Collusion through debt and managers*

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Abstract

We investigate the anticompetitive effects of debt financing and managerial incentives in a framework where managers incur personal costs of bankruptcy. We show that firms' shareholders may resort to debt and managerial incentives as complementary strategic devices to sustain collusion in the product market, provided that the managerial costs of bankruptcy are sufficiently responsive to the severity of financial distress. Limited commitment to debt and managerial contracts exacerbates shareholders' reliance on the magnitude of debt and managerial incentives for collusive purposes. These results square with the well-documented features of firms' financial structure and corporate governance in markets plagued by collusion.

KEYWORDS: Bankruptcy, collusion, commitment, common lending, corporate governance, debt financing, managerial incentives.

JEL CLASSIFICATION: D21, G32, G33, L13, L41.

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1 Introduction

An influential recent strand of empirical studies has brought back attention on firms' debt structure and corporate governance as drivers for collusion in product markets, with a focus on common lending and common ownership (e.g., Antón et al., 2022; Azar et al., 2018; Dasgupta and Žaldokas, 2019; Ha et al., 2021; Saidi and Streitz, 2021). The relationship between firms' financial structure, corporate governance, and product market competition has been investigated from different perspectives (e.g., Allen and Gale, 2000; Buccirossi and Spagnolo, 2008; MacKay and Phillips, 2005). Yet, relatively little theoretical research has been conducted so far about the collusive effects of firms' financial structure and corporate governance. This is rather surprising in the light of the aforementioned recent empirical studies and the consolidated evidence on the negative relationship between the intensity of competition and debt financing (e.g., Chevalier, 1995a, 1995b; Chevalier and Sharfstein, 1996; Kovenock and Phillips, 1995, 1997; Phillips, 1995).

Collusion is a widespread phenomenon in product markets and the overcharges imposed by collusive agreements have been estimated to be sizeable on both sides of the Atlantic (e.g., Boyer and Kotchoni, 2015; Smuda, 2014; Symeonidis, 2018). Most worryingly, in several prominent industries, firms engage in sophisticated anticompetitive tactics, which challenge antitrust authorities' deterrence and detection capabilities (e.g., Asker, 2010; Marshall and Marx, 2012; Miller, 2009). Identifying the factors that may facilitate or hinder collusion has become critical to designing institutional architectures that effectively prevent collusive practices. Previous studies have significantly improved the understanding of these factors — such as monitoring of sales and communication (e.g., Harrington and Skrzypacz, 2007, 2011) as well as the use of algorithms, machine learning, and artificial intelligence (e.g., Calvano et al., 2020; Miklós-Thal and Tucker, 2019). Our paper aims to contribute to the extant literature and to enrich the current policy debate by exploring the anticompetitive effects of debt financing and managerial incentives.

We show that, under certain conditions, firms' shareholders resort to debt and managerial incentives as complementary strategic devices to collude in the product market. Our analysis starts by considering a simple market for a homogeneous good where firms compete à la Bertrand by setting prices over an infinite time horizon. A firm's shareholders choose the debt structure and delegate pricing decisions to a self-interested manager, whose remuneration is contingent on the firm's profits. Whenever a firm is unable to repay its debt, bankruptcy occurs. Shareholders and managers are protected by limited liability. However, the manager of an insolvent firm faces personal costs of bankruptcy. Systematic empirical evidence indicates that defaulting managers typically incur reputation costs, along with either the loss of their job or a drastic wage cut.[1] Lenders often explicitly ask shareholders to hire top managers that, in

[1] As documented by Gilson (1989) and Gilson and Vetsuypens (1993), about half of the managers of firms facing financial distress are replaced without being rehired by comparable (exchange-listed) firms during the following three years and the managers retained by their firms bear significant reductions in salary and bonus. Along these lines, Eckbo and Thorburn (2003) find a median CEO income decline of 47% after bankruptcy. Eckbo et al. (2016) report that CEOs leaving the executive labor market after bankruptcy experience a median estimated compensation loss equal to five times the pre-departure income. Kaplan (1994a, 1994b) provides empirical evidence about the negative relationship between top executive turnover and firm's performance. Jenter and Kanaan (2015) document that CEOs are significantly more likely to be dismissed from their jobs after bad industry performance.

the light of their solid reputation for 'prudent behavior', significantly suffer from bankruptcy.[2] Conceivably, the managerial costs of bankruptcy increase with the severity of financial distress, namely with the amount of unrepaid debt.

In this setting, we can address a range of stimulating questions. How does debt financing affect collusion in the product market? What is the role of managers? How can managerial incentive schemes be designed to facilitate cooperation?

We find that two opposite forces shape the impact of an expansion of debt on the sustainability of collusion, as measured by the critical discount factor above which firms can achieve the collusive monopoly outcome. On the one hand, a higher level of debt makes managers more eager to deviate by undercutting the collusive price because the reversion to the competitive equilibrium in the punishment phase leads to bankruptcy, which cancels the residual debt due to limited liability. On the other hand, a higher debt inflates the costs of bankruptcy that managers incur. As a result of the trade-off between these two opposite forces, a higher amount of debt facilitates collusion when the managerial costs of bankruptcy are sufficiently responsive to the severity of financial distress. We also find that managers receiving a relatively higher share of profits are more tempted to undercut the collusive price because they can grab a more significant portion of the gains from deviation. Hence, higher-powered managerial incentive schemes hinder collusion for a given amount of debt.

Equipped with these results, we then endogenize the level of debt and managerial incentives chosen by firms' shareholders to maximize collusive profits. Endogenizing these instruments delivers additional challenging questions. Under what conditions do firms resort to debt and managerial incentives to collude in the product market? What is the interaction between these two instruments? How does their adoption depend on the market features?

We show that, for intermediate values of the discount factor, collusion is only sustainable through a suitable mix of debt and managerial incentives. In the light of the trade-off previously discussed, the managerial costs of bankruptcy must be sufficiently responsive to the severity of financial distress. Interestingly, a higher amount of debt is accompanied by higher-powered managerial incentives to ensure managers' participation. Thus, debt and managerial incentives act as complementary strategies to sustain collusion in otherwise competitive industries. The combination of debt and managerial incentives that supports the collusive outcome varies with the characteristics of the market at hand. As higher debt inflates managers' bankruptcy costs, firms' shareholders expand the amount of debt whenever their managers are more tempted to deviate from the collusive agreement. This occurs in less concentrated markets, where managers can obtain (a share of) higher profits by undercutting the collusive price or in the presence of better managerial outside options, which induce managers to command a higher profit share and make deviations more attractive. Conversely, a reduction in the managers' temptation to deviate, associated with more costly bankruptcy, higher collusive profits, or a higher discount factor, leads firms' shareholders to curb the amount of debt. The complementarity between debt and managerial incentives implies that the share of profits granted to managers moves in the same direction as the amount of debt.

[2]Gilson (1989) finds that a significant number of changes in management are initiated by creditors, especially during debt restructuring. As documented by Nini et al. (2012), creditors play an active role in corporate governance by exerting informal influence as well.

Our results are robust to several extensions. In the baseline model, firms' shareholders can commit to contracts that specify the debt structure and their managers' compensations. As we argue, shareholders can commit to contractual terms under many plausible circumstances. Yet, to broaden the scope of our analysis, we relax this hypothesis by incorporating different degrees of limited commitment into our model. Specifically, we first allow for managerial contracts to be secretly renegotiated. Then, we turn to a more general setting in which shareholders can also secretly renegotiate their financial obligations. Our analysis is further extended to a more extreme scenario where shareholders cannot commit at all to managerial contracts, which can be reneged upon tout court, and may also have limited commitment powers on the financial structure. We show that debt and managerial incentives can still facilitate collusion as long as each lender serves (at least) two rivals in the product market — i.e., under common lending relationships, a well-known phenomenon typically associated with bank specialization. Interestingly, as shareholders with weaker commitment powers find it more difficult to cooperate, limited commitment exacerbates their reliance on the magnitude of debt and managerial incentives for collusive purposes. Our results also carry over to various forms of market structure. In industries where competition is relatively soft even in the absence of collusion (e.g., because of product differentiation), or where demand is somewhat elastic, non-collusive profits can be significant. This makes managers more inclined to deviate and leads shareholders to expand debt and strengthen managerial incentives in order to stabilize collusion. Notably, our model neither resorts to any unduly restrictive assumptions on the functional forms nor requires communication across firms at any stage of the product market game, enabling us to explore the sustainability of tacit collusion.

Summing up, our analysis unveils a novel channel that connects firms' financial structure, corporate governance, and product market competition — three aspects traditionally examined in isolation — whereby throwing light upon the collusive effects of debt and managerial incentives. Our work can contribute to a more comprehensive understanding of the relationship between financial and product markets by complementing seminal pioneering studies — such as Brander and Lewis (1986) and Maksimovic (1988) — according to which higher debt should lead firms to behave more aggressively. The predictions of our model are more suitable for markets where professional managers run companies, and thus managerial incentives turn out to be relevant. Most importantly, our results provide theoretical support for the recent empirical evidence on the anticompetitive effects of debt. In particular, Dasgupta and Žaldokas (2019) identify a decline in debt after the breakdown of collusive activities associated with adopting a leniency law. Establishing a causal relationship between credit concentration and industry markup, Saidi and Streitz (2021) show that common lenders serving multiple firms reduce the cost of debt and soften product market competition. This is especially the case when a higher cost of debt is more likely to drive firms into dire straits. We find that the role of common lenders in relaxing competition is more relevant in markets where firms' shareholders have limited commitment powers on debt contracts. As thoroughly discussed in Section 7, the coordination function of a common lender can be related to the recent empirical literature about the anticompetitive effects of common ownership — i.e., the role of common lending is, de facto, equivalent to the role of common ownership. Yet, in our setting, common

lending is relevant to collusion insofar as shareholders face a limited commitment problem.

The classical empirical observations about the relationship between debt financing and market outcomes are indeed rather heterogeneous. In some studies, more indebted firms are found to charge lower prices (e.g., Busse, 2002; Zingales, 1998). However, a number of studies indicate that, primarily in concentrated industries, higher debt is associated with softer competition, in terms of higher prices, lower output, and more passive investment behavior (e.g., Chevalier, 1995a, 1995b; Chevalier and Sharfstein, 1996; Kovenock and Phillips, 1995, 1997; Phillips, 1995). Our analysis can explain the anticompetitive effects of debt, especially in concentrated industries with large companies run by managers. Our findings are also consistent with other traditional empirical regularities about debt, such as stock price rises in response to debt-increasing transactions (e.g., Harris and Raviv, 1991; James, 1987). Interestingly, we can also shed some light on the empirically documented adoption of corporate governance mechanisms that facilitate collusion in the product market through appropriate managerial incentive schemes (e.g., Ha et al., 2021; Joh, 1999).

Our work provides some implications for the role of managers within firms, suggesting that high debt can be a firm's deliberate choice to mitigate managerial aggressive behavior in the product market rather than the outcome of poor managerial performance. From a normative angle, we unveil a dark side of information sharing that has been overlooked so far. The exchange of information regarding firms' financial structure and corporate governance strengthens shareholders' commitment powers on debt and managerial contracts. This renders debt and managerial incentives more effective in sustaining collusion at the expense of final consumers. Our results recommend the incorporation of these aspects into the disclosure rules that shape corporate governance regulation.

The rest of the paper unfolds as follows. Section 2 describes the related literature. Section 3 sets out the formal model. Section 4 characterizes the combination of debt and managerial incentives to sustain collusion and examines the underlying factors. Section 5 investigates the robustness of our results to different degrees of limited commitment to debt and managerial contracts. Section 6 extends our analysis to various forms of market structure. Section 7 discusses some managerial and policy implications. Section 8 concludes the analysis. Formal proofs are collected in the Appendix and the Supplementary Appendix.

2 Related literature

Our paper belongs to the extensive literature on the interaction between firms' financial structure and product market competition. The two main traditional approaches to this issue suggest that firms endowed with more financial assets should lower their prices. According to the 'long purse' or 'deep pocket' theory of predatory pricing à la Telser (1966), a financially strong firm cuts prices in order to drive its competitors out of the market or preempt potential entrants. This argument has been rigorously established in various models of predation (e.g., Benoit, 1984; Bolton and Scharfstein, 1990; Fudenberg and Tirole, 1986). The 'limited liability' theory, stemming from Brander and Lewis (1986), argues that higher debt may help firms to commit to behave more aggressively in the product market because limited liability

provisions allow shareholders to ignore bad market states, creating a conflict of interests between debt holders and equity holders, as described by Jensen and Meckling (1976). Along these lines, Maksimovic (1988) identifies the negative impact of debt on the firms' ability to sustain tacit collusion in an infinite horizon model and characterizes the highest level of debt that prevents any deviation. Stenbacka (1994) provides further corroboration for the procompetitive effects of debt in a market for a homogeneous good where firms engage in infinitely repeated Bertrand competition and demand randomly varies over time. Poitevin (1989) shows in a model à la Brander and Lewis (1986) that a common lender may allow firms to mitigate their overly aggressive behavior in the product market through a suitable choice of the interest rate. Debt remains procompetitive and firms would be better off if they could commit not to use debt. Contrary to Poitevin (1989), we find that debt definitely relaxes competition and a common lender helps collusion only when firms' shareholders have limited commitment powers. Extending Maksimovic's (1988) framework, Hege (1998) shows that an indebted firm can achieve the highest collusive profits by repaying its debt as fast as possible and bank-financed industries can sustain more collusion compared to the case of publicly traded debt. In an infinitely repeated version of the Brander and Lewis (1986) model, Damania (1997) argues that, under certain circumstances, debt holdings facilitate collusion. A major difference with respect to Maksimovic (1988) is that demand is unknown prior to production decisions and stochastically fluctuates over time. In our paper, we establish the joint role of debt and managerial incentives in sustaining collusion, which does not rely either on unknown demand fluctuations or on the observability and inflexibility of the debt structure. Hirshleifer and Thakor (1992) find that the managerial concern for reputation aligns managers' interests with those of bond holders. Zwiebel (1996) shows that debt can be used to credibly restrict managerial empire-building ambitions. Our work indicates that the disciplinary role of debt in shaping managerial behavior extends to the sustainability of collusion, provided that managers obtain a suitable stake of collusive profits.

