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Abstract

This paper shows that obligations from debt hinder tacit collusion if equity owners are protected by limited liability. In contrast to its advantageous commitment value in short-run competition, leverage reduces profits from infinite interaction. Contrasting uncorrelated shocks with a cyclical demand development, we show that in the first case optimal pricing is anticyclical. With demand cycles, it is anticyclical only if equity holders place a low value on future profits, but procyclical otherwise. In both cases, the cyclicity of prices increases with the debt level. Contrary to traditional wisdom, a lower degree of homogeneity may raise profits of leveraged firms.

keywords: capital structure, dynamic competition, collusion

JEL classification: L41, L13, G32, E32, C73

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1 Introduction

Illegal cartels are widespread in national as well as international markets. Examples include price agreements in the paper, industrial gases, lysine, zinc phosphate and citric acid industries in Europe. In the United States, the prosecution of price-fixing by a graphite electrodes cartel and a vitamin cartel recently led to record fines. However, these are only the most striking examples of price-fixing (cf. recent press releases of the European and US antitrust authorities). Evenett, Levenstein and Suslow (2001) survey 40 international cartels lasting on average for six years. Such cartels are typically based on secret, implicit or explicit agreements and thus cannot be enforced by law-suits. Earlier work singled out numerous factors alleviating or vitiating such agreements. It showed that market conditions leading to aggressive behavior in short-run competition, as for example a low degree of product differentiation or flat marginal cost curves, might actually stabilize tacit agreements in competition with infinite or unknown duration. This reversal of effects is known as "the 'topsy-turvy' principle of supergame theory" (*Shapiro* 1989, p. 365). Although there is a large literature on the optimal financial structure of firms, its effect on the degree of product-market competition over short and long time spans has received relatively little attention in the literature so far.

Outside financing of a new business area or innovation project is widespread, however. In this case, firms choose the level of debt, e.g. the number of bonds issued, before they decide on their strategy in the product market. There is thus a strong dependency between firms' decisions on financing and pricing or production levels (quantities). Financial obligations hence can serve as a credible commitment to a certain competitive strategy. For this reason, the capital structure of firms has received considerable attention from industrial economists. Efforts to explain the choice of financing by different kinds of outside capital can roughly be divided as follows: Originating with the article of *Brander*, *Lewis* (1986), the effect of limited liability is analyzed for different market conditions (cf. e.g., *Glazer* 1994, *Damania* 1997, *Bagliano*, *Dalmazzo* 1999). *Chevalier*, *Scharfstein* (1995, 1996) consider its impact in markets where consumers incur switching costs. The seminal model by *Brander*, *Lewis* (1986) is further developed by *Showalter* (1995). He showed, that the effect of leverage in one-shot product-market competition depends on the strategic substitutability or complementarity of the short-run variable: With strategic substitutes the product-market strategy is more aggressive, whereas with strategic complements, e.g. price competition in a homogeneous market, it is less aggressive than without leverage. *Wanzenried* (2003) demonstrates that these results also obtain if goods are differentiated. Another stream of the literature starting with *Brander*, *Lewis* (1988), analyzes bankruptcy cost as a factor determining the degree of competition in the output market. Moreover, a concentrated banking sector acting as a common lender is shown to internalize and thus lessen the procompetitive effects of leverage resulting for some market conditions (*Poitevin* 1989, *Bhattacharya*, *Chiesa* 1995). Furthermore, increased leverage can serve as a shield against a hostile takeover (*Dasgupta*, *Titman* 1998). But there are negative effects of leverage too: A higher debt level reduces managers opportunities to increase their personal power by acquisitions (*Zwiebel* 1996). High indebtedness also reduces the trust of consumers and business partners in the solidity of the firm (*Maksimovic*, *Titman* 1991). Two-stage models, as for example *Brander*, *Lewis*'s (1986), are strictly valid only if firms compete only once. Supergames, in contrast, are models of competition with infinite or unknown duration. *Maksimovic* (1988) analyzes infinitely repeated competition and derives the effect of debt on firms' optimal output strategy in a market with constant demand. *Stenbacka* (1994) also analyzes a supergame. He restricts attention to the case of a homogeneous good, but allows for stochastic shocks on the demand level. Both authors conclude that debt lowers firms' incentive to participate in a collusive agreement and hence leaves them worse off. All these articles treat demand fluctuations in the simplest possible fashion, that is, as subject to independently, identically distributed shocks or neglect them altogether.

Our paper shows that debt destabilizes such price-fixing conspiracies. As *Rotemberg*, *Saloner* (1986), *Haltiwanger*, *Harrington* (1991) and *Bagwell*, *Staiger* (1997) among others have shown, the pattern of demand changes plays an important role in determining the inclination of firms to collude. Therefore, we contrast different demand patterns and show how leverage and demand changes jointly determine firms' optimal collusive pricing strategy. We show that leverage is advantageous in short-run competition, but lowers firms' profits in long-run interaction, irrespective of the demand fluctuations. As is well known, greater homogeneity of products lowers profits in one-shot competition, but alleviates tacit collusion. In extension of earlier work, we consider a heterogeneous good and demonstrate that, in this case, a low degree of product differentiation destabilizes collusion amongst leveraged firms.

To this end, we first consider the simpler case of stochastic fluctuations as introduced by *Rotemberg*, *Saloner* (1986). The effects of outside finance are shown in the setup of *Stenbacka* (1994), generalized to account for product differentiation. Martin (2002), p. 321 conjectures, that "...the logic behind their argument [Rotemberg's and Saloner's (1986)] seems likely to carry through in a price-setting model with product differentiation." Here, we show that his supposition is true and continues to hold if firms are leveraged.[1] The future development of demand can often be predicted quite well, however. This is especially true if it exhibits a recurring pattern. The demand for many goods, as for example sporting equipment, transport, and fuel oil, follows such a cyclical path. Hence, as an alternative to uncorrelated demand shocks considered first, we secondly analyze the impact of debt in a market with demand cycles. For that purpose, we introduce leverage in the model by *Haltiwanger*, *Harrington* (1991) and again extend it to the case of a differentiated good.

The development of demand determines equity holders' optimal collusive strategies. With stochastic shocks, pricing is anticyclical. If demand develops in recurring cycles, owners of firms set prices anticyclically only if they do not place high value on future profits. Otherwise, prices follow the cycle. Thus, the basic insights of *Rotemberg*, *Saloner* (1986) and *Haltiwanger*, *Harrington* (1991) continue to hold if products are differentiated and firms are leveraged. Indebtedness, however, is shown to increase the competitive pressure in long run competition. This finding is opposed to *Wanzenried* (2003)'s conclusion that leverage can be used to commit to a softer behavior in the product market. Comparison of both results highlights the fact that in dynamic competition, due to the limited liability of equity holders, repayment obligations reduce the profit stream from collusion if firms are made bankrupt by punishment. Hence, a higher debt level unambiguously reduces the gain from long run competition. Firms are insolvent in non-cooperative price competition only if products are fairly homogeneous. Contrary to the effect of product differentiation on infinite competition amongst internally financed firms, a low degree of differentiation destabilizes collusion of leveraged firms.

