in the table. The t-statistics robust to heteroskedasticity and autocorrelation are reported in square brackets.

The Interaction of Gross Profitability Premium and Financial Distress. Table 9 shows the average returns of 9 double-sorted portfolios. The cross section of industry level stock returns are first sorted into 3 bins based on their respective distress level, and then each bin is sorted into 3 bins based on their profitability. The positive numbers in column "3-1" shows that a strategy that longs high profitability stocks and short low profitability industries earns positive returns on average. This repeats the message in Panel A of Table 7. The new point of Table 9 is that this return increases with the industries' distress level. Among the high distress industries, a portfolio that long high profitability and short low profitability earns 68 basis points per month. In contrast, among the low distress industries, the return is only 3 basis points. The difference of 66 basis points is statistically significant at the 5% level.

Table 9: The Gross Profitability Premium and Financial Distress

	1 (Low Profit)	2	3 (High Profit)	$3-1$
1 (Low Distress)	0.0109***	0.0133***	0.0111***	0.0002
	[4.90]	[6.29]	[5.52]	[0.12]
2	0.0076***	0.0111***	0.0125***	0.0050**
	[3.07]	[4.02]	[4.92]	[2.50]
3 (High Distress)	0.0070**	0.0079**	0.0140***	0.0070***
	[2.13]	[2.44]	[4.71]	[2.61]
$3-1$	-0.0039	-0.0054**	0.0029	0.0068**
	[-1.52]	[-2.08]	[1.30]	[2.39]

Note: This table reports average monthly returns of 9 portfolios consisting of industries, sequentially sorted on the industry's distress and then profitability. Annual accounting data, used in the construction of the profitability measure, of year t are mapped to credit spread and return data from Q2 of year t+1 to Q1 of year t+2, as in Fama and French (1993) and Novy-Marx (2013). Quarterly accounting data used in the construction of the distress measure is mapped to return data with a two-month lag, as in Campbell, Hilscher and Szilagyi (2008). Sample starts in 1975m8, as before that month the data coverage is too unstable to performance double sorting. T-statistics are reported in square brackets.

Credit Spread Volatility and Market Concentration. Here we test the model's prediction that more concentrated industries tend to have lower volatility in credit spread in the future. We measure each industry's concentration level with the Herfindahl-Hirschman Index (HHI). As a crude way to make sure that this measure behaves well, we require at least 6 firms in each industry-year. The first row of the table shows that firms in more concentrated industries (i.e., the industries with a higher HHI), the volatility of credit spreads in the next 12 months is lower. Here both credit spread volatility and HHI are in fractional units.

5 Conclusion

In this paper, we explore the implication of endogenous competition on credit risks. We develop a general-equilibrium asset pricing model incorporating dynamic supergames of profit-margin competition among firms. In our model, firms compete more fiercely in recessions through profit-margin undercutting, resulting in low cash flows and high credit risks. The high credit risks induce more intense competition in product markets, further reducing profit margins and cash flows. This feedback mechanism between product market competition and financial leverage increases credit risks and generates high credit spreads.

Table 10: Credit Spread Volatility across Industries

	(1)	(2)
	$\text{CSVol}_{i,t}$	
	All Firms	Top 6
$HHI_{i,t}$	-0.252^{***}	-0.162^{**}
	$[-3.49]$	$[-2.46]$
$CSVol_{i,t}$	0.408^{***}	0.353^{***}
	[16.69]	[12.16]
$Distress_{i,t}$	3.625	6.721
	[0.41]	[1.56]
$OL_{i,t}$	-0.038^{*}	-0.008
	$[-1.80]$	$[-0.46]$
N	7253	4870
R^2	0.415	0.426

Note: This table reports results from the following firm-year level panel regressions: $CSVol_{i,t+1} = a + b_1 HHI_{i,t} + b_2 \text{CSVol}_{i,t} + b_3 \text{Distress}_{i,t} + b_4 \text{OL}_{i,t} + \sum_t \delta_t FE_t + \sum_i \rho_i FE_i + \epsilon_{i,t}$. Here, $CSVol_{i,t+1}$ is the volatility of the monthly credit spread for firm i over year $t+1$. The variables $HHI_{i,t}$, $Distress_{i,t}$, and $OL_{i,t}$ are the Herfindahl-Hirschman Index (HHI) for the industry of firm i, the average distress level for the industry of firm i, and the average operating leverage for the industry of firm i in year t. FE_t and FE_i are time and industry fixed effect. Average within an industry is weighted by sales. The regression is weighted by the bond's par value. The spread on which we compute the volatility are in annualized, percentage unit. All other variables are in fractional unit. The standard errors are robust to heteroskedasticity and autocorrelation. We include t-statistics in square brackets. *, **, and *** indicate statistical significance at the 10%, 5%, and 1%, respectively.

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Appendix

A Supplementary Information on Model Analyses

A.1 Boundary Condition at $M_{i,t} = +\infty$

When $M_{i,t} = +\infty$, firm i is essentially a monopoly in the industry with negligible default risk because its competitor j is negligible for any value of $M_{j,t}$. Thus, the boundary condition of firm i's equity value at $M_{i,t} = +\infty$ should satisfy:

$$\lim_{M_{i,t}\to\infty} \frac{\partial}{\partial M_{i,t}} V_i^N(x_t) = \lim_{M_{i,t}\to\infty} \frac{\partial}{\partial M_{i,t}} V_i^C(x_t) = \lim_{M_{i,t}\to\infty} \frac{\partial}{\partial M_{i,t}} V_i^D(x_t) = \lim_{M_t\to\infty} \frac{\partial}{\partial M_t} U(M_t, \gamma_t), \tag{24}$$

where $U(M_t, \gamma_t)$ is the equity value of an unlevered monopoly industry with customer base M_t. In this monopoly industry, the demand curve facing the monopoly firm is given by equation (1)

$$C_t = M_t P_t^{-\epsilon}, \tag{25}$$

and the evolution of the single firm's customer base M_t is

$$\frac{\mathrm{d}M_t}{M_t} = \left[g + \alpha (C_t/M_t)^h\right] \mathrm{d}t + \varsigma \mathrm{d}Z_t + \sigma \mathrm{d}W_t, \tag{26}$$

where W_t and Z_t are independent standard Brownian motions. Thus, the HJB equation that determines $U(M_t, \gamma_t)$ can be written as

$$0 = \max_{\theta_t} \Lambda_t \left[(1-\tau)[\omega^{1-\epsilon}\theta_t(1-\theta_t)^{\epsilon-1} M_{i,t} - b_i] - \lambda U(M_t, \gamma_t)\right] \mathrm{d}t + \mathbb{E}_t \left[\mathrm{d}(\Lambda_t U(M_t, \gamma_t))\right]. \tag{27}$$

The boundary condition of firm i's debt value at $M_{i,t} = +\infty$ is the value of a default-free consol bond with constant coupon rate b_i and value b_i/r_f.