Other theories have been proposed to explain the link between firms' financial structure and product market decisions. In a two-period version of the Brander and Lewis (1986) model, Glazer (1994) finds that long-term debt softens product market competition. Showalter (1995) shows that debt allows Bertrand competitors to raise prices when demand conditions are uncertain. Faure-Grimaud (2000) identifies the anticompetitive role of debt under asymmetric information between lenders and borrowing firms. Aghion et al. (2000) develop a model where the firm's management becomes softer or tougher in response to a higher need of outside finance according to whether the initial level of outside finance is low or high, respectively. In a duopoly setting where a financially constrained firm faces an unconstrained rival, Povel and Raith (2004) find a U-shaped relationship between the constrained firm's output and the level of its internal funds. In the presence of information asymmetries between the parties to a financial contract, Campello (2006) characterizes a non-monotonic association between debt and sales performance such that, beyond a certain threshold, more debt generates market share losses, providing empirical evidence for these results. In a general equilibrium model, Dellas and Fernandes (2014) find that the development of financial markets tends to lower firms' markups, despite the possible reduction in the number of firms. Lehar et al. (2020) show that

in vertically related markets with medium levels of concentration upstream suppliers can offer their retailers trade credit in order to achieve a more collusive outcome in the downstream sector with respect to the case of bank financing. We refer to Sertsios (2020) for an exhaustive survey, with a special focus on recent developments. A major novelty of our approach is to unveil the role of debt and managerial incentives as complementary strategic devices to sustain collusion in an infinitely repeated game.

Our study can also contribute to the literature about lenders as 'gatekeepers' in product markets, which investigates the effects of lending on market entry. The seminal paper of Bhattacharya and Chiesa (1995) shows that common lending may serve as a precommitment mechanism to share information among borrowing competitors that acquire proprietary knowledge through R&D investments, by possibly leading to a collusive outcome where only one firm enters the product market. In a 'big push' model, Da Rin and Hellmann (2002) characterize the catalytic role of dominant banks in the creation of new industries. Cestone and White (2003) find that a dominant investor deters market entry when its claim is sufficiently sensitive to the profits of the incumbent firm — by holding equity or, equivalently, risky debt — so that entrant firms do not manage to obtain any funds. Differently from these contributions, we consider an infinite horizon model to investigate collusion among firms established in the product market and derive our results in the absence of any market power in the lending sector.

Our paper is also related to the significant collection of work on collusion in vertical relationships (e.g., Jullien and Rey, 2007; Nocke and White, 2007, 2010; Piccolo and Miklós-Thal, 2012; Piccolo and Reisinger, 2011). Differently from our paper, these contributions abstract from debt financing and managerial incentives.

3 The model

Product market. We consider a market for a homogeneous good where $N \geq 2$ identical firms interact over an infinite time horizon by simultaneously setting their prices in every period $\tau \in \{1, \ldots, +\infty\}$. Each firm aims to maximize the present discounted sum of its profits, with the common discount factor $\delta \in (0, 1)$. The per period profits accruing to each firm are $\pi > 0$ when all firms charge the collusive monopoly price. If a firm deviates from the collusive agreement by undercutting the monopoly price whereas its $N - 1$ rivals still charge it, the deviant firm (approximately) collects the industry monopoly profits $N\pi$ in the deviation period. The profits of each firm reduce to zero in the unique equilibrium of the stage game where prices reflect the (constant) marginal cost. Pricing decisions in each period τ become common knowledge at the beginning of period $\tau + 1$, so the game exhibits perfect monitoring.

Credit market and firms' financial structure. There exists a competitive credit market. In period $\tau = 0$, before the product market game takes place, firms' shareholders can issue long-term debt instruments with infinite maturity.[3] A debt contract between firm $i \in \{1, ..., N\}$

[3]See, e.g., Maksimovic (1988) and Stenbacka (1994). Clearly, our results still hold with a series of debt contracts, each with finite maturity, provided that a new contract is signed as soon as the previous one has expired. In practice, shareholders play a crucial role in significant matters of corporate governance, including the issue of new securities. This is especially the case in companies with large shareholders. Boubaker et al. (2017) find compelling evidence that firms with multiple large shareholders tend to rely more heavily on bank debt financing.

and its lender consists of a pair $(L_i, \{b_{\tau i}\}_{\tau=1}^{+\infty})$ specifying a loan L_i received by firm i at the beginning of period $\tau = 1$ and a pledged repayment $b_{\tau i}$ by firm i in each period τ. The zero profit condition in the credit market yields $\sum_{\tau=1}^{+\infty} \delta^{\tau-1} b_{\tau i} = L_i$. Every firm employs its loan at the beginning of period $\tau = 1$ in unproductive activities, such as the distribution of dividends to shareholders or wasteful advertising.[4] In line with some relevant literature (e.g., Brander and Lewis, 1986; Maksimovic, 1988; Stenbacka, 1994), this approach allows us to identify the strategic value of debt as a collusive device and to neutralize the well-known effects of capital investments.[5] Hence, repayments can only be financed through sales revenues. Whenever a firm is unable to honor its debt contract, bankruptcy occurs and the firm's shareholders are protected by limited liability. Insolvent firms are sold to new owners and continue to operate in the market.[6] Without any loss of generality, each firm borrows from one lender. As it will shortly become clear, only the total size of pledged repayments matters.

Firms' organizational structure and managerial costs of bankruptcy. A firm's shareholders delegate pricing decisions to a self-interested manager. As systematically documented in the empirical literature discussed in the introduction, bankruptcy is costly for managers, despite limited liability. This creates a conflict of interest between property and management. The costs of bankruptcy faced by firm i's manager in period τ are given by

$$C(b_{\tau i}) \triangleq [k + \phi(b_{\tau i} - \pi_{\tau i})] \cdot \mathbf{1}_b, \tag{1}$$

where $k \geq 0$ is a fixed component and $\phi \geq 0$ captures the responsiveness of the costs of bankruptcy to the severity of financial distress, measured by amount of unrepaid debt in period τ corresponding to the difference between the pledged repayment $b_{\tau i}$ and the gross profits $\pi_{\tau i}$.[7] Bankruptcy occurs in period τ if and only if the pledged repayment outweighs the gross profits, i.e., $b_{\tau i} > \pi_{\tau i}$. Therefore, the indicator function $\mathbf{1}_b \in \{0, 1\}$ in (1) assumes a value of one if $b_{\tau i} > \pi_{\tau i}$ and a value of zero otherwise. Given that firms' members, namely shareholders and managers, are protected by limited liability, lenders can seize at most the product market earnings in case of default.[8]

Consistently with the empirical literature about bankruptcy, the managerial outside option depends on the manager's performance. Specifically, a non-defaulting manager has a per period reservation utility equal to u, where $0 \leq u < \pi$. After bankruptcy has occurred,

[4] As it will be clear later, including dividends into shareholders' wealth does not affect our qualitative results.

[5] The incorporation of investments into our model would complicate the analysis without providing any additional useful insights. As investments typically consist of demand-enhancing or cost-reducing activities that improve firms' profits, we refer to Section 4.3 for the impact of firms' profits on the sustainability of collusion.

[6] This approach, stemming from Maksimovic (1988) and Stenbacka (1994), is consistent with the evidence documented by Antill (2022) that 76% of defaulting large commercial and industrial companies in the US are either reorganized or acquired. Intuitively, if firms permanently exit the market after bankruptcy, predation would occur and collusion could not be sustained.

[7] As the loan exhibits infinite maturity, in equilibrium the amount of the per period default is proportional to the amount of total default. Hence, we can focus on bankruptcy costs contingent only on the severity of the firm's financial distress in the default period.

[8] We refer to Ross (1977) and Diamond (1984) for early models of bankruptcy costs in line with our formulation in (1). In Greenwald and Stiglitz (1990, 1993) bankruptcy costs increase with the firm's size, which is consistent with our approach as long as larger firms suffer from more severe financial distress. Berk et al. (2010) show that bankruptcy costs naturally arise from optimal contractual arrangements in perfectly competitive capital and labor markets.

the reservation utility declines because of the manager's reputation loss. For simplicity, the reservation utility of a defaulting manager is normalized to zero.[9]

Managerial incentive schemes. In line with the well-established empirical evidence documenting a positive relationship between managerial rewards and performance evaluation (e.g., Ha et al., 2021; Joh, 1999; Kaplan, 1994a), we assume that in every period τ the manager of firm i receives a remuneration that consists of a share $\alpha_{\tau i} \in [0,1]$ of firm i's net profits $\pi_{\tau i} - b_{\tau i}$.[10] Thus, the compensation of firm i's manager in period τ amounts to $\alpha_{\tau i}(\pi_{\tau i} - b_{\tau i})$. Such managerial incentive schemes based on net profit sharing align managers' preferences with those of shareholders except for the evaluation of bankruptcy. This allows us to isolate the effects of bankruptcy on managerial behavior. As discussed at the end of Section 4, our qualitative results persist under alternative remuneration schemes.

Collusion. Given that firms are identical, throughout the analysis we confine attention to symmetric and stationary collusive strategies that implement the monopoly outcome. In particular, a (symmetric and stationary) collusive strategy prescribes that in period $\tau = 0$ the shareholders of each firm announce (i) a debt contract, specifying a loan L and a per period pledged repayment b, where $b = (1-\delta)L$ follows from the zero profit condition in the credit market, and (ii) a managerial contract, specifying a profit sharing rule α.[11] Clearly, a collusive strategy also dictates that each firm charges the monopoly price in period $\tau = 1$ (the outset of the product market game) and continues to do so as long as each firm charged this price in any previous period. In response to a deviation from the collusive strategy, arising either at the contractual stage in period $\tau = 0$ or at the pricing stage in any period $\tau \geq 1$, firms revert to the unique equilibrium of the stage game by setting their prices at the marginal cost in any subsequent period — i.e., firms adopt grim trigger strategies to punish deviations. As a firm's profits reduce to zero, bankruptcy occurs whenever the firm must repay a loan. This behavior is rational because shareholders are protected by limited liability.

Timing and equilibrium concept. The sequence of events unfolds as follows.

- In period $\tau = 0$, firms' shareholders simultaneously announce debt and managerial contracts.
- From period $\tau = 1$ onward, firms' managers engage in the product market game and contracts are executed. If a firm does not repay its debt, bankruptcy occurs.

The announcements about debt and managerial contracts become common knowledge before the product market game commences. We look for a symmetric pure-strategy subgame

[9] This is without any loss of generality as long as the post-bankruptcy reservation utility is not too large relative to the fixed cost of bankruptcy k.

[10] The empirically documented observations of performance-based managerial remuneration schemes rely upon well-established justifications. As shown by the long-standing bulk of literature on asymmetric information, incentivizing managers to exert effort (e.g., in terms of cost-reducing or demand-enhancing activities) requires compensations contingent on market outcomes. Optimal managerial incentive schemes have been shown to exhibit linear sharing components in different moral hazard settings (e.g., Laffont and Tirole, 1986; Piccolo et al., 2014). The strategic delegation literature has also traditionally adopted linear performance-based managerial schemes even in the absence of moral hazard problems (e.g., Fershtman and Judd, 1987; Sklivas, 1987).

[11] Our qualitative results carry over to different repayment obligations, which may allow for the probability that the loan is not reimboursed, or different credit markets, where the lender may possess some market power.

perfect Nash equilibrium where the collusive monopoly outcome arises. In the baseline model, contract announcements are binding. In other terms, shareholders have full commitment powers when dealing with debt and managerial contracts. In a number of countries, this can be achieved through mandatory transparency requirements, which oblige firms to disclose verifiable information about their financial structure as well as the rewards to their top managers.[12] In countries where transparency rules are voluntary or poorly enforced, contract announcements can still exhibit some commitment value, provided that firms are able to share confidential information. This can occur through multiple channels — such as trade associations, credit bureaus or common intermediaries — established in a wide range of markets, which have been incidentally under close scrutiny by antitrust authorities in various countries.[13] Notably, a firm's shareholders can reinforce their commitment to a debt contract through a corporate policy that prescribes in each period the distribution of the firm's profits in excess of the per period pledged repayment in the form of dividends to shareholders, which implies that the debt contract cannot be revised. In Section 5, we relax the hypothesis of full commitment in different directions and show that our qualitative results persist when contract announcements are not binding.

4 Main results

4.1 A relevant benchmark

To better appreciate the role of the managerial costs of bankruptcy, it is helpful to start with the benchmark case where managers are not harmed by bankruptcy. Consider a debt structure with a per period repayment $b \in [0, \pi]$, which cannot clearly exceed the firm's collusive gross profits π, and a managerial incentive scheme characterized by a profit sharing rule $\alpha \in [0, 1]$. As discussed in Section 3, a collusive strategy dictates the monopoly price in the collusive phase and the competitive price in the punishment phase. A firm obtains $\pi - b$ in any collusive period and $N\pi - b$ in the deviation period by undercutting the monopoly price. The punishment of a deviation drives the firm into bankruptcy for $b > 0$. The incentive constraint that ensures the sustainability of collusion writes as

$$\frac{\alpha}{1-\delta}(\pi - b) \geq \alpha(N\pi - b) \implies \delta \geq \frac{N-1}{N\pi - b}\pi.$$

A firm's manager abides by the collusive agreement if and only if the managerial share of present discounted collusive profits exceeds the managerial share of deviation profits. In the absence of managerial costs of bankruptcy, managers' preferences are fully aligned with those of shareholders and managerial remuneration is inconsequential to the sustainability of

[12] We refer to Section 7 for a detailed discussion about the forms of regulation that facilitate the exchange of this type of information.