The remainder of the paper is structured as follows: Section 2 presents the basic assumptions. In sections 3 and 4 we derive the optimal collusive pricing strategy in markets with uncorrelated stochastic and cyclical demand development, respectively. As an extension, we discuss additional stochastic shocks during the demand cycle (section 5). Section 6 summarizes the results.

2 Basic Market Conditions

Our aim is to isolate the impact of the financial structure on product-market competition. To this effect, we assume that firms have to issue bonds to finance a fixed investment in order to enter the market. Alternatively, this investment may become

[1] To the best of our knowledge, the framework of *Rotemberg*, *Saloner* (1986) was never generalized to the case of product differentiation before.

necessary due to technological progress, as firms may have to adopt a new technology in order to stay competitive.

We consider a market with n firms producing a differentiated, substitutive good with equal, constant marginal costs c. The pricing behavior of these firms is perfectly observable by all market participants. $\delta \in [0, 1]$ denotes the common discount factor. Demand is continuous, bounded from above, and falling in the price of a firm p_i. i is the index for a given firm, $-i$ the index for its rivals. θ_t is a parameter determining the demand level in period t. The demand for the variety i in period t $D_i(\mathbf{p}, \theta_t)$ increases continuously in the realization of θ_t. The current demand level is known at the beginning of each period before prices are set. The profit functions are concave and twice continuously differentiable.

Before competition in the product market begins, each firm issues obligations to raise the amount $b_i/r = b_i \, \delta \, / \, (1 - \delta)$ to finance the investment. In return, firms have to repay b_i every period to the holders of these bonds. For ease of exposition, it is assumed that the need for outside funds b_i/r is identical for all firms. We thus drop the firm index on b. On the one hand, this is plausible as firms are symmetric in every respect. On the other hand, if the debt levels were different, arguments analogous to those given below would apply. The only difference would be that in absence of side payments, the firm with the highest indebtedness would determine the maximal collusive prices which do not destabilize the implicit agreement. To abstain from transfer payments is sensible as these leave a "paper trail" and thus increase the risk of detection. As obligations are issued and sold in the capital markets, the liabilities of each firm are common knowledge.[2] As lenders are rational, they will not buy corporate bonds worth more than the discounted profit stream attainable in equilibrium.

After firms have issued bonds and invested, they compete in the product market over an infinite time horizon. Payments to bondholders b are due every period. The residual profit is distributed equally amongst equity holders as dividends. Firms are run by equity holders as long as they remain solvent.[3] If a firm is insolvent,

[2] *Katz* (1991) and *Bagwell* (1995) show that perfect observability is an indispensable condition for contracts to serve as a credible commitment. Bond issues are indeed perfectly observable, so that firms can credibly commit to a competitive strategy by taking up the corresponding amount of capital in the market.

[3] In some cases, control of the bank over the management of the firm may be a condition for the provision of capital funds. Debtholders choose the product-market strategy then. This seems to apply only to a small number of financial contracts. Thus, we exclude this possibility in our analysis. *Brander*, *Lewis* (1986) discuss the strategic effect of debt in such a situation in a two-stage model. They show for Cournot competition that the effect of more aggressive behavior with outside finance is the same regardless of who controls the firm.

debtholders become claimants of current and future profits, whereas equity holders lose everything. Bankruptcy costs are excluded here (cf. *Brander*, *Lewis* (1988) for an analysis in a two-stage model).

Thus, the owners in charge of each firm aim to maximize its equity value. As is well known, firms have an incentive to alleviate competition by tacitly agreeing on higher prices if they face the same rivals in the market over a long time span. In this case, they maximize joint profits by setting the highest possible collusive prices. The value of the firm for holders of its equity is therefore equal to the discounted future profit stream in all periods, in which the firm is solvent. If a firm cheats on the implicit agreement unilaterally choosing a lower price, its rivals set the competitive price as a punishment from the following period on. Defection is thus rational only if the equity value of the firm from deviation exceeds the value resulting from continued participation in collusion. If firms are driven into insolvency by price competition, debtholders take control of the firms. The new owners write off their debt and receive shares of profit instead. After such a change of ownership due to bankruptcy in the punishment phase, lenders running the firms cannot regain the trust of their rivals. Thus, they are forced to compete in prices.[4]

As the following analysis shows, equity holders can influence the incentive to cheat on an implicit agreement by issuing debt. The influence of demand changes on the collusive strategy of equity holders is derived in section 3 for uncorrelated stochastic shocks and in section 4 for cyclical fluctuations.

3 Stochastic Demand Shocks

Our aim is to analyze whether firms can use debt strategically to soften product-market competition when market demand fluctuates. First, we analyze outside finance in markets where demand changes stochastically.[5] To analyze the impact of uncorrelated demand shocks we generalize the model proposed by *Stenbacka* (1994) to the case of a differentiated good. If limited liability of equity holders is irrelevant,

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[4] Alternatively, we could assume, that lenders running the firms start competition in a collusive equilibrium. Then, our analysis would also apply as long as firms are solvent. The same considerations could be used to derive the pricing strategy of lenders in charge of the firms. In this case, repayments have to be set to zero.

[5] This model can easily be reinterpreted to cover fluctuating production costs: In this case, θ_t is a parameter determining the per-period level of marginal cost c_t, while demand is stable over time. Then, a critical realization of marginal costs $\hat{c}$ would result, with lower levels inducing anticyclical pricing.

i.e. if firms are never bankrupt, debt has no effect on firms' inclination to collude in the product market. Therefore, the degree of product differentiation is decisive for the solvency of firms in the punishment phase. *Stenbacka*'s (1994) assumption that firms produce a homogeneous good is indeed restrictive.

We follow *Rotemberg*, *Saloner* (1986) and assume that in every period the demand level is subject to an identically, independently distributed stochastic shock $\theta_t \in [\underline{\theta}, \bar{\theta}]$. Realizations of the shock θ_t are distributed according to the density function $f(\theta_t)$ with the cumulative distribution function $F(\theta_t)$. The per-period profits of a firm given the demand level resulting from the shock realization θ_t, are $\pi^{\bar{K}}(\mathbf{p}^{\bar{K}}, \theta_t)$ and $\pi^{K}(\mathbf{p}^{K}, \theta_t)$ for perfect and imperfect collusion, respectively. If an owner of a firm deviates from the tacit agreement he earns $\pi^{A}(\mathbf{p}^{A}, \theta_t)$. In the ensuing punishment phase, however, firms compete in prices and attain profits $\pi^{B}(\mathbf{p}^{B}, \theta_t)$ in every period.