A.2 Industry of Monopolistic Competition

Consider an industry of monopolistic competition with a continuum of firms. The demand for each firm's good is determined by

$$C_{i,t} = \left(\frac{P_{i,t}}{P_t}\right)^{-\eta} P_t^{-\epsilon} M_{i,t}, \tag{28}$$

where P_t is

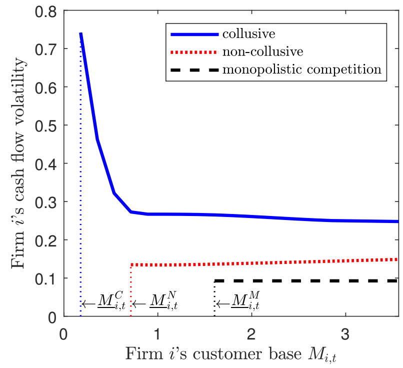
$$P_t = \left[\int_{i\in\mathcal{F}} \left(\frac{M_{i,t}}{M_t}\right) P_{i,t}^{1-\eta} \mathrm{d}i\right]^{\frac{1}{1-\eta}}. \tag{29}$$

The key difference between the price index (3) of a duopoly industry and the price index (29) is that for the latter, each firm is atomistic and takes the price index P_t as exogenously given when choosing $P_{i,t}$.

When $\alpha = 0$, the optimal profit margin chosen by any firm i is $\theta_{i,t}^* = \frac{1}{\eta}$. Thus, the profit margin index in the industry of monopolistic competition is $\theta_t^* = \frac{1}{\eta}$. In equilibrium, firm i's operating profit rate is

$$\Pi(\theta_{i,t}^*, \gamma_t) = \omega^{1-\epsilon} \left(\frac{1}{\eta}\right) \left(\frac{\eta-1}{\eta}\right)^{\epsilon-1} M_{i,t}. \tag{30}$$

When $\alpha > 0$ as in our calibration, the optimal profit margin $\theta_{i,t}^*$ needs to be solved numerically.



Note: This figure plots firm i's conditional cash flow volatility normalized by its own customer base $M_{i,t}$. Specifically, we fix the values of $\gamma_0 = \overline{\gamma}$ and $M_{j,0} = 2$ at $t = 0$. For each value of $M_{i,0}$, we run $N = 200,000$ parallel simulations for one year until $t = 1$. We then calculate firm i's cumulative cash flows $A^k_{i,0\to 1}$ from $t = 0$ to $t = 1$ for each simulation $k = 1, ..., N$. That is, $A^k_{i,0\to 1} = \int_{t=0}^{t=1} \Pi_i(\theta_{i,t}, \theta_{j,t}) M_{i,t} \mathrm{d}t$, where $\Pi_i(\theta_{i,t}, \theta_{j,t})$ is defined by equation (8). The conditional cash flow volatility per customer base corresponding to each value of $M_{i,0}$ is computed by the standard deviation of $A^k_{i,0\to 1}/M_{i,0}$ over N simulations. The blue solid and red dotted lines represent the collusive equilibrium and the non-collusive equilibrium in a duopoly industry. The black dashed line represents a generic firm in an industry of monopolistic competition with a continuum of firms. The vertical dotted lines represent default boundaries of firm i in respective cases.

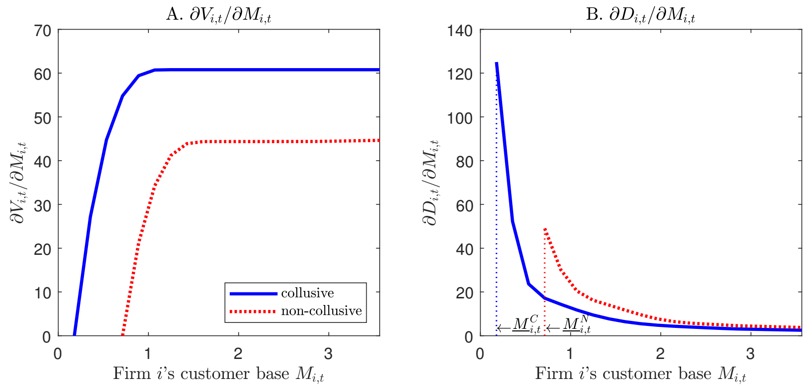
Figure A.1: Conditional cash flow volatility per customer base.

A.3 Additional Model Analyses

Cash Flow Volatility. Figure A.1 plots firm i's conditional cash flow volatility normalized by its customer base. In the industry of monopolistic competition, the conditional cash flow volatility is roughly a constant (see the black dashed line) regardless of the firm's customer base $M_{i,t}$ because the profit margin is roughly a constant. In the duopoly industry, the conditional cash flow volatility slightly increases with the firm's customer base $M_{i,t}$ in the non-collusive equilibrium (see the red dotted line), reflecting the change in profit margins due to the change in short-run price elasticity of demand (see equation 4). By contrast, in the collusive equilibrium, firm i's cash flow volatility increases substantially when the firm becomes financially distressed (see the blue solid line). This is because the feedback between financial distress and competition makes the firm's profit margins more expose to shocks in $M_{i,t}$ when the firm becomes financially distressed (see the blue solid line in panel A of Figure 3).

Exposure to Aggregate Shocks in Customer Base. Figure A.2 illustrates firm i's exposure to aggregate shocks in customer base (i.e., the term $\mathrm{d}Z_t$ equation 5). Panel A shows that the firm's equity is more exposed to aggregate shocks in customer base in the collusive equilibrium (see the blue solid line) due to the significant endogenous movement in profit margins (see the blue solid line in panel A of Figure 3). However, panel B shows that, for any customer base $M_{i,t}$, the firm's debt is less exposed to these shocks in the collusive equilibrium (see the blue solid line). This is because firm i's default risk is lower in the collusive equilibrium (comparing the blue and red vertical dotted lines in panel B).

Comparative Statics on Coupon Rates. We study the comparative statics on firms' coupon rates. Panels A and B of Figure A.3 compare the profit margins of the baseline industry with the industry where both firms' initial coupon rates are $b_0 = 15$. Both firms in the industry with a higher coupon rate set



Note: This figure illustrates firm i's exposure to aggregate shocks in customer base. Panel A plots firm i's equity exposure to aggregate shocks in customer base, i.e., $\partial V_{i,t}/\partial M_{i,t}$; panel B plots firm i's debt exposure to aggregate shocks in customer base, i.e., $\partial D_{i,t}/\partial M_{i,t}$. The blue solid and red dotted lines represent the collusive equilibrium and the non-collusive equilibrium, respectively. The vertical dotted lines represent default boundaries of firm i in respective cases. In both panels, we use $\gamma_t = \overline{\gamma}$, and $M_{j,t} = 2$.