[13] For instance, in 2011 the European Commission concluded that 17 steel producers (e.g., ArcelorMittal, Emesa, Global Steel Wire, voestalpine Austria Draht, and WDI) had operated between 1984 and 2002 a cartel to fix prices, share markets and exchange sensitive commercial information in all the countries that then formed the European Union except the United Kingdom, Ireland, and Greece. Details can be found at `https://ec.europa.eu/commission/presscorner/detail/en/IP_11_403` (last retrieved in July 2022).

collusion.[14] By inspection, collusion is more difficult to sustain when the firm's debt increases, i.e., b goes up. A deviation from the collusive agreement triggers bankruptcy, which allows the firm to avoid the reimbursement of the residual part of the loan due to limited liability. As pointed out by Maksimovic (1988), a more indebted firm is less inclined to engage in collusive activities and thus higher debt destabilizes collusion. As a result, the optimal collusive strategy mandates no debt, i.e., $b = 0$. Then, the condition for the sustainability of collusion becomes $\delta \geq (N-1)/N$, which corresponds to the standard outcome of an infinitely repeated Bertrand game. As a loan is spent on unproductive activities and firms resort to debt only for collusive purposes, we find that under this condition debt cannot enlarge the scope for collusion. Throughout the analysis, we impose the following assumption.

Assumption 1 $\delta < \frac{N-1}{N}$.

Assumption 1 ensures that the discount factor is not excessively large so that collusion cannot be sustained when managers disregard bankruptcy.

4.2 Collusion under managerial costs of bankruptcy

The result à la Maksimovic (1988) in Section 4.1, according to which firms' indebtedness impairs collusion, is obtained in the absence of managerial costs of bankruptcy. Yet, as previously argued, managers are typically harmed by bankruptcy and thus their interests may diverge from shareholders' preferences. We first characterize the condition for the sustainability of collusion in the presence of managerial costs of bankruptcy for a given managerial profit share α and a debt repayment b. Then, we study their impact on the managers' incentives to collude. For any pair (α, b), the collusion incentive constraint becomes

$$\frac{\alpha}{1-\delta}(\pi - b) \geq \alpha(N\pi - b) - \delta C(b). \tag{2}$$

Anticipating that the punishment of a deviation will trigger bankruptcy (for $b > 0$), a firm's manager considers the costs of bankruptcy $C(\cdot)$ in (1), which are weighted by the discount factor δ because bankruptcy occurs in the period subsequent to a deviation. As described in Section 3, bankruptcy brings the managerial outside option to zero due to a reputation loss, and thus a deviating manager does not obtain anything in the continuation game. The collusion incentive constraint (2) can be rewritten as

$$\delta \geq \delta^*(\alpha, b), \tag{3}$$

where $\delta^*(\alpha, b) \in (0, 1)$ identifies the (unique) solution to constraint (2) holding with equality.[15] Thus, $\delta^*(\alpha, b)$ denotes the critical discount factor above which collusion is sustainable. In the following lemma, we investigate how managerial incentive schemes and debt financing affect the scope for collusion in the presence of managerial costs of bankruptcy.

[14] Trivially, managers are indifferent about collusion for $\alpha = 0$. We refer to Section 4.3 for a discussion of this extreme case.

[15] We refer to the proof of Lemma 1 for technical details.

Lemma 1 *The critical discount factor $\delta^*(\alpha, b)$ exhibits the following features:*

(i) *higher-powered managerial incentive schemes hinder collusion — i.e., $\partial\delta^*/\partial\alpha > 0$;*

(ii) *a higher debt repayment facilitates collusion if and only if the responsiveness of the managerial costs of bankruptcy to the severity of financial distress is large enough — i.e., $\partial\delta^*/\partial b < 0$ if and only if $\phi > \widetilde{\phi}(\alpha)$, where $\partial\widetilde{\phi}/\partial\alpha > 0$;*

(iii) *higher managerial costs of bankruptcy facilitate collusion — i.e., $\partial\delta^*/\partial k < 0$ and $\partial\delta^*/\partial\phi < 0$.*

When managers incur bankruptcy costs, the managerial profit share α is no longer inconsequential to the sustainability of collusion. As managers are more inclined to collude, we find from (2) and (3) that at the critical discount factor δ^* the profits of a deviating firm exceed the present discounted collusive profits. A higher α exacerbates the managers' temptation to deviate because they can grab a larger portion of deviation profits. As point (i) of Lemma 1 reveals, for a given debt repayment, higher-powered managerial incentive schemes make collusion more difficult to sustain.

A higher debt repayment b generates two opposite forces on the scope for collusion. On the one hand, as shown in Section 4.1, the managers of more indebted firms are more eager to defect from the collusive agreement because this triggers bankruptcy and cancels the residual debt due to limited liability. On the other hand, insofar as bankruptcy entails managerial costs proportional to the severity of financial distress, higher debt renders managers more inclined to collude. As point (ii) of Lemma 1 indicates, the trade-off between these two opposite forces implies that debt facilitates collusion if and only if the responsiveness ϕ of the managerial costs of bankruptcy to the severity of financial distress is large enough. The threshold $\widetilde{\phi}(\alpha)$ above which debt encourages collusion increases with the managerial profit share α because a higher α magnifies the managers' incentives to deviate.

Point (iii) of Lemma 1 emphasizes the effects of the managerial costs of bankruptcy on the sustainability of collusion. Intuitively, for any level of debt and managerial profit share, firms can more easily achieve the collusive outcome in the product market when managers bear higher costs associated with financial distress.

4.3 Endogenizing debt and managerial incentives

Based on the insights provided in Lemma 1, we now characterize the optimal collusive strategy that implements the monopoly outcome. At the outset of the game, the shareholders of each firm announce the managerial profit share $\alpha \in [0, 1]$ and the per period debt repayment $b \in [0, \pi]$ that maximize the discounted sum of collusive profits net of managerial compensation. As shareholders have full commitment powers, the announcements about debt and managerial contracts are binding. The maximization problem of a firm's shareholders is given by

$$\max_{\{\alpha\in[0,1], b\in[0,\pi]\}} \frac{(1-\alpha)(\pi - b)}{1-\delta} \tag{4}$$

subject to the collusion incentive constraint (2) and the following managerial participation constraint

$$\alpha(\pi - b) \geq u, \tag{5}$$

which requires that the manager's remuneration (weakly) exceeds the reservation utility in every period (on the equilibrium path) so that the manager is willing to run the firm. Given that a lower managerial profit share α inflates shareholders' profits in (4) and relaxes the collusion incentive constraint (2) through a reduction in the critical discount factor δ^* in (3) as established in Lemma 1, shareholders select the lowest level of $\alpha \in [0,1]$ such that the managerial participation constraint (5) is binding in equilibrium. Then, we have

$$\alpha(b) = \min\left\{1, \frac{u}{\pi - b}\right\}, \tag{6}$$

which identifies, for any level of debt repayment b, the minimal profit share $\alpha(b)$ ensuring the manager's participation. In the subsequent analysis, we consider the relevant case $\alpha(b) < 1$, which occurs as long as the managerial reservation utility u is small enough.[16] Substituting (6) into the objective function in (4) and into the collusion incentive constraint (2), the maximization problem of a firm's shareholders in (4) can be rewritten as

$$\max_{b \in [0,\pi]} \frac{\pi - b - u}{1 - \delta} \tag{7}$$

subject to the following collusion incentive constraint

$$\frac{u}{1-\delta} \geq \frac{N\pi - b}{\pi - b} u - \delta C(b). \tag{8}$$

It is worth noting from (5) and (8) that a manager with a zero outside option ($u = 0$) is willing to accept a contract with zero remuneration ($\alpha = 0$) and to engage in collusive activities, irrespective of the debt level and the discount factor. However, such an extreme case seems rather unrealistic. Top managers typically have some market value, especially when they have not experienced bankruptcy, as discussed in Section 3. Therefore, throughout the analysis we focus on the more plausible case where the non-defaulting manager's outside option is positive ($u > 0$) so that shareholders must forego some profits in order to induce the manager's participation in the collusive agreement.[17] As a loan must be reimbursed, the shareholders' objective function in (7) decreases with the debt repayment b. Hence, shareholders decide to issue the minimal level of debt that ensures collusion, if it exists. In the following proposition, we derive the optimal combination of debt financing and managerial incentives that supports collusion when the announcements about debt and managerial contracts are binding.

Proposition 1 *Suppose that firms' shareholders can commit to debt and managerial contracts. Then, for a relatively small managerial reservation utility — i.e., $u < \overline{u}^c$ — there exist two thresholds $\overline{\delta}^c$ and $\underline{\delta}^c$ for the discount factor δ such that*

(i) if $\delta \geq \overline{\delta}^c$, in the collusive equilibrium, firms' shareholders issue (almost) no debt and provide managerial incentive schemes — i.e., $b^c_{nd} \to 0$ and $\alpha^c_{nd} \in (0,1)$;

(ii) if $\delta \in \left[\underline{\delta}^c, \overline{\delta}^c\right)$, in the collusive equilibrium, firms' shareholders issue some debt and provide higher-powered managerial incentive schemes when the responsiveness of the managerial costs

[16] The extreme case $\alpha = 1$ is concisely discussed after Proposition 1. We refer to the proof of Proposition 1 for technical details.

[17] Agency conflicts within the firm may also allow the manager to extract some rents.

of bankruptcy to the severity of financial distress is large enough — i.e., $b_d^c > 0$ *and* $\alpha_d^c \in \left(\alpha_{nd}^c, 1\right)$ *for* $\phi \geq \overline{\phi}^c$*;*

(iii) *otherwise — i.e., either if* $\delta < \underline{\delta}^c$ *or if* $\delta \in \left[\underline{\delta}^c, \overline{\delta}^c\right)$ *and* $\phi < \overline{\phi}^c$ *— the collusive monopoly outcome is not sustainable.*

The results in Proposition 1 are illustrated in Figure 1. As point (i) of Proposition 1 indicates, for a sufficiently large discount factor, collusion can be sustained through an infinitesimal amount of debt that arbitrarily converges to zero and managers receive a share of collusive profits.[18] More relevantly, point (ii) of Proposition 1 identifies an intermediate region of values for the discount factor in which shareholders resort to some debt and provide their managers with higher-powered incentive schemes to ensure managers' participation, as implied by (6). Hence, debt financing and managerial incentives act as complementary strategic devices to sustain collusion. This occurs as long as the managerial costs of bankruptcy are sufficiently responsive to the severity of financial distress so that some level of debt optimally trades off the managerial share of net profits from deviation against the managerial costs of bankruptcy. Although the previous literature has extensively studied the collusive effects arising either from debt (e.g., Maksimovic, 1988; Stenbacka, 1994) or from managerial incentives (e.g., Spagnolo, 2000, 2005), to the best of our knowledge the joint impact of debt and managerial incentives on collusion has been systematically neglected so far. Hence, our analysis unveils a new channel that relates debt financing and managerial incentive schemes to the sustainability of collusion. Clearly, when the discount factor is relatively small or the managerial costs of bankruptcy are not responsive enough to the severity of financial distress, debt and managerial incentives cannot help to achieve the collusive monopoly outcome, as established in point (iii) of Proposition 1. Then, the competitive outcome emerges in equilibrium.

The focus in Proposition 1 on the case of a sufficiently small managerial reservation utility ensures the most realistic outcome where shareholders receive at least a portion of collusive profits, i.e., $\alpha < 1$. The extreme case $\alpha = 1$ is not relevant for our analysis because shareholders forego the entire profits and become indifferent as to whether to collude or not.[19]

We now investigate the factors that affect the optimal combination of debt financing and managerial incentives for collusive purposes.

Proposition 2 *The debt repayment* b_d^c *and the managerial profit share* α_d^c *characterized in Proposition 1 exhibit the following features:*

(i) *they increase with the number of firms and the managerial reservation utility — i.e.,* $\partial b_d^c/\partial N > 0$, $\partial b_d^c/\partial u > 0$, *and* $\partial \alpha_d^c/\partial N > 0$, $\partial \alpha_d^c/\partial u > 0$*;*

(ii) *they decrease with the managerial costs of bankruptcy, the per period collusive profits, and the discount factor — i.e.,* $\partial b_d^c/\partial k < 0$, $\partial b_d^c/\partial \phi < 0$, $\partial b_d^c/\partial \pi < 0$, $\partial b_d^c/\partial \delta < 0$, *and* $\partial \alpha_d^c/\partial k < 0$, $\partial \alpha_d^c/\partial \phi < 0$, $\partial \alpha_d^c/\partial \pi < 0$, $\partial \alpha_d^c/\partial \delta < 0$.

[18] An infinitely small level of debt leads managers to incur the fixed cost of bankruptcy k when a deviation from the collusive agreement occurs. For $k = 0$, it follows from Assumption 1 that collusion cannot be generally sustained through an infinitely small level of debt. Technical details can be found in the proof of Proposition 1.

[19] Even a small probability of an antitrust case would dissuade shareholders from colluding in the product market.

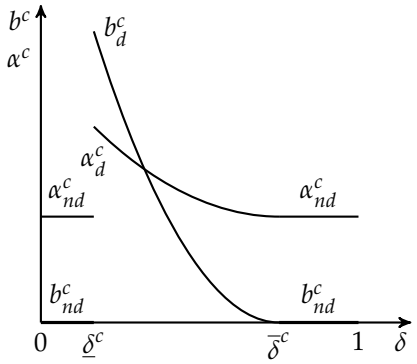

Figure 1: Debt repayment b^c and managerial profit share α^c under full commitment.

To appreciate the rationale behind the results in Proposition 2, it is helpful to note that firms' shareholders adjust the level of debt and managerial incentives according to the managers' temptation to deviate by undercutting the collusive price. In less concentrated markets, where the number of firms is higher, managers are more eager to deviate and extract the entire industry profits. This also occurs in the presence of more valuable managerial outside options, because managers ask for a higher profit share, which magnifies their incentives to defect from the collusive agreement, as established in Lemma 1. Point (i) of Proposition 2 indicates that, under these circumstances, firms' shareholders inflate the level of debt in order to make bankruptcy more costly for managers and mitigate their temptation to deviate. Given the complementarity between debt and managerial incentives, shareholders also increase the managerial profit share.

Conversely, a reduction in the managers' temptation to deviate allows shareholders to curb the size of debt and managerial incentives. This occurs in a range of situations described in point (ii) of Proposition 2. Intuitively, managers are less eager to undercut the collusive price in anticipation of more costly bankruptcy occurring in the punishment phase. In more lucrative markets, where the per period collusive profits are larger, the lower wedge between deviation and collusive profits (net of debt) alleviates the managers' incentives to deviate. Finally, with a higher discount factor, managers are more patient and care to a further extent about future collusive profits and losses from punishment relative to the spot gains from deviation. Under these circumstances, shareholders can discipline their managers through a lower level of debt and managerial incentives.