Perfect collusion is possible between leveraged firms irrespective of whether they are bankrupt in the punishment phase or not, if demand is stable at the lowest level $D_i(\mathbf{p}, \underline{\theta})$, but impossible for the highest realization $D_i(\mathbf{p}, \bar{\theta})$ even if firms do not issue debt. Equityholders abide by an implicit agreement if the resulting discounted stream of additional future profits is higher than that from deviation. Thus, these assumptions lead to the following inequalities:

$$\frac{\delta}{1-\delta}\left[\pi^{\bar{K}}(\mathbf{p}^{\bar{K}}, \underline{\theta}) - \max\left\{b,\ \pi^{B}(\mathbf{p}^{B}, \underline{\theta})\right\}\right] > \pi^{A}(p_i^{A}, \mathbf{p}_{-i}^{\bar{K}}, \underline{\theta}) - \pi^{K}(\mathbf{p}^{\bar{K}}, \underline{\theta}) \tag{1}$$

$$\frac{\delta}{1-\delta}\int_{\underline{\theta}}^{\bar{\theta}} \pi^{\bar{K}}(\mathbf{p}^{\bar{K}}, \theta)\, f(\theta) d\theta < \pi^{A}(p_i^{A}, \mathbf{p}_{-i}^{\bar{K}}, \bar{\theta}) - \pi^{K}(\mathbf{p}^{\bar{K}}, \bar{\theta}). \tag{2}$$

The left hand sides show the additional profits from continued collusion, the right hand sides the additional gain from defection. All other market conditions are as described in section 2. As perfect collusion is stable for the lowest realization of the shock, but not for the highest, there is a critical level of the shock $\hat{\theta}$ in the interval $[\underline{\theta}, \bar{\theta}]$ up to which perfect collusion is stable, but above which firms have to reduce prices and thus profits in order to reduce the incentive to deviate from the tacit agreement. This anticyclicity of prices arising from demand uncertainty is the basic finding of *Rotemberg*, *Saloner* (1986). As shown below, it also holds if the good is horizontally differentiated.

Case 1: Firms are Solvent during the Punishment Phase

Consider first a situation where firms are solvent in the case of punishment. Under such circumstances, equity holders never lose control of the firms. They take part in a joint monopolization of the market if the corresponding profits are higher than those from unilateral deviation.

$$\frac{\delta}{1-\delta}\left\{\left[\int_{\underline{\theta}}^{\hat{\theta}} \pi^{\bar{K}}(\mathbf{p}^{\bar{K}},\theta)\, f(\theta)d\theta + \left[1-F(\hat{\theta})\right]\pi^{\bar{K}}(\mathbf{p}^{\bar{K}},\hat{\theta}) - b\right]\right.$$
$$\left. - \left[\int_{\underline{\theta}}^{\bar{\theta}} \pi^{B}(\mathbf{p}^{B},\theta)\, f(\theta)d\theta - b\right]\right\} \geq \left[\pi^{A}(p_i^{A},\mathbf{p}_{-i}^{\bar{K}},\theta_t) - b\right] - \left[\pi^{\bar{K}}(\mathbf{p}^{\bar{K}},\theta_t) - b\right]. \quad (3)$$

The first term in square brackets on the left hand side contains the future profit stream from the tacit agreement, the second term the future profit stream accruing during the punishment phase. Thus, the left hand side gives the additional profits from continued collusion, whereas the right hand side gives the additional gain from deviation in the current period t. Observe, that the latter increases with the current demand realization, whereas the former is independent of θ_t due to the assumption of identically, independently distributed shocks. For high values of market demand, firms are forced to reduce the incentive to deviate by setting a lower collusive price. This is the effect of anticyclical pricing derived by *Rotemberg*, *Saloner* (1986) for a homogeneous good. The per-period obligation to pay b cancels out: If firms are solvent in the punishment phase, leverage has no effect on firms' incentive to collude but lowers its equity value, i.e. per-period profits. Thus, it is optimal to finance investments by using internal funds.

As in the original model of *Rotemberg*, *Saloner* (1986) for homogeneous goods, there is a critical level of shock $\hat{\theta}$ up to which equity holders can jointly monopolize the market. For higher demand realizations firms set prices anticyclically. To see this, consider the incentive to collude

$$V(\theta_t) \equiv \frac{\delta}{1-\delta}\left\{\int_{\underline{\theta}}^{\hat{\theta}} \pi^{\bar{K}}(\mathbf{p}^{\bar{K}},\theta)\, f(\theta)d\theta + \left[1-F(\hat{\theta})\right]\pi^{\bar{K}}(\mathbf{p}^{\bar{K}},\hat{\theta})\right.$$
$$\left. - \int_{\underline{\theta}}^{\bar{\theta}} \pi^{B}(\mathbf{p}^{B},\theta)\, f(\theta)d\theta\right\} - \pi^{A}(p_i^{A},\mathbf{p}_{-i}^{\bar{K}},\theta_t) + \pi^{\bar{K}}(\mathbf{p}^{\bar{K}},\theta_t). \quad (4)$$

Note, that $b < \int_{\underline{\theta}}^{\bar{\theta}} \pi^{B}(\mathbf{p}^{B},\theta)\, f(\theta)d\theta$ if firms are always solvent. The additional gain from continued collusion net the potential additional profit from defection $V(\theta_t)$, strictly decreases with the realization of the shock θ_t, i.e. $V'(\theta_t) < 0$: The first part containing the expected future profit streams from collusion and price competition is independent of the shock level. This follows from the assumption that shock realizations are independently, identically distributed. With such shocks, the demand realization today contains no information about demand in future periods. The additional gain from cheating, $\pi^A(p_i^A, \mathbf{p}_{-i}^{\bar{K}}, \theta_t) - \pi^{\bar{K}}(\mathbf{p}, \theta_t)$, increases in the current shock realization θ_t as long as the profits from deviation increase more than those from collusion with respect to the demand level.[6] Hence, there is a unique value $\hat{\theta} \in (\underline{\theta}, \bar{\theta})$ fulfilling $V(\hat{\theta}) = 0$. We assumed that perfect collusion is stable for the lowest, but not for the highest demand level. Thus, from (1) we have

$$V(\underline{\theta}) = \frac{\delta}{1-\delta}\left[\pi^{\bar{K}}(\mathbf{p}^{\bar{K}}, \underline{\theta}) - \pi^B(\mathbf{p}^B, \underline{\theta})\right] - \pi^A(p_i^A, \mathbf{p}_{-i}^{\bar{K}}, \underline{\theta}) + \pi^{\bar{K}}(\mathbf{p}^{\bar{K}}, \underline{\theta}) > 0.$$

From (2) we obtain

$$V(\bar{\theta}) = \frac{\delta}{1-\delta}\left\{\int_{\underline{\theta}}^{\hat{\theta}} \pi^{\bar{K}}(\mathbf{p}^{\bar{K}}, \theta)\, f(\theta)d\theta + \left[1 - F(\hat{\theta})\right]\pi^{\bar{K}}(\mathbf{p}^{\bar{K}}, \hat{\theta}) - \int_{\underline{\theta}}^{\bar{\theta}} \pi^B(\mathbf{p}, \theta)\, f(\theta)d\theta\right\} - \pi^A(p_i^A, \mathbf{p}_{-i}^{\bar{K}}, \bar{\theta}) + \pi^{\bar{K}}(\mathbf{p}^{\bar{K}}, \bar{\theta}) < 0.$$

As $V(\underline{\theta}) > 0$ and $V(\bar{\theta}) < 0$ hold and the incentive to collude strictly decreases in the demand realization $V'(\theta_t) < 0$ there is indeed a single realization of the shock $\hat{\theta} \in (\underline{\theta}, \bar{\theta})$ such that the gain from cheating is just offset by the profit stream resulting from collusion $V(\hat{\theta}) = 0$. Without bankruptcy, the stability condition (3) remains unchanged by the repayment b. Hence, the critical shock realization for stable perfect collusion $\hat{\theta}$ also remains unchanged by debt. The extent to which firms are forced to reduce collusive prices to stabilize their implicit agreement is the same for leveraged and unleveraged firms if the former are always solvent. The amplitude of prices is hence identical, too.