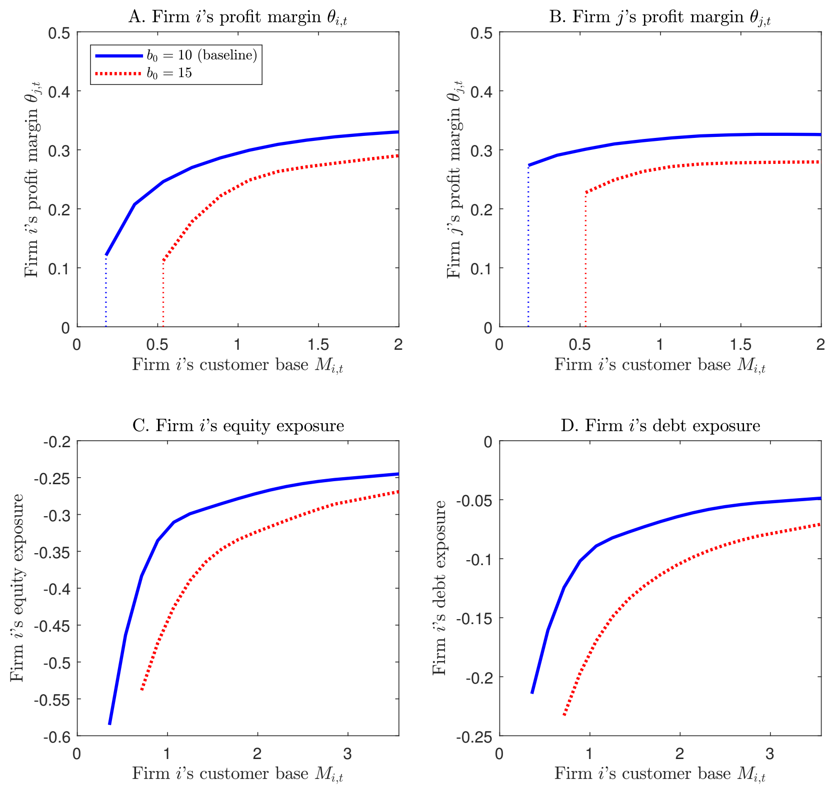
Figure A.2: Exposure to aggregate shocks in customer base.

lower profit margins in the collusive equilibrium (see the red dotted line), reflecting the feedback between competition and financial distress. Moreover, panels C and D show that both the equity and debt of firms in the industry with a higher coupon rate are more exposed to aggregate discount rate shocks.

Comparative Statics on Deep Habits. We study the comparative statics on the speed of habit formation, i.e., the parameter α. Figure A.4 compares the profit margin of firm i in the baseline industry with $\alpha = 0.01$ and in the industry with $\alpha = 0.02$. Comparing the blue solid and black dashed lines, we see that firm i's profit margin is lower in the collusive equilibrium of the baseline industry. However, comparing the red dotted and green dash-dotted lines, we see that firm i's profit margin is higher in the non-collusive equilibrium of the baseline industry.

Intuitively, a higher α generates a competition effect and a growth effect. On the one hand, a higher α implies that firms can accumulate more customer base by setting a lower profit margins. This would promote competition in the market as both firms would like to set lower profit margins to compete for customer base. Such a competition effect results in lower profit margins. On the other hand, a higher α implies that both firms can grow faster, which increase the importance of their future cash flows relative to current cash flows. Such a growth effect leads to more collusion and less competition, resulting in higher profit margins. In the non-collusive equilibrium, the second force is not absent due to the lack of collusion, thus a higher α leads both firms to set lower profit margins. In the collusive equilibrium, the second force dominates the first force, and thus both firms can collude on higher profit margins when α is higher.

To separately illustrate the competition effect of a higher α, the cyan dotted line plots firm i's profit margin in the collusive equilibrium of the industry with $\alpha = 0.02$, keeping the growth rate of the industry-level customer base unchanged (by reducing the value of g). It is shown clearly that the cyan dotted line is below the blue solid line, indicating that a higher α reduces profit margins by inducing more competition for customer base.



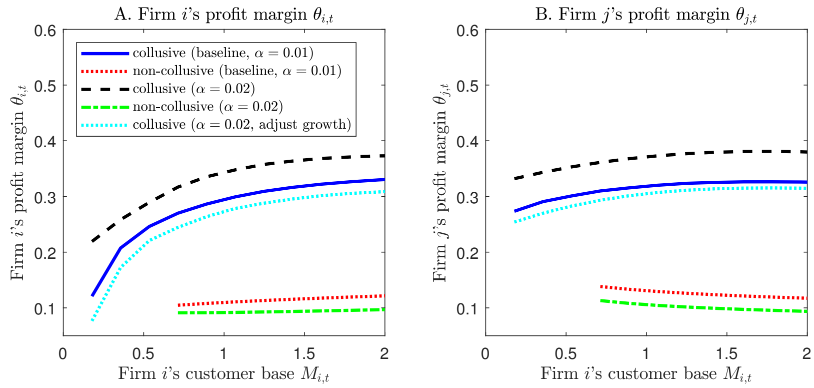
Note: Panel A plots firm i's profit margin as a function of its own customer base $M_{i,t}$; and panel B plots firm j's profit margin as a function of firm i's customer base $M_{i,t}$. Panel C plots firm i's equity exposure (defined in equation 21) as a function of its customer base $M_{i,t}$; and panel D plots firm i's debt exposure (defined in equation 22) as a function of its customer base $M_{i,t}$. In all panels, the blue solid line represents the baseline industry with coupon rate $b_0 = 10$ in the collusive equilibrium. The red dotted line represents the industry with coupon rate $b_0 = 15$ in the collusive equilibrium. The vertical dotted lines represent default boundaries of firm i in respective cases. In all panels, we use $\gamma_t = \overline{\gamma}$, $\gamma_H = \overline{\gamma} + 2\text{std}(\gamma_t)$, and $M_{j,t} = 2$.

Figure A.3: Firms' profit margins and risk exposure with different coupon rates b_0.

A.4 Determination of the Price-War Boundary

In this appendix, we illustrate how the price-war boundary is determined in the industry with $\kappa = 0$. In Figure A.5, we compare each firm's equity value in the collusive and non-collusive equilibria. Panel B shows that firm j's equity value in the collusive equilibrium (the blue solid line) intersects with that in the non-collusive equilibrium (the red-dotted line) at $M_{i,t} = 0.9$. This is the critical point when firm j's PC constraint (13) becomes binding. For $M_{i,t} > 0.9$, both firms' PC constraints are always satisfied and not binding for the collusive profit-margin schemes that satisfy the IC constraints (14), and thus they want to collude with each other. For $M_{i,t} < 0.9$, the PC constraint (13) becomes binding for firm j. This implies that if the two firms collude on profit margins that are higher than the non-collusive ones, the PC constraint of firm j will be violated even though the IC constraints (14) are honored.