Our results provide theoretical corroboration for the empirically documented anticompetitive effects of debt and managerial incentives, as discussed in the introduction. Differently from the previous literature, we identify the joint role of debt financing and managerial incentive schemes for collusive purposes in markets where managers incur personal costs of bankruptcy. Before extending our analysis to different degrees of limited commitment to debt and managerial contracts, we highlight some points in the following two remarks.

Remark 1 It is well known that, in the absence of managerial costs of bankruptcy, for sufficiently large values of the discount factor such that the monopoly outcome can be sustained, an infinitely repeated Bertrand model admits a continuum of equilibria with the price ranging from the marginal cost to the monopoly level. Otherwise, there exists a unique equilibrium

where the price reflects the marginal cost. This classical bang-bang property no longer holds when managers incur costs of bankruptcy. Despite the monopoly solution being unfeasible, firms' shareholders may be still able to coordinate on non-competitive outcomes that generate positive profits. We refer to Piccolo and Miklós-Thal (2012) for insights into this direction.

Remark 2 Throughout the paper, we consider managerial remuneration schemes contingent on firms' profits net of debt repayment. When managerial rewards are based on gross profits, the anticompetitive effects of debt identified in our work can be even more pronounced because debt would clearly make managers more reluctant to deviate due to bankruptcy costs, without affecting their remuneration. Therefore, the procompetitive effects of debt à la Maksimovic (1988) would be removed ex abrupto by assumption. Our focus on managerial incentives contingent on firms' profits net of debt repayment allows for a more insightful analysis. This approach is also more coherent with the empirical evidence (discussed in Section 3) that managerial rewards are related to performance evaluation. More sophisticated compensation schemes (such as stock options) would facilitate collusion (e.g., Spagnolo, 2000, 2005). Along these lines, the adoption of history dependent managerial compensation structures — such as discrete bonuses in the collusive phase and penalties during price wars — would definitely enlarge the scope for collusion.

5 Limited commitment

In the baseline model, we assume that firms' shareholders are able to commit to debt and managerial contracts. Can collusion still be sustained when shareholders have limited commitment powers? What are the effects of limited commitment on the combination of debt and managerial incentives for collusive purposes? To suitably address these issues, we examine different sources of limited commitment. It is well established in the literature (e.g., Dewatripont, 1988; Katz, 1991) that the commitment value of contracts vis-à-vis third parties can be significantly eroded by the agents' ability to secretly renegotiate the announced contracts. We first consider a scenario in which shareholders have the opportunity to secretly renegotiate the managerial contracts but they can still credibly announce the debt structure. Afterward, we allow for secret renegotiations that involve not only the managerial remuneration but also the amount of debt. Then, we extend our analysis to a more extreme situation where shareholders are not able to commit at all to managerial contracts, which can be secretly reneged upon tout court, and may also engage in secret renegotiations about debt contracts.[20] We show that, in line with the baseline model, under certain circumstances, shareholders resort to some level of debt bundled with managerial incentives in order to sustain collusion in the product market. As it will become clear in the subsequent analysis, the magnitude of shareholders' commitment powers crucially affects the optimal combination of debt and managerial incentives.

Under limited commitment, the timing of the game unfolds as follows.

- In period $\tau = 0$, firms' shareholders simultaneously announce debt and managerial contracts. In any period, such contracts can be secretly modified.

[20] The breach of a debt contract would clearly drive the firm into bankruptcy.

- From period $\tau = 1$ onward, firms' managers engage in the product market game and contracts are executed. If a firm does not repay its debt, bankruptcy occurs.

Given that contractual revisions are secret, the solution concept is perfect Bayesian equilibrium, with the standard refinement of 'passive beliefs' or 'market-by-market bargaining' conjectures (e.g., Hart and Tirole, 1990; McAfee and Schwartz, 1994). A firm's manager that receives an 'unexpected' (i.e., out-of-equilibrium) offer from the firm's shareholders still believes that the managers of the other firms shall follow their equilibrium strategies. This captures the natural idea that shareholders cannot signal to their managers information that they do not possess about rivals, because the shareholders of each firm are independent and act simultaneously.

5.1 Secret renegotiations

Each contract announced at the outset of the game is legally valid but the contractual parties can secretly renegotiate it and stipulate another (legally valid) contract in order to achieve a mutually beneficial outcome. This preserves some minimal commitment value for debt and managerial contracts. As argued later, our approach is reasonable in the context at hand. Essentially, firms' shareholders do not deceive the market about their contractual choices, which can, however, be subsequently amended through a secret renegotiation process.

Renegotiations about managerial contracts. In order to properly identify the effects of contract renegotiations on collusion, we first consider the case where a firm's shareholders are able to commit to a debt structure, but they can secretly renegotiate the specific terms of the contract with their manager at no cost.[21] The idea that debt contracts are binding turns out to be particularly compelling when lenders systematically share information on borrowers' histories, with special attention on their total exposure (e.g., Degryse et al., 2016). In a number of countries, publicly managed credit registries consolidate information on borrowers' credit worthiness, which typically includes their total indebtedness. There are also several countries, such as the US and Italy, where different private information sharing systems — known as credit bureaus — have been developed by financial intermediaries on a voluntary basis, in response to information asymmetries between borrowers and lenders. Credit registries and bureaus often gather data about borrowers' past debts and report their total indebtedness, instead of just documenting borrowers' characteristics and past delinquencies. Such information sharing activities can help firms' shareholders to confer credibility on their announcements about firms' financial situation even when they are not able to refrain from secretly revising managerial contracts.

Consider a candidate equilibrium where in period $\tau = 0$ each firm announces the contractual pair (α, b) specifying the managerial profit share $\alpha \in [0, 1]$ and the per period debt repayment $b \in [0, \pi]$ that support the collusive outcome. The present discounted collusive profits accruing to a firm's shareholders are given by

$$V(\alpha, b) \triangleq \frac{1-\alpha}{1-\delta}(\pi - b). \tag{9}$$

[21] Any positive cost of renegotiation would definitely reinforce our results.

Furthermore, we denote by

$$\widetilde{V}(\alpha, b) \triangleq \max_{\widetilde{\alpha} \in [0,1]} (1 - \widetilde{\alpha})(N\pi - b) \quad s.t. \ \widetilde{\alpha}(N\pi - b) - \delta C(b) \geq \frac{\alpha}{1 - \delta}(\pi - b) \tag{10}$$

the maximum profits that a firm's shareholders can obtain in a secret renegotiation process by offering the manager a new profit share $\widetilde{\alpha}$ that guarantees at least the same remuneration as in the original contract and induces the manager to undercut the collusive price. The manager obtains a share $\widetilde{\alpha}$ of the deviation profits $N\pi$ net of the debt repayment b and incurs the costs of bankruptcy $C(\cdot)$ in the punishment phase.

Given that firms' shareholders can commit to the debt structure, it follows from (9) and (10) that any managerial contract is renegotiation proof if and only if

$$V(\alpha, b) \geq \widetilde{V}(\alpha, b). \tag{11}$$

This condition indicates that a firm's shareholders cannot benefit from secretly renegotiating the original contract with their manager at the rivals' expense. In this case, the contractual pair (α, b) is immune to renegotiations and allows shareholders to achieve the collusive outcome. Using (11), in the following lemma we characterize the condition for the renegotiation proofness of managerial contracts and investigate whether the full commitment solution derived in Section 4.3 survives the threat of secret renegotiations.

Lemma 2 *Suppose that firms' shareholders can commit to debt contracts but they can secretly renegotiate managerial contracts. Then, any managerial contract is renegotiation proof if and only if*

$$\frac{\pi - b}{1 - \delta} \geq N\pi - b - \delta C(b). \tag{12}$$

The full commitment contractual pair $\left(\alpha_d^c, b_d^c\right)$ characterized in Proposition 1 is not renegotiation proof.

Lemma 2 shows that, when managerial contracts are vulnerable to secret renegotiations, collusion is still sustainable as long as the whole firm — intended as the coalition of the firm's shareholders and manager — does not have any incentive to defect from the collusive agreement. This occurs if and only if the discounted sum of the aggregate collusive profits exceeds the aggregate deviation profits net of the managerial costs of bankruptcy — i.e., the renegotiation proofness constraint (12) is satisfied. Note from (2) and (12) that, differently from the case of full commitment, managers no longer affect the scope for collusion at the 'intensive margin' through the profit share α but only at the 'extensive margin' through the managerial costs of bankruptcy. To gain further insights, consider a candidate equilibrium where each firm announces a contractual pair (α, b) that implements the collusive outcome. Suppose that, in a certain period, a firm's shareholders deviate from the candidate equilibrium by offering their manager a new profit share $\widetilde{\alpha}$, which induces the manager to undercut the collusive price. Anticipating that price undercutting will trigger bankruptcy, the manager commands a compensation for the associated loss. Renegotiations between the firm's shareholders and their manager are mutually beneficial if and only if the aggregate deviation profits net of the managerial costs of bankruptcy more than compensate the discounted sum of the aggregate

collusive profits — i.e., the renegotiation proofness constraint (12) fails to hold.

Lemma 2 also indicates that the full commitment contractual pair $\left(\alpha_d^c, b_d^c\right)$ characterized in Proposition 1, specifying the managerial profit share α_d^c and the debt repayment b_d^c, is not robust to the threat of secret renegotiations. Recall from Lemma 1 that a larger profit share α tightens the collusion incentive constraint (2), which coincides with the renegotiation proofness constraint (12) if and only if $\alpha = 1$. Then, the full commitment contractual pair $\left(\alpha_d^c, b_d^c\right)$ violates the renegotiation proofness constraint (12). The full commitment solution succumbs to secret renegotiations and cannot be supported in equilibrium because it neglects the deviation incentives of the firm as a whole.

Equipped with the results in Lemma 2, we now derive the optimal design of debt and managerial incentives that satisfies the renegotiation proofness constraint (12) and thus sustains collusion under the threat of secret renegotiations about managerial contracts.

Proposition 3 *Suppose that firms' shareholders can commit to debt contracts but they can secretly renegotiate managerial contracts. Then, for a relatively small managerial reservation utility — i.e., $u < \overline{u}^{rm}$ — there exist two thresholds $\overline{\delta}^r$ and $\underline{\delta}^r$ for the discount factor δ such that*

(i) if $\delta \geq \overline{\delta}^r$, in the collusive equilibrium, firms' shareholders issue (almost) no debt and provide managerial incentive schemes — i.e., $b_{nd}^{rm} \to 0$ and $\alpha_{nd}^{rm} \in (0,1)$;

(ii) if $\delta \in \left[\underline{\delta}^r, \overline{\delta}^r\right)$, in the collusive equilibrium, firms' shareholders issue some debt and provide higher-powered managerial incentive schemes when the responsiveness of the managerial costs of bankruptcy to the severity of financial distress is large enough — i.e., $b_d^{rm} > 0$ and $\alpha_d^{rm} \in \left(\alpha_{nd}^{rm}, 1\right)$ for $\phi \geq \overline{\phi}^r$;

(iii) otherwise — i.e., either if $\delta < \underline{\delta}^r$ or if $\delta \in \left[\underline{\delta}^r, \overline{\delta}^r\right)$ and $\phi < \overline{\phi}^r$ — the collusive monopoly outcome is not sustainable.

The debt repayment b_d^{rm} and the managerial profit share α_d^{rm} in point (ii) are higher than in the scenario of full commitment characterized in Proposition 1 — i.e., $b_d^{rm} > b_d^c$ and $\alpha_d^{rm} > \alpha_d^c$.

Proposition 3 shows that, notwithstanding the vulnerability of managerial contracts to secret renegotiations, there is still scope for collusion in the product market. Specifically, for intermediate values of the discount factor, shareholders can achieve the collusive outcome through a mix of debt and managerial incentives, provided that the managerial costs of bankruptcy are sufficiently sensitive to financial distress, in line with the full commitment solution characterized in Proposition 1.[22] Note from Lemma 2 that the managerial costs of bankruptcy relax the renegotiation proofness constraint (12), but the managerial profit share is inconsequential, which makes the collusive outcome more difficult to achieve. Hence, in order to insulate managerial contracts from secret renegotiations, shareholders must expand the amount of debt compared to the case of full commitment. Given the complementarity between debt and managerial incentives, a higher profit share is required by managers in order to ensure their participation.

Renegotiations about debt and managerial contracts. In the light of the results in Proposition 3, it is legitimate to wonder whether the sustainability of collusion crucially hinges upon the

[22] When the discount factor is large enough, the amount of debt is so small as to converge to zero, similarly to Proposition 1. We refer to the proof of Proposition 3 for technical details.

shareholders' ability to commit to debt contracts. As previously argued, debt contracts can exhibit a significant commitment value. However, the possibility that debt contracts are also susceptible to secret renegotiations definitely deserves some attention. To this aim, we now consider a situation where shareholders' commitment powers are so weak that shareholders cannot refrain from secretly renegotiating both debt and managerial contracts. Our analysis reveals that, under certain circumstances, a combination of debt and managerial incentives can still facilitate collusion. To begin with, it is helpful to provide the following result.