Case 2: Firms are Bankrupt in the Case of Punishment

The simplest case where firms are driven to bankruptcy by punishment is price competition with a homogeneous good considered by *Stenbacka* (1994). But due to a low degree of product differentiation, profits from price competition could also be insufficient to meet the obligations to repay the debt. This is the case if per-period profits from competition are insufficient to meet the financial obligations even for the highest demand realization, i.e. $b > \pi^B(\mathbf{p}^B, \bar{\theta})$ holds. In contrast to the previously

[6] In a linear model with additive or multiplicative demand shocks, the slope of the profit from deviation with respect to the demand realization is strictly larger than that of the per-period collusive profit.

investigated situation, debt in these cases changes the condition for a stable implicit agreement. Equityholders incentive to collude is now given by

$$V^b(\theta_t) \equiv \frac{\delta}{1-\delta}\left\{\int_{\underline{\theta}}^{\hat{\theta}^b} \pi^{\bar{K}}(\mathbf{p}^{\bar{K}},\theta)\, f(\theta)d\theta + \left[1-F(\hat{\theta}^b)\right]\pi^{\bar{K}}(\mathbf{p}^{\bar{K}},\hat{\theta}^b) - b\right\} - \pi^A(p_i^A,\mathbf{p}_{-i}^{\bar{K}},\theta_t) + \pi^{\bar{K}}(\mathbf{p}^{\bar{K}},\theta_t), \qquad (5)$$

with index b as a shorthand for bankruptcy. As producers earn zero profits from price competition due to low differentiation and / or high indebtedness, there are no profits in the punishment phase. Firms are therefore insolvent and debtholders take charge of the firms.[7] Repayments are due if equity holders collude or deviate, but due to limited liability owners are free from financial obligations if firms are bankrupt in the punishment phase. Only the profit stream from collusion is reduced by the repayments, whereas it nets out in the additional gain from deviation. Hence, the tacit agreement is destabilized by increased reliance on outside funds. Ceteris paribus, the critical level of the demand realization up to which perfect collusion is stable is lower with than without leverage.

To prove this, we first show that there is again a unique realization of the demand shock where gains are identical whether equity holders abide by the tacit agreement or cheat. Then, we argue that this critical realization is indeed lower if firms are driven to bankruptcy by a breakdown of their implicit agreement. The incentive to collude is now independent of profits in the punishment phase. As equity holders are protected by limited liability, they have to consider the reduction of per-period profits from collusion due to the repayments. Existence of a single value of the demand shock $\hat{\theta}^b \in (\underline{\theta},\bar{\theta})$ leaving equity holders indifferent between collusion and deviation if bankruptcy occurs during the punishment phase, $V^b(\hat{\theta}^b) = 0$, can be shown analogously to the existence of $\hat{\theta}$ before. By (1) we still have perfect collusion if demand is constant at its lowest level $V^b(\underline{\theta}) > 0$. Inequality (2) shows that joint monopolization of the market is impossible if demand is currently at the highest level, $V^b(\bar{\theta}) < 0$. But in the case of bankruptcy the additional gain from collusion is lower as per-period profits are now reduced by the repayment and not by the lower per-period profit from price competition. Thus, for all demand realizations it is more difficult to stabilize the tacit agreement. For all demand levels the incentive to collude is smaller

[7] Note that equity holders anticipate the insolvency in the period after deviation. As they receive zero profits anyway, they are indifferent between the Bertrand-Nash price and all lower prices. For the argument given above, however, it is sufficient that equity holders receive nothing in this period. The exact value of the equilibrium price in the period of deviation is not decisive. *Maksimovic* (1988), p. 393 gives an analogous reasoning for quantity competition and stable demand.

than in the case of solvency in the punishment phase. Hence, we have $V^b(\underline{\theta}) < V(\underline{\theta})$ and $V^b(\bar{\theta}) < V(\bar{\theta})$. Again, the future additional profit stream from collusion is unaffected by the current demand level if shock realizations are stochastically independent. The incentive to collude $V(\theta_t)$ is changed by a variation in the demand level only by its effect on the additional gain from cheating. The latter is the same regardless whether firms are made bankrupt by punishment or not. Hence, the slope must also be identical in both cases, $V^{b'}(\theta_t) = V'(\theta_t)$. With $0 < V^b(\underline{\theta}) < V(\underline{\theta})$, $0 > V(\bar{\theta}) > V^b(\bar{\theta})$ and $V^{b'}(\theta_t) = V'(\theta_t)$ as shown, the shock realization leaving equity holders indifferent between collusion and defection is indeed lower if firms are insolvent in the punishment phase. $\hat{\theta^b} < \hat{\theta}$ holds, as claimed above. If the good is differentiated, but firms nevertheless are made bankrupt by a breakdown of collusion, the conclusion reached by *Stenbacka* (1994) for a homogeneous good continues to apply.

As is well known, the firms' profits are higher the greater the degree of horizontal product differentiation (cf. *Martin* 2002, p. 59 and 63). Thus, the condition for bankruptcy in the punishment phase $\pi^B(\mathbf{p}^B, \theta_t) \leq b$ leading to the different cases discussed above, translates to a critical degree of differentiation where the profits from price competition are just sufficient to meet the obligations from outside finance. There is a critical level of substitutability up to which firms are driven into bankruptcy, if punishment sets in. But if firms are solvent when facing price competition, higher substitutability leads to a higher punishment. Then, collusion is more stable, if products are less differentiated.[8] Hence, the degree of product differentiation has two opposite effects on the stability of collusion between leveraged firms. Moreover, the impact of debt on the intensity of competition in the market is non-monotonous in that parameter. This effect is not captured by the model for a homogeneous good by *Stenbacka* (1994).

[8] With a linear demand function $D_i(\mathbf{p}) = \theta_t - bp_i + d\sum_{i,i\neq j}^{n} p_j$ the slope of the critical threshold of the discount factor for stable perfect collusion in price competition $\underline{\delta}^{\bar{K}}$ is $\partial\, \underline{\delta}^{\bar{K}}/\partial\, d = \{4bd(n-1)^2\,[2b-d(n-1)]\}/[8b^2-8bd(n-1)+d^2(n-1)^2)]^2$. As long as the effect of a change in a firm's price on demand is higher than the effect a of change in rivals' prices, $2b-d(n-1) > 0$ is true. Thus, for substitutive goods, this threshold is increasing in the degree of differentiation d. Collusion is indeed facilitated by greater homogeneity of products as claimed above.