On the other hand, panel A of Figure A.5 shows that firm i's equity value in the collusive equilibrium is strictly higher than that in the non-collusive equilibrium when $M_{i,t} \geq 0.9$, indicating that firm i would



Note: Panel A plots firm i's profit margin as a function of its own customer base $M_{i,t}$; and panel B plots firm j's profit margin as a function of firm i's customer base $M_{i,t}$. The blue solid and red dotted lines represent the baseline industry with $\alpha = 0.01$ in the collusive and non-collusive equilibria. The black dashed and green dash-dotted lines represent the industry with $\alpha = 0.02$ in the collusive and non-collusive equilibria. The cyan dotted line represents the industry with $\alpha = 0.02$ in the collusive equilibrium with the same average growth rate of industry-level customer base as that in the collusive equilibrium of the baseline industry. In both panels, we use $\gamma_t = \overline{\gamma}$ and $M_{j,t} = 2$.

Figure A.4: Firms' profit-margin decisions with different speed of habit formation (α).

always want to collude with firm j. Only when $M_{i,t} < 0.9$, firm i's equity value in the collusive equilibrium is equal to that in the non-collusive equilibrium because firm j chooses not to collude. At $M_{i,t} = 0.9$, there is an endogenous jump in firm i's equity value. Therefore, our model implies that it is the firm with a stronger financial condition (or larger customer base when the two firms pay the same coupon rates) that wants to abandon collusion and wages a price war.

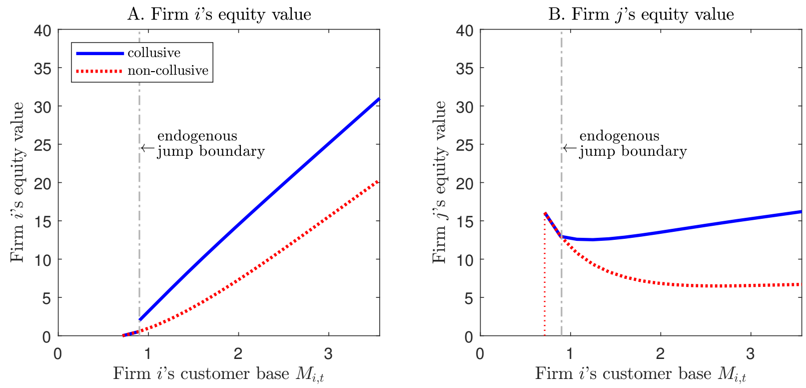
B Numerical Algorithm

In this section, we detail the numerical algorithm that solves the model. To give an overview, our algorithm proceeds in the following steps:

(1). We solve the non-collusive equilibrium. This requires us to solve the subgame perfect equilibrium of the dynamic game played by two firms. The simultaneous-move dynamic game requires us to solve the intersection of the two firms' best response (i.e., optimal decisions on profit margins and default) functions, which themselves are optimal solutions to coupled PDEs.

(2). We solve the collusive equilibrium using the value functions in the non-collusive equilibrium as punishment values. Because we are interested in the highest collusive profit margins with binding incentive-compatibility constraints, this requires us to solve a high-dimensional fixed-points problem. We thus use an iteration method inspired by Abreu, Pearce and Stacchetti (1986, 1990*b*), Ericson and Pakes (1995), and Fershtman and Pakes (2000) to solve the problem.

Note that standard methods for solving PDEs with free boundaries (e.g. finite difference or finite element) can easily lead to non-convergence of value functions. To mitigate such problems and obtain accurate solutions, we solve the continuous-time game using a discrete-time dynamic programming method, as in Dou, Ji and Wu (2020). In Appendix B.1, we present the discretized recursive formulation for the model, including firms' problems in non-collusive equilibrium, collusive equilibrium, and deviation. In



Note: Panels A plots firm i's equity value as a function of its own customer base $M_{i,t}$; and panel B plots firm j's equity value as a function of firm i's customer base $M_{i,t}$. The blue solid and red dash-dotted lines represent the collusive equilibrium and the non-collusive equilibrium in the industry with $\kappa = 0$. The vertical red dotted line represents default boundaries of firm i. The vertical dash-dotted line represents the endogenous jump (i.e., switching between collusion and non-collusion) boundary. In all panels, we use $\gamma_t = \overline{\gamma}$ and $M_{j,t} = 2$.

Figure A.5: Illustration of the price-war boundary in the industry with $\kappa = 0$.

Appendix B.2, we discuss how we discretize the stochastic processes, time grids, and state variables in the model. Finally, in Appendix B.3, we discuss the details on implementing our numerical algorithms, including finding the equilibrium profit margins in the non-collusive equilibrium and solving the optimal collusive profit margins and default boundaries.

B.1 Discretized Dynamic Programming Problem

We solve the model in risk-neutral measure, where we have

$$\mathrm{d}Z_t = -\gamma_t \mathrm{d}t + \mathrm{d}\tilde{Z}_t, \tag{31}$$

$$\mathrm{d}Z_{\gamma,t} = -\zeta \mathrm{d}t + \mathrm{d}\tilde{Z}_{\gamma,t}. \tag{32}$$

Because firm 1 and firm 2 are symmetric, one firm's equity value and policy functions are obtained directly given the other firm's equity value and policy functions. We first illustrate the non-collusive equilibrium and then we illustrate the collusive equilibrium.

B.1.1 Non-Collusive Equilibrium

Below, we first present the recursive formulation for the firm's equity value in the non-collusive equilibrium. Next, we present the conditions that determine the non-collusive (Nash) equilibrium.

Recursive Formulation for The Value of Equity in Non-Collusive Equilibrium Firm i's state is characterized by three state variables, including firm i's customer base $M_{i,t}$, firm j's customer base $M_{j,t}$, and the aggregate state γ_t. Denote the equity value functions in the non-collusive equilibrium as $V_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$ for $i = 1, 2$, where b_i and b_j are the two firms' coupon rates. In our baseline calibration, we set $b_i = b_j = b_0$. We make coupon rate explicitly as state variables because upon defaults of any incumbent firms, the coupon rate of new entrants is b_{new}, which may be different from b_0.