Lemma 3 *Suppose that firms' shareholders can secretly renegotiate debt and managerial contracts. If each firm borrows from an exclusive lender, firms' shareholders issue no debt and collusion cannot be sustained.*

Lemma 3 emphasizes that, under exclusive lending relationships, the collusive outcome collapses when any contract can be secretly renegotiated. An exclusive lender does not internalize the negative effects that debt renegotiations with its client impose on the other firms, which go bankrupt as a consequence of the renegotiating firm's deviation in product market. The vertical structure, consisting of an exclusive lender and a firm, benefits from secret changes both in the debt contract, through the reimbursement of (at least) the entire loan to the lender, and in the managerial contract, through a new profit share that leaves the manager (at least) as well off and induces a defection from the collusive agreement.[23]

Things change dramatically in the commonly observed situation where a lender deals simultaneously with multiple firms — i.e., under common lending relationships. In this case, in order to accept a new proposal by one client, the lender requests a premium in anticipation of the losses arising from bankruptcy of the other borrowing firms. Intuitively, if this premium is high enough, renegotiations about the debt contract cannot be mutually beneficial. Hence, the establishment of a financial network, with multiple firms served by the same lender, can help to sustain collusion in the product market because it allows the lender to internalize the negative externalities of debt renegotiations. In order to convey our results in the most intuitive manner, we first consider the simplest financial network where all firms borrow from a single lender. Suppose that, in a certain period (after all loans have been spent on wasteful activities), one firm makes the lender an offer that stipulates the termination of the original debt contract in exchange for an up-front lump sum transfer from the firm to the lender. In anticipation of the firm's deviation in the product market and the consequential default of the other firms, the lender is willing to accept the deviating firm's offer for a transfer (at least) given by $bN/(1-\delta)$, which ensures a renegotiation premium corresponding to the present discounted value of the per period debt repayments promised by all N firms.[24] Hence, a debt contract is

[23] Lemma 3 differs from the findings of Acemoglu (1998), according to which secret renegotiations within a vertical structure could be prevented by offering the manager sufficiently large rents so that the renegotiation process becomes overly expensive. Acemoglu's (1998) solution, however, requires the manager's rents to be partially financed by the lender. This implies that the manager is simultaneously on the payroll of the lender and of the firm, a type of agreement rarely adopted in practice.

[24] As in an infinitely repeated game each subgame that commences in a certain period is identical to the original game, a contractual revision in that period corresponds to the one occurring at the outset of the game. Given the debt $L = b/(1-\delta)$ in the initial period $\tau = 1$, the present discounted value of the residual debt of each firm in any subsequent period $\tau \in \{2, ..., +\infty\}$ is $L/\delta^{\tau-1} - \sum_{t=1}^{\tau-1} b/\delta^t = b/(1-\delta)$.

renegotiation proof if and only if

$$\frac{\pi - b}{1-\delta} \geq N\pi - \frac{b}{1-\delta}N \implies b \geq \frac{(1-\delta)N-1}{N-1}\pi, \tag{13}$$

which identifies the lowest level of debt repayment such that the present discounted collusive profits accruing to a firm outweigh the gains from renegotiations in terms of deviation profits net of the renegotiation premium to the lender.[25] When secret renegotiations can affect both debt and managerial contracts, the renegotiation proofness constraints (12) and (13) must be simultaneously satisfied in order to sustain collusion. The following proposition shows that, even in the case where any contract is susceptible to secret renegotiations, firms' shareholders can still combine debt and managerial incentives to soften competition.

Proposition 4 *Suppose that firms' shareholders can secretly renegotiate debt and managerial contracts. Then, for a relatively small managerial outside option — i.e., $u < \overline{u}^r$ — there exist two thresholds $\overline{\delta}^r$ and $\underline{\delta}^r$ for the discount factor δ such that*

(i) if $\delta \geq \overline{\delta}^r$, in the collusive equilibrium, firms' shareholders issue some debt and provide managerial incentive schemes — i.e., $b_d^r = b_d^{rd} > 0$ and $\alpha_d^r = \alpha_d^{rd} \in \left(\alpha_{nd}^{rm}, 1\right)$;

(ii) if $\delta \in \left[\underline{\delta}^r, \overline{\delta}^r\right)$, in the collusive equilibrium, firms' shareholders issue some debt and provide managerial incentive schemes when the responsiveness of the managerial costs of bankruptcy to the severity of financial distress is large enough — i.e., $b_d^r = \max\left\{b_d^{rd}, b_d^{rm}\right\}$ and $\alpha_d^r = \max\left\{\alpha_d^{rd}, \alpha_d^{rm}\right\}$ for $\phi \geq \overline{\phi}^r$;

(iii) otherwise — i.e., either if $\delta < \underline{\delta}^r$ or if $\delta \in \left[\underline{\delta}^r, \overline{\delta}^r\right)$ and $\phi < \overline{\phi}^r$ — the collusive monopoly outcome is not sustainable.

The debt repayment $b_d^r = \max\left\{b_d^{rd}, b_d^{rm}\right\}$ and the managerial profit share $\alpha_d^r = \max\left\{\alpha_d^{rd}, \alpha_d^{rm}\right\}$ in point (ii) are strictly higher than in the scenario of commitment to debt contracts and secret renegotiations about managerial contracts characterized in Proposition 3 when the responsiveness of the managerial costs of bankruptcy to the severity of financial distress is large enough — i.e., $b_d^r = b_d^{rd} > b_d^{rm}$ and $\alpha_d^r = \alpha_d^{rd} > \alpha_d^{rm}$ for $\phi > \widetilde{\phi}^r$.

Proposition 4 indicates that the level of debt and managerial incentives characterized in Proposition 3 in a setting where only managerial contracts can be renegotiated may not suffice to render debt contracts immune to renegotiations as well. Hence, under certain circumstances, shareholders must expand the amount of debt and strengthen managerial incentives in order to ensure collusion in the product market. Specifically, when the discount factor is large enough, some (non-negligible) amount of debt is required to remove any temptation to renegotiate debt contracts — i.e., the renegotiation proofness constraint (13) is binding in equilibrium. For intermediate values of the discount factor, a combination of debt and managerial incentives allows shareholders to achieve the collusive outcome, provided that the managerial costs of bankruptcy are sufficiently responsive to the severity of financial distress. The level of debt and managerial incentives crucially depends on the relative magnitude of the scope for renegotiations about debt vis-à-vis managerial contracts. When the responsiveness of the managerial costs of bankruptcy to the severity of financial distress is large enough, managers

[25] Note from Assumption 1 that the lowest level of debt repayment in (13) is strictly positive.

become relatively reluctant to revise their contracts and thus debt renegotiations are more attractive. In this case, the renegotiation proofness constraint (13) about debt contracts is more stringent than the renegotiation proofness constraint (12) about managerial contracts and thus it is binding in equilibrium. Otherwise, the possibility of also renegotiating debt contracts does not alter the optimal mix of debt and managerial incentives that sustains collusion compared to the case where only managerial contracts can be renegotiated.

We have focused so far on the presence of a single lender. Notably, our results can be generalized to multiple financial networks, where only a subset of firms borrows from the same lender. To fix ideas, consider a collusive strategy such that each lender serves $M < N$ firms, which implies that there are N/M lenders in equilibrium.[26] It follows from Lemma 3 that each lender must serve at least two firms in the collusive equilibrium, i.e., $M \geq 2$.[27] Following the same rationale as in the previous analysis, a lender is willing to accept a deviating firm's offer for a transfer (at least) given by $bM/(1-\delta)$, which ensures a renegotiation premium corresponding to the present discounted value of the per period debt repayments promised by the lender's M clients. Hence, a debt contract is renegotiation proof if and only if

$$\frac{\pi - b}{1-\delta} \geq N\pi - \frac{b}{1-\delta}M \implies b \geq \frac{(1-\delta)N - 1}{M-1}\pi. \tag{14}$$

The lowest level of debt repayment in (14) that makes a debt contract immune to renegotiations decreases with the number M of firms belonging to the lender's network. Thus, the establishment of larger financial networks — with a higher number of firms borrowing from the same lender — reduces the amount of debt and enhances the scope for collusion. We now present our results under multiple financial networks.

Proposition 5 *Suppose that firms' shareholders can secretly renegotiate debt and managerial contracts. Then, if a number $M < N$ of firms borrow from the same lender and hence there are N/M active lenders, the results characterized in Proposition 4 hold, with the debt repayment b_d^{rd} and the managerial profit share α_d^{rd} being replaced by $b_d^{rdn} > b_d^{rd}$ and $\alpha_d^{rdn} > \alpha_d^{rd}$, respectively.*

Proposition 5 shows that the collusive outcome can still be achieved through a multiplicity of independent financial networks — such as the Japanese 'keiretsu' or the German 'house bank' system — by resorting to a higher level of debt and managerial incentives with respect to the case of a single lender.[28] In a similar vein, our qualitative results apply to the case where firms borrow from more than one bank (e.g., Carletti, 2004; Carletti et al., 2007; Detragiache et al., 2000), provided that the bank holds a debt share of some firms. Interestingly, our results

[26] Without any loss of insights, we assume that N/M is an integer number.

[27] This occurs in a wide range of plausible circumstances. As discussed in Section 7, a lender typically deals with multiple firms operating in the same market. In our setting, if a lender denies credit to a firm in order to establish an exclusive relationship with another firm, the collusive phase would not start because the firm without credit could not engage in wasteful activities at the outset of the game in the reasonable situation where the number of potential lenders is lower than the number of firms. This would clearly remove any incentive to form an exclusive lending relationship. A fortiori, credit denial could be prevented through information sharing among lenders about their borrowers, which is described in Section 7.

[28] The proof of Proposition 5 is omitted. It directly follows from the proof of Proposition 4, with the only difference being that the relevant renegotiation proofness constraint is given by (14) instead of (13). The debt repayment b_d^{rdn} and the managerial profit share α_d^{rdn} are respectively determined by the binding constraints (14) and (5).

can be also related to the investigation into the formation of networks involving buyers and sellers (e.g., Kranton and Minehart, 2001).

5.2 No commitment

To substantiate the robustness of our results to more extreme forms of limited commitment, we now consider the situation where a firm's shareholders cannot commit to any contract whatsoever with their manager. Hence, shareholders can secretly renege upon the original contractual obligations and offer the manager a new contract. In other terms, the announcements about managerial contracts are cheap talk. We denote by

$$\widehat{V}(b) \triangleq \max_{\widehat{\alpha}\in[0,1]} (1-\widehat{\alpha})(N\pi - b) \quad s.t.\ \widehat{\alpha}(N\pi - b) - \delta C(b) \geq u \tag{15}$$

the maximum profits that a firm's shareholders can obtain by breaching the original contract and offering their manager a new profit share $\widehat{\alpha}$ that ensures at least the reservation utility u and induces the manager to deviate in the product market by undercutting the collusive price. The manager obtains a share $\widehat{\alpha}$ of the deviation profits $N\pi$ net of the debt repayment b and incurs the costs of bankruptcy $C(\cdot)$ in the punishment phase.

As in the previous analysis, we start with the case where debt contracts can be credibly announced. Using (9) and (15), we find that a firm's shareholders cannot benefit from reneging upon any managerial contract if and only if

$$V(\alpha, b) \geq \widehat{V}(b). \tag{16}$$

Any contractual pair (α, b) that satisfies the no-commitment constraint (16) allows shareholders to achieve the collusive outcome. We find the following results.

Proposition 6 *Suppose that firms' shareholders can commit to debt contracts but they can secretly renege upon managerial contracts. Then, for a relatively small managerial outside option — i.e., $u < \overline{u}^{nm}$ — there exist two thresholds $\overline{\delta}^n$ and $\underline{\delta}^n$ for the discount factor δ such that*

(i) if $\delta \geq \overline{\delta}^n$, in the collusive equilibrium, firms' shareholders issue (almost) no debt and provide managerial incentive schemes — i.e., $b_{nd}^{nm} \to 0$ and $\alpha_{nd}^{nm} \in (0,1)$;

(ii) if $\delta \in \left[\underline{\delta}^n, \overline{\delta}^n\right)$, in the collusive equilibrium, firms' shareholders issue some debt and provide higher-powered managerial incentive schemes when the responsiveness of the managerial costs of bankruptcy to the severity of financial distress is large enough — i.e., $b_d^{nm} > 0$ and $\alpha_d^{nm} \in \left(\alpha_{nd}^{nm}, 1\right)$ for $\phi \geq \overline{\phi}^n$;

(iii) otherwise — i.e., either if $\delta < \underline{\delta}^n$ or if $\delta \in \left[\underline{\delta}^n, \overline{\delta}^n\right)$ and $\phi < \overline{\phi}^n$ — the collusive monopoly outcome is not sustainable.

The debt repayment b_d^{nm} and the managerial profit share α_d^{nm} in point (ii) are strictly higher than in the scenario of commitment to debt contracts and secret renegotiations about managerial contracts characterized in Proposition 3 — i.e., $b_d^{nm} > b_d^{rm}$ and $\alpha_d^{nm} > \alpha_d^{rm}$.

Proposition 6 shows that the collusive role of debt and managerial incentives persists when firms' shareholders lack any commitment powers on managerial contracts but they can still

	commitment to D and M	commitment to D and renegotiations about M	renegotiations about D and M	commitment to D and no commitment to M	renegotiations about D and no commitment to M
D	b_d^c	$b_d^{rm} > b_d^c$	$b_d^r = \max\{b_d^{rd}, b_d^{rm}\}$	$b_d^{nm} > b_d^{rm}$	$b_d^n = \max\{b_d^{rd}, b_d^{nm}\}$
M	α_d^c	$\alpha_d^{rm} > \alpha_d^c$	$\alpha_d^r = \max\{\alpha_d^{rd}, \alpha_d^{rm}\}$	$\alpha_d^{nm} > \alpha_d^{rm}$	$\alpha_d^n = \max\{\alpha_d^{rd}, \alpha_d^{nm}\}$

Table 1: Debt (D) and managerial incentives (M) under different commitment scenarios.

commit to the debt structure. The opportunity to secretly renege upon managerial contracts makes collusion more difficult to sustain compared to the case of secret renegotiations — i.e., the no-commitment constraint (16) is more stringent than the renegotiation proofness constraint (11).[29] As Propositions 3 and 6 reveal, this magnifies shareholders' reliance on the magnitude of debt and managerial incentives for collusive purposes. A higher level of debt makes managers more reluctant to deviate in the product market and reduces shareholders' benefits from breaching managerial contracts.

We now turn to the case of secret renegotiations about debt contracts.