Case 3: Firms are Made Bankrupt by Punishment Only if Demand is Very Low

Suppose the profits from price competition are smaller than the repayment only if the demand level is lower than a certain critical level $D_i(\mathbf{p}^B, \theta^*)$. Then, firms are driven into insolvency by punishment and ownership of the firm changes only with some probability.[9] As long as the shock realizations are higher than the critical value θ^*, firms are solvent and equity holders stay in charge of the firm even after a deviation from the tacit agreement. In this case, denoted by the index p, equity holders' incentive to collude is given as

$$\begin{aligned} V^p(\theta_t) \;\; &\equiv \frac{\delta}{1-\delta}\left\{\int_{\underline{\theta}}^{\hat{\theta}^p} \pi^{\bar{K}}(\mathbf{p}^{\bar{K}}, \theta)\, f(\theta) d\theta + \left[1 - F(\hat{\theta}^p)\right] \pi^{\bar{K}}(\mathbf{p}^{\bar{K}}, \hat{\theta}^p) - b\right\} \\ &\quad - \sum_{\tau=1}^{\infty} \delta^\tau \left[\int_{\theta^*}^{\bar{\theta}} \pi^B(\mathbf{p}^B)\, f(\theta)\, d\theta - b\right] \mathbf{S} - \pi^A(p_i^A, \mathbf{p}_{-i}^{\bar{K}}, \theta_t) + \pi^{\bar{K}}(\mathbf{p}^{\bar{K}}, \theta_t). \qquad (6) \end{aligned}$$

$\mathbf{S}$ is an indicator function, that takes the value 1 until $\theta_t < \theta^*$ holds for the first time and 0 thereafter. If firms are solvent, the repayment is due irrespective of the firms' decision to abide by the implicit agreement or to violate it. As the second term in (6) shows, for demand levels higher than $D_i(\mathbf{p}^B, \theta^*)$, the profit stream from collusion is reduced by the per-period profits from price competition. If, however, current demand is lower, firms are forced into bankruptcy and ownership changes. For such realizations, financial obligations reduce the profits from collusion. As for such low demand levels the repayment is higher than the per-period profit from price competition, the reduction of the collusive profit stream is greater here compared to situations where firms are solvent in the punishment phase. By the same argument, the reduction is lower than if bankruptcy occurs after defection regardless of the demand realization, $V(\theta_t) > V^p(\theta_t) > V^b(\theta_t)$. This is true for all demand realizations $\theta_t \in [\underline{\theta}, \bar{\theta}]$. Thus, the respective incentives to collude are higher the lower the shock realization inducing insolvency in the punishment phase is. By (1) and (2), perfect collusion is still stable if demand is constant at its lowest level but not if the current demand is determined by the highest possible realization. Hence, the inequalities $0 < V^b(\underline{\theta}) < V^p(\underline{\theta}) < V(\underline{\theta})$ and $0 > V(\bar{\theta}) > V^p(\bar{\theta}) > V^b(\bar{\theta})$ hold. The additional gain from defection is not changed by firms' bankruptcy in the punishment phase. Again, the additional future profits from collusion are independent of the present demand

[9] Note that case 3 contains the results of cases 1 and 2 as special cases. Case 1 results, if the critical demand level for solvency in price competition θ^* is lower than the smallest possible realization of the shock $\underline{\theta}$, whereas case 2 results, if θ^* is larger than $\bar{\theta}$, the upper bound of the support of the distribution function of the shock realization.

realization. Thus, limited liability has no effect on the slope of the incentive to collude, ${V^p}'(\theta_t) = {V^b}'(\theta_t) = V'(\theta_t)$. If firms are bankrupt in the punishment phase only if the demand realization is low, the critical threshold for indifference between collusion and deviation $\hat{\theta}^p$ lies between the value corresponding to situations where firms are always solvent or bankrupt after defection, i.e. $\hat{\theta} > \hat{\theta}^p > \hat{\theta}^b$. This shows, that the anticyclicity of pricing is higher in this case than if firms were always solvent, but lower than if they are bankrupt due to punishment for all demand realizations.

Again, the critical realization of the shock θ^* where firms are still solvent in price competition is lower the greater the degree of product differentiation. As firms are less likely to be bankrupt then, the stability of collusion and hence the critical value of the demand realization where equity holders are indifferent between collusion and deviation is rising in the degree of heterogeneity. In contrast to traditional results for infinitely repeated competition between unleveraged firms (cf. e.g. *Shapiro* 1989, p. 365), a greater degree of product differentiation can facilitate collusion if firms are indebted.

If market prices are lower than those resulting from perfect collusion, this is not necessarily a sign that there is no tacit agreement. Alternatively, firms could be hindered to attain the maximal degree of collusion by unfavorable shocks on demand as well as by the need for outside funds.

If demand is stable at some level $D_i(\mathbf{p}, \theta)$, $\theta = \text{const.}$, $\theta \in [\underline{\theta}, \bar{\theta}]$, the stability condition (3) simplifies. Solving the resulting inequality for the discount factor, we obtain the reduced stability condition

$$\delta > \underline{\delta}^{\bar{K}} = \frac{\pi^A(p_i^A, \mathbf{p}_{-i}) - \pi^{\bar{K}}(\mathbf{p}^{\bar{K}})}{\pi^A(p_i^A, \mathbf{p}_{-i}) - \max\{\pi^B(\mathbf{p}^B), b\}}, \tag{7}$$

where $\underline{\delta}^{\bar{K}}$ is the critical threshold leaving firms indifferent between collusion and deviation. Thus, as long as firms are solvent in price competition, $b < \pi^B(\mathbf{p}^B)$, equity holders' inclination to collude is again independent of the debt level. In this case, repayments are due, irrespective of whether firms compete, collude or deviate. If, however, firms are bankrupt due to punishment, the critical value of the discount factor increases with rising repayments b. If equity holders value future profits higher than indicated by this threshold, perfect collusion is stable. Then, the maximal repayment which does not destabilize the agreement on joint monopolization of the market, is the amount $\bar{b}$ fulfilling the stability condition (7) with equality. If equity holders are less patient ($\delta < \underline{\delta}^{\bar{K}}$), collusion is more constrained the higher the debt level is. In this case, owners of firms reduce prices to stabilize the tacit agreement. In contrast to markets with stochastic shocks, these price reductions do not vary over time. Hence, the above model with stochastic shocks contains the results of

Maksimovic (1988) as a special case, where the support of the distribution function of the shock realization is reduced to a single value.

Thus, with stochastic shocks, outside finance has the same effect on product-market competition as in a market with a constant demand level. In sum, our extension of *Maksimovic* (1988) and *Stenbacka* (1994) shows that an increase in the debt level leads to more aggressive competition if producers of a heterogeneous good compete over an infinite horizon in a market where demand is subject to identically, independently distributed stochastic shocks. The equity value in the case of collusion is reduced by debt, both as the payment b rises and as the interval of demand levels allowing for perfect collusion $[\underline{\theta}, \hat{\theta}^p]$ is smaller. Equityholders have to reduce prices for lower demand levels to keep the implicit agreement stable: The anticyclicity of pricing is stronger due to limited liability of equity holders. Firms cannot gain a competitive advantage by issuing debt. On the contrary, collusion is destabilized by leverage.