To characterize the equilibrium value functions, it is more convenient to introduce two off-equilibrium value functions. Let $\widehat{V}_i^N(M_{i,t}, M_{j,t}, \gamma_t; \theta_{j,t}, d_{j,t}; b_i, b_j)$ be firm $i(=1,2)$'s value when its competitor j's profit margin is any (off-equilibrium) value $\theta_{j,t}$ and default status is any (off-equilibrium) value $d_{j,t} = 0, 1$.

Firm $i = 1, 2$ solves the following problem:

$$\widehat{V}_i^N(M_{i,t}, M_{j,t}, \gamma_t; \theta_{j,t}, d_{j,t}; b_i, b_j) = \max_{\theta_{i,t}, d_{i,t}} (1 - d_{i,t}) \Big\{ (1-\tau) \left[\omega^{1-\epsilon} \theta_{i,t} (1-\theta_{i,t})^{\eta-1} (1-\theta_t)^{\epsilon-\eta} M_{i,t} - b_i \right] \Delta t$$
$$+ e^{-(r_f+\lambda)\Delta t} \mathbb{E}_t \left[(1-d_{j,t}) V_i^N(M_{i,t+\Delta t}, M_{j,t+\Delta t}, \gamma_{t+\Delta t}; b_i, b_j) + d_{j,t} V_i^N(M_{i,t+\Delta t}, M_{new}, \gamma_{t+\Delta t}; b_i, b_{new}) \right] \Big\}, \quad (33)$$

subject to the following constraints. (1) The industry's profit margin is given by

$$1 - \theta_t = \left[\frac{M_{i,t}(1-\theta_{i,t})^{\eta-1} + M_{j,t}(1-\theta_{j,t})^{\eta-1}}{M_t} \right]^{\frac{1}{\eta-1}} \quad \text{with} \quad M_t = M_{i,t} + M_{j,t}. \quad (34)$$

(2) The customer base evolves according to

$$M_{i,t+\Delta t} = M_{i,t} + \left[g + \alpha (1-\theta_{i,t})^{\eta h} (1-\theta_t)^{(\epsilon-\eta)h} \omega^{-\epsilon h} \right] M_{i,t} \Delta t + \varsigma M_{i,t} (-\gamma_t \Delta t + \Delta \tilde{Z}_t) + \sigma M_{i,t} \Delta W_{i,t}, \quad (35)$$
$$M_{j,t+\Delta t} = M_{j,t} + \left[g + \alpha (1-\theta_{j,t})^{\eta h} (1-\theta_t)^{(\epsilon-\eta)h} \omega^{-\epsilon h} \right] M_{j,t} \Delta t + \varsigma M_{j,t} (-\gamma_t \Delta t + \Delta \tilde{Z}_t) + \sigma M_{j,t} \Delta W_{j,t}. \quad (36)$$

(3). The aggregate state γ_t evolves according to

$$\gamma_{t+\Delta t} = \gamma_t - \varphi(\gamma_t - \overline{\gamma})\Delta t - \nu_m(-\zeta \Delta t + \Delta \tilde{Z}_{\gamma,t}). \quad (37)$$

Non-Collusive (Nash) Equilibrium Denote the equilibrium profit margin and default functions as $\theta_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$ and $d_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$. Denote the off-equilibrium profit margin and default functions as $\widehat{\theta}_i^N(M_{i,t}, M_{j,t}, \gamma_t; \theta_{j,t}, d_{j,t}; b_i, b_j)$ and $\widehat{d}_i^N(M_{i,t}, M_{j,t}, \gamma_t; \theta_{j,t}, d_{j,t}; b_i, b_j)$.

Given firm j's profit margin $\theta_{j,t}$ and default decision $d_{j,t}$, firm i optimally sets the profit margin $\theta_{i,t}$ and makes default decision $d_{i,t}$. The non-collusive (Nash) equilibrium is derived from the fixed point—each firm's profit margin and default are optimal given the other firm's optimal profit margin and default:

$$\theta_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) = \widehat{\theta}_i^N(M_{i,t}, M_{j,t}, \gamma_t; \theta_j^N(M_{j,t}, M_{i,t}, \gamma_t; b_j, b_i), d_j^N(M_{j,t}, M_{i,t}, \gamma_t; b_j, b_i); b_i, b_j), \quad (38)$$
$$d_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) = \widehat{d}_i^N(M_{i,t}, M_{j,t}, \gamma_t; \theta_j^N(M_{j,t}, M_{i,t}, \gamma_t; b_j, b_i), d_j^N(M_{j,t}, M_{i,t}, \gamma_t; b_j, b_i); b_i, b_j). \quad (39)$$

The equilibrium value functions are given by

$$V_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) = \widehat{V}_i^N(M_{i,t}, M_{j,t}, \gamma_t; \theta_j^N(M_{j,t}, M_{i,t}, \gamma_t; b_j, b_i), d_j^N(M_{j,t}, M_{i,t}, \gamma_t; b_j, b_i); b_i, b_j). \quad (40)$$

B.1.2 Collusive Equilibrium

Below, we present the recursive formulation for the firm's value in the collusive equilibrium. Then we present the recursive formulation for the firm's value when it deviates from the collusive equilibrium.

Finally, we present the incentive compatibility constraints to determine the equilibrium collusive profit margins. After finding the equilibrium collusive profit margin scheme, we check whether the participation constraints are satisfied. There are two cases, if the participation constraints are satisfied, the two firms will collude on the equilibrium profit margin scheme. If the participation constraints are not satisfied, the two firms will set profit margins according to their non-collusive ones.

Recursive Formulation for The Value of Equity in The Collusive Equilibrium Denote $\overline{V}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \overline{\Theta}^C(\cdot))$ as firm $j(=1,2)$'s value in the collusive equilibrium with collusive profit margin scheme $\overline{\Theta}^C(\cdot)$. Denote $\widehat{V}_i^C(M_{i,t}, M_{j,t}, \gamma_t; d_{j,t}; b_i, b_j; \overline{\Theta}^C(\cdot))$ be firm $i(=1,2)$'s value in the collusive equilibrium with collusive profit margin scheme $\overline{\Theta}^C(\cdot)$ when its competitor j's default status is any (off-equilibrium) value $d_{j,t} = 0,1$.