Proposition 7 *Suppose that firms' shareholders can secretly renegotiate debt contracts and they can secretly renege upon managerial contracts. Then, for a relatively small managerial outside option — i.e., $u < \overline{u}^n$ — there exist two thresholds $\overline{\delta}^n$ and $\underline{\delta}^n$ for the discount factor δ such that*

(i) if $\delta \geq \overline{\delta}^n$, in the collusive equilibrium, firms' shareholders issue some debt and provide managerial incentive schemes — i.e., $b_d^n = b_d^{rd} > 0$ and $\alpha_d^n = \alpha_d^{rd} \in (\alpha_{nd}^{nm}, 1)$;

(ii) if $\delta \in \left[\underline{\delta}^n, \overline{\delta}^n\right)$, in the collusive equilibrium, firms' shareholders issue some debt and provide managerial incentive schemes when the responsiveness of the managerial costs of bankruptcy to the severity of financial distress is large enough — i.e., $b_d^n = \max\{b_d^{rd}, b_d^{nm}\}$ and $\alpha_d^n = \max\{\alpha_d^{rd}, \alpha_d^{nm}\}$ for $\phi \geq \overline{\phi}^n$;

(iii) otherwise — i.e., either if $\delta < \underline{\delta}^n$ or if $\delta \in \left[\underline{\delta}^n, \overline{\delta}^n\right)$ and $\phi < \overline{\phi}^n$ — the collusive monopoly outcome is not sustainable.

The debt repayment $b_d^n = \max\{b_d^{rd}, b_d^{nm}\}$ and the managerial profit share $\alpha_d^n = \max\{\alpha_d^{rd}, \alpha_d^{nm}\}$ in point (ii) are strictly higher than in the scenario of commitment to debt contracts and no commitment to managerial contracts characterized in Proposition 6 when the responsiveness of the managerial costs of bankruptcy to the severity of financial distress is large enough — i.e., $b_d^n = b_d^{rd} > b_d^{nm}$ and $\alpha_d^n = \alpha_d^{rd} > \alpha_d^{nm}$ for $\phi > \widetilde{\phi}^n$.

Proposition 7 indicates that the vulnerability of debt contracts to secret renegotiations can exacerbate the shareholders' propensity to resort to debt and managerial incentives to sustain collusion. Similarly to the case of renegotiations about debt and managerial contracts (formalized in Proposition 4), shareholders now issue some debt even for a sufficiently large discount factor — i.e., the renegotiation proofness constraint (13) is binding in equilibrium. Furthermore, we find from Propositions 6 and 7 that, under no commitment to managerial contracts,

[29] Using (6), we find that the right-hand side of the constraint in (15) is lower than the right-hand side of the constraint in (10).

the threat of secret renegotiations about debt contracts can lead shareholders to expand the amount of debt and to strengthen managerial incentives with respect to full commitment to debt contracts. This occurs as long as the managerial costs of bankruptcy are sufficiently sensitive to the severity of financial distress so that managers become relatively reluctant to deviate in the product market and debt renegotiations are more attractive. In this case, the renegotiation proofness constraint (13) is more stringent than the no-commitment constraint (16) and thus it is binding in equilibrium. Our main results about debt financing and managerial incentive schemes under different commitment scenarios are summarized in Table 1.

6 Market structure

Throughout the paper, we examine a standard Bertrand framework where firms sell a homogeneous good and compete in prices. A firm that defects from the collusive agreement is able to collect the entire industry profits whereas in the punishment phase all firms revert to the competitive equilibrium by setting their prices at the marginal cost and making zero profits, which implies that loans cannot be reimbursed and bankruptcy arises. How does the sustainability of collusion vary with the market structure? What effects do the magnitude of deviation profits and the degree of competition in the absence of collusion exhibit on the shareholders' propensity to use debt and managerial incentives for collusive purposes? To address these issues, in the spirit of Harrington and Chang (2009), we extend our model to a framework in which the firm's deviation profits are $\eta\pi$, where $\eta > 1$ captures the degree of demand elasticity, and the firm's punishment profits amount to $\gamma\pi$, where $\gamma \in [0,1)$ is an inverse measure of the intensity of competition in the absence of collusion (for instance, driven by the degree of product differentiation).[30] Faced with a debt repayment b, a firm obtains $\pi - b$ in any collusive period and $\eta\pi - b$ in the deviation period. A firm goes bankrupt in the punishment phase if and only if the debt repayment is larger than punishment profits, i.e., $b > \gamma\pi$. This brings the manager's outside option to zero and engenders managerial costs of bankruptcy $C(b) = [k + \phi(b - \gamma\pi)] \cdot \mathbf{1}_b$, where the indicator function $\mathbf{1}_b \in \{0,1\}$ assumes a value of one if $b > \gamma\pi$ and a value of zero otherwise. As in the baseline model, we consider a setting where firms' shareholders can commit to debt and managerial contracts. The incentive constraint that ensures the sustainability of collusion writes as

$$\frac{\alpha}{1-\delta}(\pi - b) \geq \alpha\left[\eta\pi - b + \frac{\delta}{1-\delta}\max\{\gamma\pi - b, 0\}\right] - \delta C(b), \tag{17}$$

where the firm obtains zero profits during punishment in the case of bankruptcy that occurs if and only if the debt repayment exceeds punishment profits, i.e., $b > \gamma\pi$. In the absence of debt and associated costs of bankruptcy, i.e., $b = C(b) = 0$, collusion is sustainable if and only if $\delta \geq (\eta - 1)/(\eta - \gamma)$. We impose the following assumption.

Assumption 2 $\delta < \frac{\eta-1}{\eta-\gamma}$.

[30] This setting reduces to our baseline model à la Bertrand for $\eta = N$ and $\gamma = 0$. A linear Cournot model where the collusive price is at the monopoly level arises for $\eta = (N+1)^2/4N$ and $\gamma = 4N/(N+1)^2$.

Assumption 2 is a natural extension of Assumption 1 and guarantees that the discount factor is not excessively large so that collusion cannot be sustained in the absence of debt.

To gain insights into our analysis, we provide the following result.

Lemma 4 *In the collusive equilibrium, the debt repayment must exceed the firm's punishment profits — i.e.,* $b > \gamma\pi$.

Intuitively, a necessary condition for the sustainability of collusion is that managers incur costs of bankruptcy after a deviation, which requires that a firm is not able to reimburse its debt in the punishment phase.[31] In the light of the result in Lemma 4, we focus hereafter on the case $b > \gamma\pi$. The collusion incentive constraint (17) becomes

$$\frac{\alpha}{1-\delta}(\pi - b) \geq \alpha(\eta\pi - b) - \delta[k + \phi(b - \gamma\pi)]. \tag{18}$$

As in the baseline model, the debt structure generates a trade-off in terms of collusion. A higher level of debt makes managers keener to deviate, because the consequential default in the punishment phase cancels the reimbursement of the residual debt. However, the managerial costs of bankruptcy increase with the amount of debt. Interestingly, the magnitude of this trade-off varies with the market structure. In particular, softer competition (i.e., a higher γ) reduces the severity of financial distress, which translates into lower managerial costs of bankruptcy. Moreover, a more elastic demand (i.e., a higher η) leads to an increase in the firm's deviation profits. Both effects make the collusion incentive constraint (18) more stringent. This suggests that in markets with softer competition and higher elasticity of demand firms' shareholders should rely to a further extent on the magnitude of debt and managerial incentives for collusive purposes. The following proposition substantiates our claims.

Proposition 8 *Consider a market structure with intensity of competition* $\gamma \in [0, 1)$ *and demand elasticity* $\eta > 1$. *Suppose that firms' shareholders can commit to debt and managerial contracts. Then, for a relatively small managerial outside option — i.e.,* $u < \overline{u}^{cs}$ *— there exist two thresholds* $\overline{\delta}^{cs}$ *and* $\underline{\delta}^{cs}$ *for the discount factor* δ *such that*

(*i*) *if* $\delta \geq \overline{\delta}^{cs}$, *in the collusive equilibrium, firms' shareholders issue some debt and provide managerial incentive schemes — i.e.,* $b_d^{cs} \to \gamma\pi$ *and* $\alpha_d^{cs} \in (0, 1)$;

(*ii*) *if* $\delta \in \left[\underline{\delta}^{cs}, \overline{\delta}^{cs}\right)$, *in the collusive equilibrium, firms' shareholders issue a higher amount of debt and provide higher-powered managerial incentive schemes when the responsiveness of the managerial costs of bankruptcy to the severity of financial distress is large enough — i.e.,* $b_{hd}^{cs} > \gamma\pi$ *and* $\alpha_{hd}^{cs} \in \left(\alpha_d^{cs}, 1\right)$ *for* $\phi \geq \overline{\phi}^{cs}$;

(*iii*) *otherwise — i.e., either if* $\delta < \underline{\delta}^{cs}$ *or if* $\delta \in \left[\underline{\delta}^{cs}, \overline{\delta}^{cs}\right)$ *and* $\phi < \overline{\phi}^{cs}$ *— the collusive monopoly outcome is not sustainable.*

Proposition 8 indicates that shareholders can still combine debt and managerial incentives to achieve collusion in markets with structural characteristics that differ from the standard Bertrand setting. As implied by Lemma 4, debt is now used for collusive purposes even when

[31] The proof of Lemma 4 is omitted. It directly follows from the observation that for $b \leq \gamma\pi$ the collusion incentive constraint (17) fails to hold under Assumption 2.

the discount factor is relatively large. Collusion is sustainable for intermediate values of the discount factor by inflating the amount of debt and managerial incentives, provided that the managerial costs of bankruptcy are sufficiently responsive to the severity of financial distress. Based on the results in Proposition 8, we conduct the following comparative statics analysis.

Corollary 1 *The debt repayment b_d^{cs} and the managerial profit share α_d^{cs} characterized in Proposition 8 decrease with the intensity of competition and increase with the degree of demand elasticity — i.e., $\partial b_d^{cs}/\partial\gamma > 0$, $\partial b_d^{cs}/\partial\eta > 0$, and $\partial\alpha_d^{cs}/\partial\gamma > 0$, $\partial\alpha_d^{cs}/\partial\eta > 0$.*

As the discussion after Lemma 4 suggests, softer competition (i.e., a higher γ) reduces the managerial costs of bankruptcy, which leads shareholders to increase the amount of debt for collusive purposes. Analogously, a more elastic demand (i.e., a higher η) generates higher deviation profits and thus collusion can only be supported through an expansion of debt. This translates into a higher managerial profit share in order to ensure managers' participation.

7 Managerial and policy implications

Our work provide some implications for the role of managers within firms. Shareholders can combine debt financing and managerial incentives in order to discipline managers' behavior in the product market. Managers are inclined to compete too fiercely compared to what shareholders would ideally prefer. To mitigate managers' aggressive behavior, shareholders expand the level of debt, which induces managers to behave more leniently in the fear of bankruptcy, and provide managers with higher-powered incentive schemes that ensure managers' participation. Thus, our findings suggest that high debt can be a firm's deliberate choice with the purpose to soften competition rather than the outcome of poor managerial performance.

High debt has been traditionally deemed as an impediment to collusion. Our study can help policymakers with the design of compelling guidelines and protocols that assist antitrust authorities in deterring collusive activities. Our results about the collusive effects of common lending can be related to the literature on the anticompetitive effects of common ownership. A firm that owns a stake in the rivals' profits (partially) internalizes the losses that a price cut imposes on them. Gilo et al. (2006) identify the conditions under which partial cross ownership facilitates collusion. As shown by Azar et al. (2018) using data from the US airline industry, common ownership generates anticompetitive effects that are more than ten times larger compared to what is 'presumed to be likely to enhance market power' according to the 2010 US Merger Horizontal Guidelines. We find that a common lender stabilizes collusion by taking into account the negative externalities of debt renegotiations with a firm arising from bankruptcy of the other borrowing firms. Thus, the role of common lending in sustaining collusion corresponds to the role of common ownership. However, in our framework common lending only matters under limited commitment. Notably, the collusive mechanism based on common lending seems to be a more subtle matter for antitrust policy than common ownership because the prevalence of common lenders can be justified by obvious arguments of bank specialization. Antón et al. (2022) document that managerial incentives are less performance-sensitive in firms with more common ownership. The idea is that common owners (partially)

internalize the reduction in the profitability of competing firms due to lower prices driven by productivity-improving managerial effort. By contrast, we find that, in the absence of common ownership, shareholders strengthen managerial incentives for collusive purposes.

Our model also delivers policy implications for the role of information sharing systems in credit markets. It has been widely recognized in the literature since Sharpe (1990) and Pagano and Jappelli (1993) that lenders can acquire monopoly power from privileged information about their own customers and information sharing among lenders may arise endogenously, which leads to an increase in the volume of lending when the problem of adverse selection is particularly severe. As pointed out by Padilla and Pagano (1997, 2000), the lenders' commitment to share information promotes the borrowers' effort to repay loans and the exchange of information about borrowers' past defaults may improve their performance. Yet, this literature has not typically taken into consideration the impact of information sharing agreements on product markets and ultimately on welfare.

Our study unveils a dark side of information sharing that has been hitherto neglected. The exchange of information about firms' financial structure strengthens shareholders' commitment powers, which renders debt and managerial incentives more effective in sustaining collusion especially when information involves new or outstanding debt instead of poor repayment behavior.[32] This advocates a suitable formulation of the disclosure rules that shape corporate governance regulation. In the US, public companies are required to report to the Securities and Exchange Commission (SEC) certain material corporate events, including changes in financial obligations, by filing the so-called 'Form 8-K' — introduced by the Securities Exchange Act of 1934 and amended in 2004 to expand disclosure requirements — within four business days of their occurrence. Such reports are publicly available in the SEC's EDGAR database, which collects information about public companies' financial operations.[33] The well-recognized social benefits of transparency rules in terms of investors' protection and limitation of financial market manipulation can be traded off against the exacerbation of the anticompetitive effects of debt highlighted in our analysis. This point is evocative of Stigler's (1964) classical observation that transparency rules aimed at improving accountability may indeed facilitate the formation and stability of bidding rings by allowing bidders to monitor their rivals' choices. Given that firms can be disciplined by sufficiently severe market competition and corporate governance matters exactly when competitive pressure is relatively weak (Giroud and Mueller, 2010, 2011), our results imply that transparency rules designed to improve market efficiency may be counterproductive by undermining the disciplinary role of competition.

8 Concluding remarks

In this paper we investigate the effects of debt financing and managerial incentives on product market competition when managers incur personal costs of bankruptcy. Challenging the tra-

[32] Bennardo et al. (2015) characterize a different negative aspect of information sharing in credit markets in a model where borrowers do not compete in the product market. Information sharing about borrowers' credit histories may lead the credit market to collapse insofar as it exacerbates the moral hazard problems faced by lenders competing for the same borrower.