In this respect the result is contradictory to the findings of *Showalter* (1995) and *Wanzenried* (2003). They show that leverage is beneficial for firms competing in one-shot price competition. Then, equity holders can credibly commit to a less aggressive product-market strategy by issuing bonds. The profits from price competition are thus higher. If, however, competition continues infinitely or ends at an unknown date in the future, leverage is disadvantageous: Equity holders running the firms decide on whether to adhere to or defect from a tacit agreement comparing the profit streams resulting in both cases. Whenever firms are insolvent in non-cooperative price competition, they cannot meet the repayments in the punishment phase. In this case, obligations from debt do not cancel in the comparison of profits from continued collusion against those from defection and the ensuing punishment. Thus, the potential costs of cheating, i.e. the forgone future profits from the tacit agreement, are lower the higher the repayment is. Hence, leverage rises the competitive pressure in dynamic competition, exactly opposite to its effect in the short run.

4 Cyclical Demand Fluctuations

In this section we demonstrate that debt also increases the intensity of long run competition if market demand develops in recurring cycles.

Demand for many commodities and services is subject to cyclical changes. Replacement of equipment is cyclical in various industries. Moreover, there is a large number of products from heating oil and sporting equipment to sugar for canning that are subject to seasonal fluctuations. In the basic model of repeated competition with cyclical development of demand developed by *Haltiwanger*, *Harrington* (1991), the demand pattern is assumed to be known in advance by all market participants. As firms producing such goods can often quite accurately forecast future demand levels, this is a reasonable assumption for many markets. As the degree of product differentiation proved decisive for the effect of outside finance on product-market competition, we generalize *Haltiwanger*, *Harrington* (1991)'s model for the case of a differentiated good and consider the possibility of outside finance in that setup.

The demand level in period t is determined by the parameter θ_t.[10] Over the cycle of length $\bar{t}$, θ_t changes according to the following pattern

$$\theta_t = \begin{cases} \theta_1 & \text{for } \ t = 1, \bar{t}+1, 2\bar{t}+1, 3\bar{t}+1, ... \\ \theta_2 & \text{for } \ t = 2, \bar{t}+2, 2\bar{t}+2, 3\bar{t}+2, ... \\ \vdots & \vdots \\ \theta_{\hat{t}} & \text{for } \ t = \hat{t}, \bar{t}+\hat{t}, 2\bar{t}+\hat{t}, ... \\ \vdots & \vdots \\ \theta_{\bar{t}} & \text{for } \ t = \bar{t}, 2\bar{t}, 3\bar{t}, ... \end{cases}$$

$$\text{with } \ \theta_1 < \theta_2 < ... < \theta_{\hat{t}} > ... > \theta_{\bar{t}-1} > \theta_{\bar{t}}. \tag{8}$$

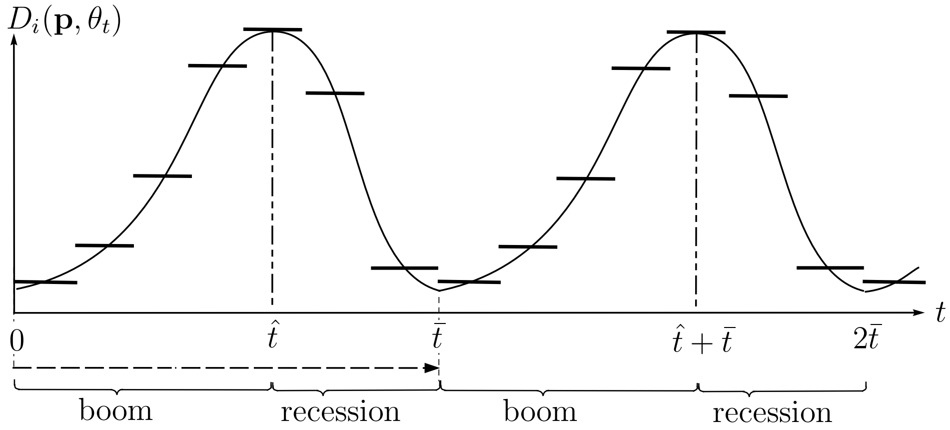
Thus, the demand level increases from period 1 until the peak of a cycle in $\hat{t}$ and falls afterwards until it reaches the initial level again in period $\bar{t}+1$. This single peaked cycle is repeated infinitely over time (see figure 1).[11]

Constant demand considered by *Maksimovic* (1988) is also contained in this model. It results as a special case if the demand parameter is constant over the cycle, $\theta_t = \text{const.} \; \forall \, t = 1, ..., \bar{t}$.

[10] Again, this version can easily be reinterpreted to cover fluctuating production costs: In this case θ_t is a parameter determining the per period level of marginal cost c_t, while demand is stable over time. If marginal costs decrease in θ_t, the same pattern of per-period profits results, whether θ_t changes the demand level or marginal cost. As it is this cyclicity of profits that changes the incentive to collude over time, the results derived below hold both for cyclical demand and cost development.

[11] Demand levels are discrete here. The solid line is included as it emphasizes the cyclicity of the demand development.

Figure 1: Development of Demand Over the Cycle



The ability to collude depends on the discounted profit stream from an indefinitely repeated cycle starting in the current period t. To shorten notation we drop the arguments of the profit function and define

$$\bar{K}(t,\delta) \equiv (\pi_t^{\bar{K}} + \delta\pi_{t+1}^{\bar{K}} + ... + \delta^{\bar{t}-t}\pi_{\bar{t}}^{\bar{K}} + \delta^{\bar{t}-t+1}\pi_1^{\bar{K}} + ... + \delta^{\bar{t}-1}\pi_{t-1}^{\bar{K}})/(1-\delta^{\bar{t}}) \tag{9}$$

as the discounted profits from perfect collusion starting in t when the discount factor is given by δ, whereas

$$K(t,\delta) \equiv (\pi_t^{K} + \delta\pi_{t+1}^{K} + ... + \delta^{\bar{t}-t}\pi_{\bar{t}}^{K} + \delta^{\bar{t}-t+1}\pi_1^{K} + ... + \delta^{\bar{t}-1}\pi_{t-1}^{K})/(1-\delta^{\bar{t}}), \tag{10}$$

$$B(t,\delta) \equiv (\pi_t^{B} + \delta\pi_{t+1}^{B} + ... + \delta^{\bar{t}-t}\pi_{\bar{t}}^{B} + \delta^{\bar{t}-t+1}\pi_1^{B} + ... + \delta^{\bar{t}-1}\pi_{t-1}^{B})/(1-\delta^{\bar{t}}) \tag{11}$$

are the analogous profit streams from any stable implicit agreement or from unrestrained price competition, respectively.[12] Note, that the above profit streams are gross per-period obligations, where the financial obligations of firms are not taken into account.