Firm i solves the following problem:

$$\widehat{V}_i^C(M_{i,t}, M_{j,t}, \gamma_t; d_{j,t}; b_i, b_j; \overline{\Theta}^C(\cdot)) = \max_{d_{i,t}}(1-d_{i,t})\left\{(1-\tau)\left[\omega^{1-\epsilon}\overline{\theta}_{i,t}^C(1-\overline{\theta}_{i,t}^C)^{\eta-1}(1-\overline{\theta}_t^C)^{\epsilon-\eta}M_{i,t} - b_i\right]\Delta t\right.$$
$$\left. + e^{-(r_f+\lambda)\Delta t}\mathbb{E}_t\left[(1-d_{j,t})\overline{V}_i^C(M_{i,t+\Delta t}, M_{j,t+\Delta t}, \gamma_{t+\Delta t}; b_i, b_j; \overline{\Theta}^C(\cdot)) + d_{j,t}\overline{V}_i^C(M_{i,t+\Delta t}, M_{new}, \gamma_{t+\Delta t}; b_i, b_{new}; \overline{\Theta}^C(\cdot))\right]\right\}, \tag{41}$$

subject to the following constraints. (1) The industry's profit margin is given by

$$1 - \overline{\theta}_t^C = \left[\frac{M_{i,t}(1-\overline{\theta}_{i,t}^C)^{\eta-1} + M_{j,t}(1-\overline{\theta}_{j,t}^C)^{\eta-1}}{M_t}\right]^{\frac{1}{\eta-1}} \quad \text{with} \quad M_t = M_{i,t} + M_{j,t}. \tag{42}$$

(2) The customer base evolves according to

$$M_{i,t+\Delta t} = M_{i,t} + \left[g + \alpha(1-\theta_{i,t})^{\eta h}(1-\theta_t)^{(\epsilon-\eta)h}\omega^{-\epsilon h}\right]M_{i,t}\Delta t + \varsigma M_{i,t}(-\gamma_t\Delta t + \Delta\tilde{Z}_t) + \sigma M_{i,t}\Delta W_{i,t}, \tag{43}$$
$$M_{j,t+\Delta t} = M_{j,t} + \left[g + \alpha(1-\theta_{j,t})^{\eta h}(1-\theta_t)^{(\epsilon-\eta)h}\omega^{-\epsilon h}\right]M_{j,t}\Delta t + \varsigma M_{j,t}(-\gamma_t\Delta t + \Delta\tilde{Z}_t) + \sigma M_{j,t}\Delta W_{j,t}. \tag{44}$$

(3). The aggregate state γ_t evolves according to

$$\gamma_{t+\Delta t} = \gamma_t - \varphi(\gamma_t - \overline{\gamma})\Delta t - \nu_m(-\zeta\Delta t + \Delta\tilde{Z}_{\gamma,t}). \tag{45}$$

Denote the equilibrium default function as $\overline{d}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \overline{\Theta}^C(\cdot))$. Denote the off-equilibrium default function as $\widehat{d}_i^C(M_{i,t}, M_{j,t}, \gamma_t; d_{j,t}; b_i, b_j; \overline{\Theta}^C(\cdot))$. The default decisions are determined in Nash equilibrium. In particular, given firm j's default decision $d_{j,t}$, firm i optimally makes default decision $d_{i,t}$. The Nash equilibrium is derived from the fixed point—each firm's default is optimal given the other firm's optimal default:

$$\overline{d}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \overline{\Theta}^C(\cdot)) = \widehat{d}_i^C(M_{i,t}, M_{j,t}, \gamma_t; \overline{d}_j^C(M_{j,t}, M_{i,t}, \gamma_t; b_j, b_i; \overline{\Theta}^C(\cdot)); b_i, b_j; \overline{\Theta}^C(\cdot)). \tag{46}$$

The equilibrium value functions are given by

$$\overline{V}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \overline{\Theta}^C(\cdot)) = \widehat{V}_i^C(M_{i,t}, M_{j,t}, \gamma_t; \overline{d}_j^C(M_{j,t}, M_{i,t}, \gamma_t; b_j, b_i; \overline{\Theta}^C(\cdot)); b_i, b_j; \overline{\Theta}^C(\cdot)). \tag{47}$$

Recursive Formulation for The Value of Equity upon Deviation The deviation value is obtained by assuming that firm i optimally sets its profit margin conditional on firm j setting the profit margin according to the collusive profit margin scheme, i.e., $\overline{\theta}_j^C(M_{j,t}, M_{i,t}, \gamma_t; b_j, b_i; \overline{\Theta}^C(\cdot))$ and default decision $\overline{d}_j^C(M_{j,t}, M_{i,t}, \gamma_t; b_j, b_i; \overline{\Theta}^C(\cdot))$. Denote $\overline{V}_i^D(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \overline{\Theta}^C(\cdot))$ as firm i's deviation value.

Firm i solves the following problem:

$$\overline{V}_i^D(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \overline{\Theta}^C(\cdot)) = \max_{\theta_{i,t}, d_{i,t}} (1 - d_{i,t}) \left\{ (1-\tau) \left[\omega^{1-\epsilon} \theta_{i,t} (1-\theta_{i,t})^{\eta-1} (1-\overline{\theta}_t^D)^{\epsilon-\eta} M_{i,t} - b_i \right] \Delta t \right.$$
$$+ e^{-(r_f+\lambda)\Delta t} \mathbb{E}_t \left[d_{j,t} \left((1-\xi\Delta t) \overline{V}_i^D(M_{i,t+\Delta t}, M_{new}, \gamma_{t+\Delta t}; b_i, b_{new}; \overline{\Theta}^C(\cdot)) + \xi \Delta t V_i^N(M_{i,t+\Delta t}, M_{new}, \gamma_{t+\Delta t}; b_i, b_{new}) \right) \right.$$
$$\left.\left. (1-d_{j,t}) \left((1-\xi\Delta t) \overline{V}_i^D(M_{i,t+\Delta t}, M_{j,t+\Delta t}, \gamma_{t+\Delta t}; b_i, b_j; \overline{\Theta}^C(\cdot)) + \xi \Delta t V_i^N(M_{i,t+\Delta t}, M_{j,t+\Delta t}, \gamma_{t+\Delta t}; b_i, b_j) \right) \right] \right\} \tag{48}$$

subject to the following constraints. (1) The industry's profit margin is given by

$$1 - \overline{\theta}_t^D = \left[\frac{M_{i,t}(1-\theta_{i,t})^{\eta-1} + M_{j,t}(1-\overline{\theta}_{j,t}^C)^{\eta-1}}{M_t} \right]^{\frac{1}{\eta-1}} \quad \text{with} \quad M_t = M_{i,t} + M_{j,t}. \tag{49}$$

(2) The customer base evolves according to

$$M_{i,t+\Delta t} = M_{i,t} + \left[g + \alpha(1-\theta_{i,t})^{\eta h}(1-\theta_t)^{(\epsilon-\eta)h}\omega^{-\epsilon h} \right] M_{i,t}\Delta t + \varsigma M_{i,t}(-\gamma_t \Delta t + \Delta \tilde{Z}_t) + \sigma M_{i,t} \Delta W_{i,t}, \tag{50}$$
$$M_{j,t+\Delta t} = M_{j,t} + \left[g + \alpha(1-\theta_{j,t})^{\eta h}(1-\theta_t)^{(\epsilon-\eta)h}\omega^{-\epsilon h} \right] M_{j,t}\Delta t + \varsigma M_{j,t}(-\gamma_t \Delta t + \Delta \tilde{Z}_t) + \sigma M_{j,t} \Delta W_{j,t}. \tag{51}$$