[33] Further details are available at `https://www.sec.gov/edgar/about` (last retrieved in July 2022).

ditional view that higher debt hinders the firms' ability to collude, we show that, under some relevant circumstances, firms' shareholders combine debt and managerial incentives in order to collude in product markets. The use of debt and managerial incentives for collusive purposes is more effective when shareholders can commit to debt and managerial contracts. Our results carry over to settings with different degrees of limited commitment, where disclosure rules about firms' financial structure and corporate governance are lacking or poorly enforced. In particular, we find that limited commitment magnifies the level of debt and managerial incentives required to sustain collusion. As discussed in the introduction, our study attempts to reconcile theory, which has traditionally emphasized the procompetitive effects of debt, with a large body of empirical evidence documenting the collusive effects of debt and managerial incentive schemes. We provide novel insights into the role of managers within firms and the use of debt to manipulate managerial behavior as well as into the design of antitrust policy and corporate governance rules that can effectively deter collusion.

Our results are suggestive of the interactions between firms' financial structure and corporate governance mechanisms as determinants of collusion in product markets. Specifically, our model predicts that collusion is more likely to emerge in markets where firms resort more extensively to debt financing and performance-based managerial remuneration schemes.[34] Furthermore, in settings characterized by lower enforcement of disclosure rules (which weakens shareholders' commitment powers), collusion can be sustained only through a higher level of debt and managerial incentives. A similar pattern is expected to arise in industries where competition is softer even in the absence of collusion (for instance, due to product differentiation) or market demand is somewhat elastic. An additional element potentially conducive to collusion is common lending, especially when disclosure rules are poorly enforced. The effects of common lending share relevant similarities with those of common ownership. As such, our study delivers a range of testable predictions and a new guidance on the empirical assessment of the channels through which firms' financial structure and corporate governance affect collusion in product markets.

Appendix

This Appendix collects the proofs. The proofs of Propositions 6, 7, and 8 as well as the proof of Corollary 1 are available in the Supplementary Appendix.

Proof of Lemma 1. Define

$$\Gamma(\alpha, b) \triangleq \frac{\alpha}{1-\delta}(\pi - b) - \alpha(N\pi - b) + \delta C(b), \tag{A1}$$

where $C(\cdot)$ is given by (1). The collusion incentive constraint (2) is satisfied if and only if $\Gamma(\cdot,\cdot) \geq 0$. Given that for $\alpha = 0$ it holds $\Gamma(\cdot,\cdot) \geq 0$, we focus hereafter on the case $\alpha > 0$. Note from (A1) that $\Gamma(\cdot,\cdot) \to -\alpha(N-1)\pi < 0$ for $\delta \to 0$ and $\Gamma(\cdot,\cdot) \to +\infty$ for $\delta \to 1$. It follows from the intermediate value theorem that there exists at least a value for $\delta \in (0,1)$ such that

[34] A cross-country empirical investigation could rely on the changes in regulations across countries that translate into different managerial costs of bankruptcy.

$\Gamma(\cdot,\cdot)=0$. Differentiating $\Gamma(\cdot,\cdot)$ in (A1) with respect to δ yields

$$\frac{\partial\Gamma}{\partial\delta}=\alpha\frac{\pi-b}{(1-\delta)^2}+C(b)>0.$$

Then, there exists a unique threshold $\delta^*(\alpha,b)\in(0,1)$ such that $\Gamma(\cdot,\cdot)\geq 0$ if and only if $\delta\geq\delta^*(\alpha,b)$, where $\Gamma(\cdot,\cdot)=0$ if and only if $\delta=\delta^*(\alpha,b)$. The threshold $\delta^*(\alpha,b)$ is given by

$$\delta^*(\alpha,b)=\frac{\alpha\pi N+C(b)-\alpha b-\sqrt{[\alpha\pi N+C(b)-\alpha b]^2-4\alpha\pi(N-1)C(b)}}{2C(b)}. \tag{A2}$$

Applying the implicit function theorem to $\Gamma(\cdot,\cdot)=0$, where $\Gamma(\cdot,\cdot)$ is defined by (A1), yields

$$\frac{\partial\delta^*}{\partial\alpha}=-\frac{\partial\Gamma/\partial\alpha}{\partial\Gamma/\partial\delta}\bigg|_{\delta=\delta^*}=\frac{(1-\delta^*)[(1-\delta^*)(\pi N-b)-(\pi-b)]}{\alpha(\pi-b)+(1-\delta^*)^2C(b)}>0,$$

where the inequality follows from $(1-\delta^*)(\pi N-b)-(\pi-b)>0$ (as $\Gamma(\cdot,\cdot)=0$). Furthermore, we have

$$\frac{\partial\delta^*}{\partial b}=-\frac{\partial\Gamma/\partial b}{\partial\Gamma/\partial\delta}\bigg|_{\delta=\delta^*}=\frac{\delta^*(1-\delta^*)[\alpha-\phi(1-\delta^*)]}{\alpha(\pi-b)+(1-\delta^*)^2C(b)}<0,$$

where the inequality holds if and only if $\frac{\alpha}{\phi}<1-\delta^*$. As $\delta^*(\cdot,\cdot)$ increases with α (see above) and decreases with ϕ (see below), we find that $\frac{\partial\delta^*}{\partial b}<0$ if and only if α is small enough and ϕ is large enough. To derive this condition explicitly, we take the derivative of $\delta^*(\cdot,\cdot)$ in (A2) with respect to b, which yields

$$\begin{aligned}\frac{\partial\delta^*}{\partial b}=&-\frac{\alpha-\phi}{2C(b)}-\frac{(\alpha-\phi)[\alpha b-C(b)]-\alpha\pi[\alpha N+\phi(N-2)]}{2C(b)\sqrt{[\alpha\pi N+C(b)-\alpha b]^2-4\alpha\pi(N-1)C(b)}}\\&-\phi\frac{\alpha\pi N+C(b)-\alpha b-\sqrt{[\alpha\pi N+C(b)-\alpha b]^2-4\alpha\pi(N-1)C(b)}}{2C(b)^2}.\end{aligned}$$

Using (1), we find that $\frac{\partial\delta^*}{\partial b}<0$ if and only if $\phi>\widetilde{\phi}(\alpha)$, where

$$\widetilde{\phi}(\alpha)\triangleq\frac{\alpha\pi N-k+\sqrt{(\alpha\pi N-k)^2+4\alpha k\pi}}{2\pi}\ \text{ and }\ \frac{\partial\widetilde{\phi}}{\partial\alpha}=\frac{N}{2}+\frac{\alpha\pi N^2-(N-2)k}{2\sqrt{(\alpha\pi N-k)^2+4\alpha k\pi}}>0.$$

Applying the implicit function theorem to $\Gamma(\cdot,\cdot)=0$, where $\Gamma(\cdot,\cdot)$ is defined by (A1), yields

$$\frac{\partial\delta^*}{\partial k}=-\frac{\partial\Gamma/\partial k}{\partial\Gamma/\partial\delta}\bigg|_{\delta=\delta^*}=-\frac{\delta^*(1-\delta^*)^2}{\alpha(\pi-b)+(1-\delta^*)^2C(b)}<0;$$

$$\frac{\partial\delta^*}{\partial\phi}=-\frac{\partial\Gamma/\partial\phi}{\partial\Gamma/\partial\delta}\bigg|_{\delta=\delta^*}=-\frac{b\delta^*(1-\delta^*)^2}{\alpha(\pi-b)+(1-\delta^*)^2C(b)}<0.\ \blacksquare$$

Proof of Proposition 1. Define

$$\Theta(b)\triangleq\frac{u}{1-\delta}-\frac{\pi N-b}{\pi-b}u+\delta C(b), \tag{A3}$$

where $C(\cdot)$ is given by (1). The collusion incentive constraint (8) is satisfied if and only if $\Theta(\cdot) \geq 0$. The shareholders' objective function in (7) decreases with b. Evaluating $\Theta(\cdot)$ in (A3) at $b = 0$ (which implies $C(\cdot) = 0$) yields

$$\Theta(b)|_{b=0} = \frac{u}{1-\delta} - uN < 0,$$

where the inequality follows from Assumption 1. Furthermore, we have

$$\lim_{b\to 0^+} \Theta(b) = \frac{u}{1-\delta} - uN + \delta k. \tag{A4}$$

As $\lim_{b\to 0^+} \Theta(b) = -u(N-1) < 0$ for $\delta \to 0$ and $\lim_{b\to 0^+} \Theta(b) = +\infty$ for $\delta \to 1$, it follows from the intermediate value theorem that there exists at least a value for $\delta \in (0,1)$ such that $\lim_{b\to 0^+} \Theta(b) = 0$. Given that $\lim_{b\to 0^+} \Theta(b)$ is strictly convex in δ, there exists a unique threshold $\overline{\delta}^c \in (0,1)$ such that $\lim_{b\to 0^+} \Theta(b) \geq 0$ if and only if $\delta \geq \overline{\delta}^c$, where $\lim_{b\to 0^+} \Theta(b) = 0$ if and only if $\delta = \overline{\delta}^c$. The threshold $\overline{\delta}^c$ is given by

$$\overline{\delta}^c \triangleq \frac{k + uN - \sqrt{(k-uN)^2 + 4ku}}{2k},$$

where $\overline{\delta}^c < \frac{N-1}{N}$. Then, for $\delta \geq \overline{\delta}^c$, in the collusive equilibrium, the amount of debt is $b^c_{nd} \to 0$. Using (6), the managerial profit share is $\alpha^c_{nd} \to \frac{u}{\pi} \in (0,1)$.

Now, suppose that $\delta < \overline{\delta}^c$. Note from (A4) that $\lim_{b\to 0^+} \Theta(b) < 0$ (as $\delta < \overline{\delta}^c$). Furthermore, differentiating $\Theta(\cdot)$ in (A3) with respect to b yields

$$\frac{\partial \Theta}{\partial b} = \delta\phi - \frac{(N-1)\pi u}{(\pi - b)^2} \text{ and } \frac{\partial^2 \Theta}{\partial b^2} = -\frac{2(N-1)\pi u}{(\pi-b)^3} < 0,$$

which implies that $\Theta(\cdot)$ is strictly concave in b. Then, a necessary condition for $\Theta(\cdot) \geq 0$ writes as

$$\lim_{b\to 0^+} \frac{\partial \Theta}{\partial b} = \delta\phi - \frac{(N-1)u}{\pi} > 0.$$

This condition holds if and only if $\delta \geq \underline{\delta}^c$, where the threshold $\underline{\delta}^c$ is given by

$$\underline{\delta}^c \triangleq \frac{(N-1)u}{\pi\phi}.$$

The lowest (positive) solution to $\Theta(\cdot) = 0$ with respect to b writes as

$$\begin{aligned} b^c_d \triangleq\ & \frac{(1-\delta)(\pi\phi - k) - u}{2(1-\delta)\phi} \\ & - \frac{\sqrt{\delta(1-\delta)^2(k+\pi\phi)^2 + 2u(1-\delta)[\delta k + \pi\phi(2 - \delta + 2\delta N - 2N)] + \delta u^2}}{2\sqrt{\delta}(1-\delta)\phi}. \end{aligned} \tag{A5}$$

It holds $\Theta(\cdot) \geq 0$ if and only if $\phi \geq \overline{\phi}^c$, where

$$\overline{\phi}^c \triangleq \frac{[2(1-\delta)N + \delta - 2]u - \delta(1-\delta)k + 2\sqrt{u(1-\delta)(N-1)[(1-\delta)(uN - \delta k) - u]}}{\delta(1-\delta)\pi}.$$

Then, for $\delta \in \left[\underline{\delta}^c, \overline{\delta}^c\right)$ and $\phi \geq \overline{\phi}^c$, in the collusive equilibrium, the amount of debt is given by $b_d^c > 0$ in (A5) and the managerial profit share is given by $\alpha_d^c = \frac{u}{\pi - b_d^c} \in \left(\alpha_{nd}^c, 1\right)$. Now, we show that $\alpha_d^c < 1$ when u is small enough. Applying the implicit function theorem to $\Theta(\cdot) = 0$, where $\Theta(\cdot)$ is defined by (A3), yields

$$\frac{\partial b_d^c}{\partial u} = -\left.\frac{\partial \Theta / \partial u}{\partial \Theta / \partial b}\right|_{b=b_d^c} > 0, \tag{A6}$$

where the inequality follows from $\left.\frac{\partial \Theta}{\partial u}\right|_{b=b_d^c} = \frac{1}{1-\delta} - \frac{\pi N - b_d^c}{\pi - b_d^c} < 0$ and $\left.\frac{\partial \Theta}{\partial b}\right|_{b=b_d^c} = \delta\phi - \frac{(N-1)\pi u}{\left(\pi - b_d^c\right)^2} > 0$, using the expression for b_d^c in (A5). This implies that $\alpha_d^c = \frac{u}{\pi - b_d^c}$ increases with u and $\alpha_d^c < 1$ if and only if $u < \overline{u}^c$, where

$$\overline{u}^c \triangleq \frac{(1-\delta)\left(\pi + \delta\pi\phi + \delta k - \pi N\right)}{\delta\left(\phi - \delta\phi - 1\right)}.$$

In the remaining region of parameters, where either $\delta < \underline{\delta}^c$ or $\delta \in \left[\underline{\delta}^c, \overline{\delta}^c\right)$ and $\phi < \overline{\phi}^c$, the collusive monopoly outcome is not sustainable. ■