If a tacit agreement to set prices above the competitive level $\mathbf{p}_t^B$ is stable, firms can set every price in the interval $[\mathbf{p}_t^B, \mathbf{p}_t^K]$ in a collusive equilibrium in period t. As before, we assume that they implicitly agree on the highest possible price to maximize the gain from the tacit agreement. Thus, they set prices that fulfill the stability condition (12) with equality and thus exhaust the scope of collusion. The resulting path of maximal collusive prices is denoted by $\{\mathbf{p}_\tau^K\}_{\tau=0}^{\infty}$.

As we will see, equity holders reduce prices in some periods of the cycle to offset the incentive to deviate resulting from high demand. The implicit agreement is therefore always stable. Punishment is thus only a threat and is never actually used in

[12] Note that multiplication with $1/(1-\delta^{\bar{t}})$ correctly discounts the profits from an infinitely repeated cycle, e. g. $(\pi_t^{\bar{K}}+\delta\pi_{t+1}^{\bar{K}}+\delta^2\pi_{t+2}^{\bar{K}}+...+\delta^{\bar{t}-t}\pi_{\bar{t}}^{\bar{K}}+\delta^{\bar{t}-t+1}\pi_1^{\bar{K}}+...+\delta^{\bar{t}-1}\pi_{t-1}^{\bar{K}})/(1-\delta^{\bar{t}}) = \sum_{\tau=0}^{\infty}\delta^{\bar{t}\tau}(\pi_t^{\bar{K}} + \delta\pi_{t+1}^{\bar{K}} + \delta^2\pi_{t+2}^{\bar{K}} + ... + \delta^{\bar{t}-t}\pi_{\bar{t}}^{\bar{K}} + \delta^{\bar{t}-t+1}\pi_1^{\bar{K}} + ... + \delta^{\bar{t}-1}\pi_{t-1}^{\bar{K}})$.

equilibrium. Investors in the capital market buy corporate bonds only if firms' profits are large enough to serve the resulting financial obligations. The resulting repayments are therefore not higher than the smallest per-period profits attainable in equilibrium. Profits from price competition are still lower than those from constrained collusion, so that firms can be forced into bankruptcy by punishment if they issue the maximal number of bonds. Let us again consider the different cases concerning the insolvency of firms in the punishment phase in turn.

Case 1: Firms are Solvent during the Punishment Phase

To analyze the effect of demand cycles on the pricing strategy of leveraged firms, consider first the case where firms are always solvent in the punishment phase. Then, the amount b has to be paid in every period irrespective of whether firms violate the implicit agreement or not. Hence, the repayment has no influence on equity holders' incentive to collude. The pricing strategy of leveraged and unleveraged firms is thus identical. We present this strategy using the framework of *Haltiwanger*, *Harrington* (1991), extended to account for product differentiation. As we will see, their reasoning continues to apply if goods are heterogeneous and firms are always solvent.

As in the case of uncorrelated demand shocks, leverage does not change firms' optimal collusive strategy if punishment does not lead to bankruptcy. Hence, the results derived by *Haltiwanger*, *Harrington* (1991) also hold if firms are leveraged and produce a differentiated good.

The condition for stable collusion in all periods of the cycle is given by

$$\delta \ \{[K(t+1,\delta)-b]-[B(t+1,\delta-b)]\} \geq \left[\pi_t^A - b\right] - \left[\pi_t^K - b\right], \ \forall\, t. \qquad (12)$$

It shows that the additional future gains from collusion (left hand side) must be higher than the additional per-period profits attainable by defection (right hand side). With cyclical demand development, the future discounted profit streams as well as the gain from defection depend on the starting period. Thus, the critical value of the discount factor fulfilling this condition with equality also varies with that period. To analyze the price strategy, we define the incentive to collude in period t if the discount factor takes the value δ as

$$V(t,\pi_1^K,...,\pi_t^K,\delta) \equiv \delta \ [K(t+1,\delta)-B(t+1,\delta)] - \pi_t^A + \pi_t^K. \qquad (13)$$

If the implicit agreement is stable, condition (12) and $V(t,\pi_1^K,...,\pi_t^K,\delta) \geq 0$ hold.

Perfect Collusion

Equityholders' incentive to participate in perfect collusion is given as the difference of the additional profits attainable if they abide by or violate this implicit agreement.

$$V(t, \pi_1^{\bar{K}}, ..., \pi_{\hat{t}}^{\bar{K}}, \delta) \equiv \delta \left[\bar{K}(t+1, \delta) - B(t+1, \delta)\right] - \pi_t^A + \pi_t^{\bar{K}}. \tag{14}$$

If it is positive, perfect collusion is stable in all periods of the cycle. The price path is therefore $\{\mathbf{p}^{\bar{\mathbf{K}}}{}_{\tau}\}_{\tau=0}^{\infty}$. The additional gain from collusion (right hand side of (12)) increases with $\delta \in [0, 1]$, whereas the additional gain from deviation (left hand side) remains constant. Depending on the position of the actual period t in the cycle, equity holders attain different discounted profit streams per cycle. For a discount factor at or above the critical value $\underline{\delta}_t^{\bar{K}}$, owners of firms have an incentive to participate in perfect collusion, i.e. $V(t, \pi_1^{\bar{K}}, ..., \pi_{\hat{t}}^{\bar{K}}, \delta) \geq 0$. Then, the price path $\{\mathbf{p}^{\bar{\mathbf{K}}}{}_{t}\}_{\tau=0}^{\infty}$ exactly follows the movement of demand and the price develops procyclically.
If the demand is stable at the highest level, the maximal per-period profit $\pi_{\hat{t}}^{\bar{K}}$ can be reached in all periods. Perfect collusion is then stable if

$$V(\hat{t}, \pi_{\hat{t}}^{\bar{K}}, ..., \pi_{\hat{t}}^{\bar{K}}, \delta) \equiv \frac{\delta}{1-\delta}\left(\pi_{\hat{t}}^{\bar{K}} - \pi_{\hat{t}}^{B}\right) - \pi_{\hat{t}}^{A} + \pi_{\hat{t}}^{\bar{K}} \geq 0. \tag{15}$$

In this case, equity holders' incentive to collude is positive for discount factors $\delta > \underline{\delta}_{\hat{t}} \equiv (\pi_{\hat{t}}^A - \pi_{\hat{t}}^{\bar{K}})/(\pi_{\hat{t}}^A - \pi_{\hat{t}}^B)$. Due to the cyclical demand development, this maximal profit $\pi_{\hat{t}}^{\bar{K}}$ is not attained in all periods. Hence, the discounted future profit stream from collusion is lower with cyclical demand than with demand stable at the highest level. Even if competition starts at the peak of the cycle in period $\hat{t}$, the incentive to collude given by (14) is negative for $\underline{\delta}_{\hat{t}}$. The lower bound of the discount factor for perfect collusion is situated above the critical value for a market without a cyclical demand development, i.e. $\underline{\delta}_{\hat{t}}^{\bar{K}} > \underline{\delta}_{\hat{t}}$. If equity holders do not value future profits highly enough, perfect collusion is impossible.