(3). The aggregate state γ_t evolves according to

$$\gamma_{t+\Delta t} = \gamma_t - \varphi(\gamma_t - \overline{\gamma})\Delta t - \nu_m(-\zeta \Delta t + \Delta \tilde{Z}_{\gamma,t}). \tag{52}$$

Solving For Equilibrium Profit Margins The collusive equilibrium is a subgame perfect Nash equilibrium if and only if the collusive profit margin scheme $\overline{\Theta}^C(\cdot)$ satisfies the following PC and IC constraints:

$$\overline{V}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \overline{\Theta}^C(\cdot)) \geq V_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j), \tag{53}$$
$$\overline{V}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \overline{\Theta}^C(\cdot)) \geq \overline{V}_i^D(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \overline{\Theta}^C(\cdot)), \tag{54}$$

for all $M_{i,t} \in [0, +\infty)$, $\gamma_t \in \mathbb{R}$, and $i = 1, 2$.

There exist infinitely many subgame perfect Nash equilibria. We focus on the collusive equilibrium with the collusive profit margins lie on the "Pareto efficient frontier" (denoted by $\Theta^C(\cdot)$), which are obtained when all incentive compatibility constraints are binding, i.e.

$$\overline{V}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \Theta^C(\cdot)) = \overline{V}_i^D(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \Theta^C(\cdot)), \tag{55}$$

for all $M_{i,t} \in [0, +\infty)$, $\gamma_t \in \mathbb{R}$, and $i = 1, 2$. The collusive equilibrium is solved by finding profit margin scheme $\Theta^C(\cdot)$ such that the PC constraint (53) and the IC constraint (55) are satisfied simultaneously.

We denote $V_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$ as firm i's value in the collusive equilibrium with collusive profit margin scheme $\Theta_i^C(\cdot)$. In solving the equilibrium, we first ignore the PC constraint (53) and solve for $\Theta^C(\cdot)$ that satisfies the IC constraint (55). Then given $\Theta^C(\cdot)$, we check whether the PC constraint (53) is satisfied for each value of $M_{i,t}$, $M_{j,t}$, and γ_t. If it is satisfied, we have

$$V_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) = \overline{V}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \Theta^C(\cdot)), \tag{56}$$

$$\theta_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) = \overline{\theta}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \Theta^C(\cdot)) \tag{57}$$

If it is not satisfied, we guess the endogenous collusion boundary $\zeta(M_{j,t}, \gamma_t; b_i, b_j)$ (through iterations) at which one of the firm's participation constraint is just binding. For $M_{i,t} \leq \zeta(M_{j,t}, \gamma_t; b_i, b_j)$, we set

$$V_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) = V_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j), \tag{58}$$

$$\theta_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) = \theta_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j). \tag{59}$$

For $M_{i,t} > \zeta(M_{j,t}, \gamma_t; b_i, b_j)$, we have

$$V_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) = \overline{V}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \Theta^C(\cdot)), \tag{60}$$

$$\theta_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) = \overline{\theta}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j; \Theta^C(\cdot)) \tag{61}$$

Value of Debt Firm i's value of debt in the collusive equilibrium is given by

$$\begin{aligned} D_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) =& (1 - d_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)) \left\{ b_i \Delta t + e^{-(r_f+\lambda)\Delta t} \mathbb{E}_t \left[D_i^C(M_{i,t+\Delta t}, M_{j,t+\Delta t}, \gamma_{t+\Delta t}; b_i, b_j) \right] \right\} \\ &+ d_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) \nu A_i^C(M_{i,t}, M_{j,t}, \gamma_t; 0, b_j), \end{aligned} \tag{62}$$

where $d_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$ and $A_i^C(M_{i,t}, M_{j,t}, \gamma_t; 0, b_j)$ are the optimal default decision and the unlevered asset value in the collusive equilibrium under the collusive profit margin scheme $\Theta^C(\cdot)$.

Firm i's value of debt in the non-collusive equilibrium is determined similarly using the optimal default decision and the unlevered asset value in the non-collusive equilibrium.

B.2 Discretization

We discretize the aggregate state γ_t based on n_γ grids using the method of Tauchen (1986). We approximate the persistent AR(1) process of long-run growth rates θ_t using n_θ discrete states based on the method of Rouwenhorst (1995). The time line is discretized into intervals with length Δt. We choose a large n_γ to ensure the continuous process is accurately approximated.

We use collocation methods to solve each firm's problem. Let $S_M \times S_M \times S_\gamma \times S_b \times S_b$ be the grid of collocation nodes for a firm's equilibrium value, $S_M \times S_M \times S_\gamma \times S_\theta \times S_d \times S_b \times S_b$ be the grid of collocation nodes for a firm's off-equilibrium value in the non-collusive equilibrium, and $S_M \times S_M \times S_\gamma \times S_d \times S_b \times S_b$ be the grid of collocation nodes for a firm's off-equilibrium value in the collusive equilibrium. We have $S_M = \{M_1, M_2, ..., M_{n_M}\}$, $S_\gamma = \{\gamma_1, \gamma_2, ..., \gamma_{n_\gamma}\}$ $S_\theta = \{\theta_1, \theta_2, ..., \theta_{n_\theta}\}$, $S_d = \{0, 1\}$, and $S_b = \{b_1, b_2, ..., b_{n_b}\}$.

We approximate the firm's value function $V(\cdot)$ and $D(\cdot)$ on the grid of collocation notes using a linear spline with coefficients corresponding to each grid point. We first form a guess for the spline's coefficients, then we iterate to obtain a vector that solves the system of Bellman equations.

B.3 Implementation

The numerical algorithms are implemented using C++. The program is run on the server of MIT Economics Department, supply.mit.edu and demand.mit.edu, which are built on Dell PowerEdge R910 (64 cores, Intel(R) Xeon(R) CPU E7-4870, 2.4GHz) and Dell PowerEdge R920 (48 cores, Intel(R) 4 Xeon E7-8857 v2 CPUs). We use OpenMP for parallelization when iterating value functions and simulating the model.