Proof of Proposition 2. First, we consider the debt repayment b_d^c. Recall from the proof of Proposition 1 that $\left.\frac{\partial \Theta}{\partial b}\right|_{b=b_d^c} > 0$, where $\Theta(\cdot)$ is defined by (A3) and b_d^c by (A5). We know from (A6) that $\frac{\partial b_d^c}{\partial u} > 0$. Applying the implicit function theorem to $\Theta(\cdot) = 0$ yields

$$\left.\frac{\partial \Theta}{\partial N}\right|_{b=b_d^c} = -\frac{\pi u}{\pi - b_d^c} < 0 \implies \frac{\partial b_d^c}{\partial N} = -\left.\frac{\partial \Theta / \partial N}{\partial \Theta / \partial b}\right|_{b=b_d^c} > 0;$$

$$\left.\frac{\partial \Theta}{\partial \pi}\right|_{b=b_d^c} = \frac{b_d^c u (N-1)}{\left(\pi - b_d^c\right)^2} > 0 \implies \frac{\partial b_d^c}{\partial \pi} = -\left.\frac{\partial \Theta / \partial \pi}{\partial \Theta / \partial b}\right|_{b=b_d^c} < 0;$$

$$\left.\frac{\partial \Theta}{\partial k}\right|_{b=b_d^c} = \delta > 0 \implies \frac{\partial b_d^c}{\partial k} = -\left.\frac{\partial \Theta / \partial k}{\partial \Theta / \partial b}\right|_{b=b_d^c} < 0;$$

$$\left.\frac{\partial \Theta}{\partial \phi}\right|_{b=b_d^c} = \delta b_d^c > 0 \implies \frac{\partial b_d^c}{\partial \phi} = -\left.\frac{\partial \Theta / \partial \phi}{\partial \Theta / \partial b}\right|_{b=b_d^c} < 0;$$

$$\left.\frac{\partial \Theta}{\partial \delta}\right|_{b=b_d^c} = \frac{u}{(1-\delta)^2} + k + \phi b_d^c > 0 \implies \frac{\partial b_d^c}{\partial \delta} = -\left.\frac{\partial \Theta / \partial \delta}{\partial \Theta / \partial b}\right|_{b=b_d^c} < 0.$$

Now, we turn to the managerial profit share α_d^c. Recalling from the proof of Proposition 1 that $\alpha_d^c = \frac{u}{\pi - b_d^c}$, it follows from the previous results that

$$\frac{\partial \alpha_d^c}{\partial N} = \frac{u}{\left(\pi - b_d^c\right)^2}\frac{\partial b_d^c}{\partial N} > 0; \ \frac{\partial \alpha_d^c}{\partial u} = \frac{1}{\left(\pi - b_d^c\right)^2}\left(\pi - b_d^c + u\frac{\partial b_d^c}{\partial u}\right) > 0;$$

$$\frac{\partial \alpha_d^c}{\partial \pi} = -\frac{u}{\left(\pi - b_d^c\right)^2}\left(1 - \frac{\partial b_d^c}{\partial \pi}\right) < 0; \ \frac{\partial \alpha_d^c}{\partial k} = \frac{u}{\left(\pi - b_d^c\right)^2}\frac{\partial b_d^c}{\partial k} < 0;$$

$$\frac{\partial \alpha_d^c}{\partial \phi} = \frac{u}{\left(\pi - b_d^c\right)^2}\frac{\partial b_d^c}{\partial \phi} < 0; \ \frac{\partial \alpha_d^c}{\partial \delta} = \frac{u}{\left(\pi - b_d^c\right)^2}\frac{\partial b_d^c}{\partial \delta} < 0. \ \blacksquare$$

Proof of Lemma 2. The objective function in (10) decreases with $\widetilde{\alpha}$ and thus the associated constraint is binding. This implies that

$$\widetilde{\alpha} = \frac{\alpha(\pi - b) + \delta(1-\delta)C(b)}{(\pi N - b)(1-\delta)}.$$

Substituting this expression into $\widetilde{V}(\alpha, b)$ in (10) and using $V(\alpha, b)$ in (9), we find that $V(\alpha, b) \geq \widetilde{V}(\alpha, b)$ — i.e., the condition in (11) for renegotiation proofness is satisfied — if and only if

$$\frac{\pi - b}{1-\delta} \geq \pi N - b - \delta C(b),$$

which corresponds to the renegotiation proofness constraint (12).

At the full commitment contractual pair $\left(\alpha_d^c, b_d^c\right)$ characterized in Proposition 1, we find from the binding collusion incentive constraint (2) that

$$V\left(\alpha_d^c, b_d^c\right) - \widetilde{V}\left(\alpha_d^c, b_d^c\right) = -\frac{\delta\left(1-\alpha_d^c\right)C\left(b_d^c\right)}{\alpha_d^c} < 0,$$

where the inequality follows from $\alpha_d^c \in (0,1)$ and $C\left(b_d^c\right) > 0$. The pair $\left(\alpha_d^c, b_d^c\right)$ violates the condition in (11) and thus it is not renegotiation proof. ■

Proof of Proposition 3. Define

$$\Lambda(b) \triangleq \frac{\pi - b}{1-\delta} - (\pi N - b) + \delta C(b), \tag{A7}$$

where $C(\cdot)$ is given by (1). The renegotiation proofness constraint (12) is satisfied if and only if $\Lambda(\cdot) \geq 0$. The shareholders' objective function in (4) decreases with b. Evaluating $\Lambda(\cdot)$ in (A7) at $b = 0$ (which implies $C(\cdot) = 0$) yields

$$\Lambda(b)|_{b=0} = \frac{\pi}{1-\delta} - \pi N < 0,$$

where the inequality follows from Assumption 1. Furthermore, we have

$$\lim_{b \to 0^+} \Lambda(b) = \frac{\pi}{1-\delta} - \pi N + \delta k. \tag{A8}$$

It holds $\lim_{b\to 0^+} \Lambda(b) \geq 0$ if and only if $\delta \geq \overline{\delta}^r$, where the threshold $\overline{\delta}^r$ is given by

$$\overline{\delta}^r \triangleq \frac{\pi N + k - \sqrt{(\pi N - k)^2 + 4k\pi}}{2k}, \tag{A9}$$

where $\overline{\delta}^r < \frac{N-1}{N}$. Then, for $\delta \geq \overline{\delta}^r$, in the collusive equilibrium, the amount of debt is $b_{nd}^{rm} \to 0$. Using (6), the managerial profit share is $\alpha_{nd}^{rm} \to \frac{u}{\pi} \in (0,1)$.

Now, suppose that $\delta < \overline{\delta}^r$. Note from (A8) that $\lim_{b\to 0^+} \Lambda(b) < 0$ (as $\delta < \overline{\delta}^r$). Moreover, we find from (A7) that $\Lambda(b)|_{b=\pi-u} = (1 + \delta\phi - N)\pi + \delta k + \frac{1-\phi(1-\delta)}{1-\delta}\delta u$, where $b = \pi - u$ is the highest value for b that ensures non-negative profits in (7). As $\Lambda(b)|_{b=\pi-u} \to -(N-1)\pi < 0$ for $\delta \to 0$ and $\Lambda(b)|_{b=\pi-u} \to +\infty$ for $\delta \to 1$, it follows from the intermediate value theorem that there exists at least a value for $\delta \in (0,1)$ such that $\Lambda(b)|_{b=\pi-u} = 0$. Given that $\Lambda(b)|_{b=\pi-u}$ is strictly convex in δ, there exists a unique threshold $\underline{\delta}^r \in (0,1)$ such that $\Lambda(b)|_{b=\pi-u} \geq 0$ if

and only if $\delta \geq \underline{\delta}^r$, where $\Lambda(b)|_{b=\pi-u} = 0$ if and only if $\delta = \underline{\delta}^r$. The threshold $\underline{\delta}^r$ is given by

$$\underline{\delta}^r \triangleq \frac{\pi(\phi+N-1)+u(1-\phi)+k}{2[k+\phi(\pi-u)]} - \frac{\sqrt{[\pi(\phi+N-1)+u(1-\phi)+k]^2-4\pi(N-1)[k+\phi(\pi-u)]}}{2[k+\phi(\pi-u)]}. \tag{A10}$$

Furthermore, differentiating $\Lambda(\cdot)$ in (A7) with respect to b yields

$$\frac{\partial \Lambda}{\partial b} = 1+\delta\phi-\frac{1}{1-\delta}.$$

As $\Lambda(\cdot)$ is linear in b, it follows from the intermediate value theorem that there exists a non-empty interval for b such that $\Lambda(b) \geq 0$ if and only if $\delta \geq \underline{\delta}^r$. In this case, $\Lambda(\cdot)$ increases with b and the unique solution to $\Lambda(\cdot) = 0$ with respect to b writes as

$$b_d^{rm} \triangleq \frac{(1-\delta)(\pi N-\delta k)-\pi}{\delta[\phi(1-\delta)-1]}. \tag{A11}$$

Note from (A9) and (A10) that $\overline{\delta}^r \geq \underline{\delta}^r$ if and only if $\phi \geq \overline{\phi}^r$, where

$$\overline{\phi}^r \triangleq \frac{\pi N-k+\sqrt{(\pi N-k)^2+4k\pi}}{2\pi}.$$

Then, for $\delta \in \left[\underline{\delta}^r, \overline{\delta}^r\right)$ and $\phi \geq \overline{\phi}^r$, in the collusive equilibrium, the amount of debt is given by $b_d^{rm} > 0$ in (A11) and the managerial profit share is given by $\alpha_d^{rm} = \frac{u}{\pi - b_d^{rm}} \in \left(\alpha_{nd}^{rm}, 1\right)$. It holds $\alpha_d^{rm} < 1$ if and only if $u < \overline{u}^{rm}$, where

$$\overline{u}^{rm} \triangleq \frac{(1-\delta)[(1+\delta\phi-N)\pi+\delta k]}{\delta[\phi(1-\delta)-1]}. \tag{A12}$$

Substituting the binding collusion incentive constraint (2) into (A7) yields $\Lambda\left(b_d^c\right) < 0$. As $\Lambda(\cdot)$ increases with b, we have $b_d^{rm} > b_d^c$ and thus $\alpha_d^{rm} > \alpha_d^c$.

In the remaining region of parameters, where either $\delta < \underline{\delta}^r$ or $\delta \in \left[\underline{\delta}^r, \overline{\delta}^r\right)$ and $\phi < \overline{\phi}^r$, the renegotiation proofness constraint (12) fails to hold and thus the collusive monopoly outcome is not sustainable. ■

Proof of Lemma 3. Consider a candidate equilibrium contractual pair (α, b), with $b > 0$, announced in period $\tau = 0$ to support collusion. A firm's shareholders can profitably deviate by offering the exclusive lender the reimbursement of the entire loan in period $\tau = 1$ and inducing the manager to deviate in the product market. The maximum profits of the deviating firm's shareholders are given by

$$V^o(\alpha, b) \triangleq \max_{\alpha^o \in [0,1]} (1-\alpha^o)\left(\pi N - \frac{b}{1-\delta}\right) \quad s.t. \quad \alpha^o\left(\pi N - \frac{b}{1-\delta}\right) \geq \alpha\frac{\pi-b}{1-\delta}, \tag{A13}$$

where the constraint ensures that the manager is willing to accept the new contract and deviates in the product market. As the objective function in (A13) decreases with α^o and thus the

associated constraint is binding, we find that

$$\alpha^o = \frac{\alpha(\pi - b)}{(1-\delta)\pi N - b}.$$

Substituting this expression into $V^o(\alpha, b)$ in (A13) and using $V(\alpha, b)$ in (9) yields

$$V(\alpha, b) - V^o(\alpha, b) = \frac{1-(1-\delta)N}{1-\delta}\pi < 0,$$

where the inequality follows from Assumption 1. Then, the pair (α, b) is not renegotiation proof and cannot be supported in equilibrium. ■

Proof of Proposition 4. We know from the renegotiation proofness constraint (13) that a debt contract is renegotiation proof if and only if

$$b \geq b_d^{rd} \triangleq \frac{(1-\delta)N - 1}{N-1}\pi, \tag{A14}$$

where $b_d^{rd} > 0$ follows from Assumption 1. Recall from Lemma 2 that a managerial contract is renegotiation proof if and only if the renegotiation proofness constraint (12) is satisfied. In the light of the proof of Proposition 3, we find that, for $\delta \geq \overline{\delta}^r$, in the collusive equilibrium, the amount of debt is given by $b_d^{rd} > 0$. Using (6), the managerial profit share is given by $\alpha_d^{rd} = \frac{u}{\pi - b_d^{rd}} \in \left(\alpha_{nd}^{rm}, 1\right)$. It holds $\alpha_d^{rd} < 1$ if and only if $u < \overline{u}^r$, where $\overline{u}^r$ corresponds to

$$\overline{u}^{rd} \triangleq \frac{\delta\pi N}{N-1}. \tag{A15}$$

Now, suppose that $\delta < \overline{\delta}^r$. It follows from the proof of Proposition 3 that, for $\delta \in \left[\underline{\delta}^r, \overline{\delta}^r\right)$ and $\phi \geq \overline{\phi}^r$, in the collusive equilibrium, the amount of debt is given by $b_d^r = \max\left\{b_d^{rd}, b_d^{rm}\right\}$ and the managerial profit share is given by $\alpha_d^r = \max\left\{\alpha_d^{rd}, \alpha_d^{rm}\right\}$. It holds $\alpha_d^r < 1$ if and only if $u < \overline{u}^r$, where $\overline{u}^r$ corresponds to $\overline{u}^{rd}$ in (A15) for $b_d^r = b_d^{rd}$ and $\overline{u}^r$ corresponds to $\overline{u}^{rm}$ in (A12) for $b_d^r = b_d^{rm}$. Using (A7), we have $\Lambda\left(b_d^{rd}\right) > 0$ if and only if

$$\phi > \widetilde{\phi}^r \triangleq \frac{\delta + N - 1}{\delta(1-\delta)} - \frac{(N-1)k}{\pi\left[(1-\delta)N - 1\right]}.$$

As $\Lambda(\cdot)$ increases with b whenever it admits a non-empty interval for b such that $\Lambda(\cdot) \geq 0$ (see the proof of Proposition 3), we find that, for $\delta \in \left[\underline{\delta}^r, \overline{\delta}^r\right)$ and $\phi > \widetilde{\phi}^r$, it holds $b_d^r = b_d^{rd} > b_d^{rm}$ and thus $\alpha_d^r = \alpha_d^{rd} > \alpha_d^{rm}$.

In the remaining region of parameters, where either $\delta < \underline{\delta}^r$ or $\delta \in \left[\underline{\delta}^r, \overline{\delta}^r\right)$ and $\phi < \overline{\phi}^r$, the renegotiation proofness constraint (12) fails to hold and thus the collusive monopoly outcome is not sustainable. ■

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