Selection of Grids We set $n_\gamma = 51$, $n_M = 101$, $n_\theta = 11$ $n_b = 5$, $\Delta t = 1/24$. The grid of customer base S_M is discretized into 22 nodes from $M_1 = 0$ to $M_{n_M} = 8$. We use 80 grids with equal spaces to discretize the region $[0, 1.5]$ to capture the large nonlinearity around the default boundary and use 20 grids with equal spaces to discretize the region $[1.5, 8]$. The upper bound $M_{n_M} = 8$ is determined so that the marginal value of $M_{i,t}$ becomes a constant. This ensures that the boundary condition at infinity is accurately solved and satisfied. The time interval Δt is set to be $1/24$ (i.e., half month). A higher Δt implies faster convergence for the same number of iterations but lower accuracy. We checked that the solution is accurate enough for $\Delta t = 1/24$, further reducing Δt would not improve the accuracy much. With $\Delta = 1/24$, 5000 times iterations allow us to achieve convergence in value functions. The profit margin grid is discretized into 11 nodes from 0 to $1/\epsilon$ with equal spaces. The lowest coupon rate is set to be zero to consider unlevered firms. The highest coupon rate is set to be our calibrated value $b_0 = 10$.

Solving the Non-Collusive Equilibrium Given the value functions from the previous iteration, we use the golden section search method to find the optimal profit margins. The computational complexity of this algorithm is at the order of $\log(n)$, much faster and more accurate than a simple grid search. The optimal default decisions can be trivially solved by checking two cases with $d_{i,t}^N = 0$ and $d_{i,t}^N = 1$.

Searching for the equilibrium profit margin is challenging because we have to solve a fixed-point problem that involves both firms' simultaneous profit margin decisions. Our solution technique is to iteratively solve the following three steps.

First, given $V_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$, we solve the off-equilibrium value $\widehat{V}_i^N(M_{i,t}, M_{j,t}, \gamma_t; \theta_j, d_{j,t}; b_i, b_j)$ and the off-equilibrium policy functions $\widehat{\theta}_i^N(M_{i,t}, M_{j,t}, \gamma_t; \theta_{j,t}, d_{j,t}; b_i, b_j)$ and $\widehat{d}_i^N(M_{i,t}, M_{j,t}, \gamma_t; \theta_{j,t}, d_{j,t}; b_i, b_j)$. Second, for each $(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) \in S_M \times S_M \times S_\gamma \times S_b \times S_b$, we solve equations (38 – 39) and obtain the equilibrium profit margins $\theta_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$ and defaults $d_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$. Third, we solve equations (40) and obtain equilibrium value functions $V_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$.

Solving the Collusive Equilibrium To solve the collusive equilibrium, we have to simultaneously solve the endogenous default boundaries and the endogenous collusive profit margins within the collusion boundaries. We implement a nested iteration method. First, we guess the default boundaries. Second, we solve for the highest collusive profit margins within the boundary using the iteration algorithm below. The profit margins associated with the states below the default boundaries are indeterminate because firms are in default. For these states, we set firms' profit margins at the non-collusive profit margins $\theta_i^N(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$. Third, we check whether the implied default boundaries are consistent with our guessed boundaries. If not, we update our guess and resolve the highest collusive profit margins.

We modify the golden section search method to find the highest collusive profit margins $\theta^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$ within the default boundaries by iterations. For each iteration, we guess collusive profit margins $\overline{\theta}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$, and given the guessed profit margins, we solve firms' collusion value and deviation value using standard recursive methods. We update the guessed collusive profit margins until the incentive compatibility constraints (55) are binding for all states.

There are two key differences between our method and a standard golden section search method. First, to increase efficiency, we guess and update the collusive profit-margin scheme $\overline{\theta}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$ simultaneously for all $(M_{i,t}, M_{j,t}, \gamma_t) \in S_M \times S_M \times S_\gamma$, instead of doing it one by one for each state. A natural problem introduced by the simultaneous updating is that there might be overshooting. For example, if for some particular state $(M^*_{i,t}, M^*_{j,t}, \gamma^*_t)$, we updated a collusive profit margin $\overline{\theta}_i^C(M^*_{i,t}, M^*_{j,t}, \gamma^*_t; b_i, b_j)$ too high in the previous iteration, the collusive profit margin for some other states $(M_{i,t}, M_{j,t}, \gamma_t) \neq (M^*_{i,t}, M^*_{j,t}, \gamma^*_t)$ might be affected in this iteration and never achieve a binding incentive compatibility constraint. Eventually, this may lead to non-convergence.

We solve this problem by gradually updating the collusive profit margins. In particular, in each round of iteration, we first compute the updated collusive profit-margin schme $\overline{\theta}_i^{C'}(M_{i,t}, M_{j,t}, \gamma_t)$ implied by the golden section search method. Then, instead of changing the upper search bound or lower search bound to $\overline{\theta}_i^{C'}(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$ directly, we change it to $(1 - adj) \times \overline{\theta}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j) + adj \times \overline{\theta}_i^{C'}(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$, i.e., a weighted average of the current iteration's collusive profit margin $\overline{\theta}_i^C(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$ and the updated collusive profit margin $\overline{\theta}_i^{C'}(M_{i,t}, M_{j,t}, \gamma_t; b_i, b_j)$. If $adj = 0.5$, our algorithm is essentially the same as bisection search algorithm. A lower adj is more suitable to solve the problem in which different states have a higher degree of interdependence. We set a relatively low $adj = 0.05$ to ensure convergence.

C Construction of Idiosyncratic Shocks

Method 1:

(i) Compute the annual sales growth of individual firms, censoring the rare instances where the sales of the last year is negative.

(ii) Compute the panel means of the sales growth on top 100 firms of each cross section.

(iii) Winsorize the sales growth at the panel means plus and minus 30%.

(iv) Compute the aggregate sales growth as the average of the winsorized sales growth on the top 100 firms.

(v) Compute firm level idiosyncratic shock as winsorized sales growth subtracting the average sales growth.

(vi) Aggregate idiosyncratic shock to the industry-year level, weighting by last year's sale.

This methodology closely aligns with the method used in (Gabaix, 2011) with the exception of the winsorization bounds. The bounds were 20% in (Gabaix, 2011), which we relax to 30%.
Method 2:

(i) Compute the aggregate sales growth as in Method 1.

(ii) Conduct firm level time series regression of sales growth on aggregate sales growth and a constant. Take the residual as the idiosyncratic shock.

(iii) Aggregate idiosyncratic shock to the industry-year level, weighting by last year's sale.

Method 3:

(i) Aggregate the winsorized firm-year level sales growth to industry-year level.

(ii) Over the 50 year of 1968 to 2017, drop those industries with less than 45 non-missing sales growth measures.

(iii) For the remaining industry-year, replace missing sales growth with the cross sectional average sales growth among the available industry-year sales growths.

(iv) Extract the first principal component from the panel of industry-year level sales growth.

(v) Conduct firm level time series regression of sales growth on the PC and a constant. Take the residual as the idiosyncratic shock.

(vi) Aggregate idiosyncratic shock to the industry-year level, weighting by last year's sale.