Imperfect Collusion

Any implicit agreement is stable if the resulting discounted profit stream is higher than that from deviation. The incentive to participate in imperfect collusion is given by (13). To maximize the profits from the implicit agreement, equity holders choose the prices $\{\mathbf{p}^{\mathbf{K}}{}_{t}\}_{t=0}^{\infty}$, where the gain from cheating is just offset by the additional profits from continued collusion. Equityholders' inclination to collude $V(t, \pi_1^K, ..., \pi_{\hat{t}}^K, \delta)$ is zero then. For a discount factor slightly below $\underline{\delta}_t^{\bar{K}}$, equity holders are forced to reduce the potential gain from deviation to stabilize their implicit agreement. Therefore, they set prices lower than those from perfect collusion in the most critical period t^*: $\mathbf{p}^{\mathbf{K}}{}_{t^*} < \mathbf{p}^{\bar{\mathbf{K}}}{}_{t^*}$. As the pricing strategy is continuous in the discount factor, in a small interval below the critical lower bound for perfect collusion $\underline{\delta}_t^{\bar{K}}$, this price $\mathbf{p^K}_{t^*}$ does not yet fall below the prices of the neighboring periods $\mathbf{p^{\bar{K}}}_{t^*-1}$ and $\mathbf{p^{\bar{K}}}_{t^*+1}$. For values of the discount factor in the range $\delta \in [\bar{\delta}_t,\ \underline{\delta}_t^{\bar{K}}]$, the collusive price path fulfills the chain of inequalities

$$\mathbf{p^{\bar{K}}}_{1+k\bar{t}} < ... < \mathbf{p^{\bar{K}}}_{\hat{t}+k\bar{t}} > ... > \mathbf{p^{K}}_{t^*+k\bar{t}} > ... > \mathbf{p^{\bar{K}}}_{(k+1)\bar{t}-1} > \mathbf{p^{\bar{K}}}_{(k+1)\bar{t}},\ \forall\, k \in \mathbb{N}_0. \quad (16)$$

In all but the most critical period t^*, equity holders agree on perfect collusion. In the interval $[\bar{\delta}_t,\ \underline{\delta}_t^{\bar{K}})$, the price path exactly follows the demand development, although perfect collusion is not stable over the whole cycle.

If the discount factor decreases further, firms are forced to reduce per-period profits by lowering prices in an increasing number of periods. For a discount factor still relatively close to $\underline{\delta}^{\bar{K}}$, price reductions are necessary only in periods of falling demand. The price path is hence still procyclical but diverges from the demand pattern in some periods. Note, however, that prices are lower for lower demand levels only in periods where demand is falling, whereas prices exactly follow the demand pattern for the same levels but rising demand. The pricing strategy here is only in some respect contrary to the finding of anticyclical pricing by *Rotemberg*, *Saloner* (1986) and *Stenbacka* (1994): In our model, firms' reactions depend on the slope of demand, whereas in their framework it is the level of demand that is decisive.

If the discount factor decreases even more, prices have to be cut in ever more periods, i.e., not only in recessions but also in some periods with rising demand. Hence, pricing is anticyclical in a growing part of the demand cycle. This part is larger the lower the discount factor is. In the interval $[\underline{\delta}_t,\ \bar{\delta}_t)$, we observe the result of anticyclical pricing derived by *Rotemberg*, *Saloner* (1986) for uncorrelated demand shocks even in the case of cyclical demand development.

If the discount factor approaches the critical threshold for stable demand $D(\mathbf{p}, \theta_t)$, $\theta_t = \text{constant}\ \forall\ t = 1, ...\bar{t}$, i.e.

$$\underline{\delta}_t \equiv \frac{\pi_t^A - \pi_t^K}{\pi_t^A - \pi_t^B}, \quad (17)$$

the collusive per-period profit π_t^K must be constant over the cycle. With the single peaked demand development given by (8), firms can ensure this only if the collusive price path $\{\mathbf{p^K}_t\}_{t=0}^{\infty}$ is anticyclical. This can be shown by contradiction: Equityholders cannot reduce per-period profits tacitly agreeing on a price above that resulting with perfect collusion. Hence, if the price path is not strictly anticyclical and the discount factor is close to $\underline{\delta}_t$, there is at least one period t', for which the per-period profit from collusion is larger than that in other periods. We have $\pi_{t'}^K \geq \pi_t^K$, $\forall\, t = 1, ..., \bar{t}$

and $\pi^K_{t'} > \pi^K_t$ for some $t \neq t'$. Therefore,

$$V(t', \pi^K_1, ..., \pi^K_{\hat{t}}, ..., \pi^K_{\bar{t}}, \delta) < V(t', \pi^K_{t'}, ..., \pi^K_{t'}, ..., \pi^K_{t'}, \delta), \tag{18}$$

with the incentive to collude for period t' on the left hand side of (18) and the respective value for constant per-period profits $\pi^K_{t'}$ on the right hand side. This condition is valid with strict inequality as $V(\cdot)$ increases in π^K_t. For $\delta \to \underline{\delta}_t$ the right hand side approaches zero. Thus, the contradiction $V(t', \pi^K_1, ..., \pi^K_{\hat{t}}, ..., \pi^K_{\bar{t}}, \delta) < 0$ follows. If the per-period profits are not constant, and therefore the price path is not exactly anticyclical, the collusive agreement is not stable for values of δ close to $\underline{\delta}_t$. Due to the continuity of the profit stream in δ, prices are adjusted continuously. If the discount factor increases above $\underline{\delta}_t$, the collusive price can be increased in one of the periods. In the interval $\delta \in [\underline{\delta}_t, \tilde{\delta}_t)$, the price in this period will not yet be higher than the prices in the neighboring periods. For such values of the discount factor, equity holders agree on prices $\{\mathbf{p^K}_t\}_{t=0}^{\infty}$ that fulfill

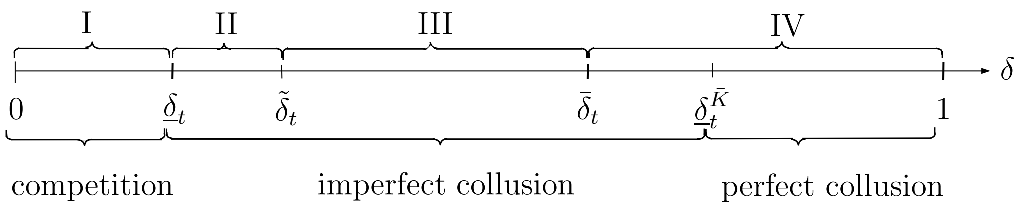
$$\mathbf{p^K}_{1+k\bar{t}} > \mathbf{p^K}_{2+k\bar{t}} \cdots > \mathbf{p^K}_{\hat{t}+k\bar{t}} < ... < \mathbf{p^K}_{(k+1)\bar{t}-1} < \mathbf{p^K}_{(k+1)\bar{t}}, \; \forall\, k \in \mathbb{N}_0, \tag{19}$$

in which the profit of one period is already larger than the remaining per-period profits of the cycle. For discount factors higher than $\tilde{\delta}_t$, firms can reach an implicit agreement with one or more prices violating the chain of inequalities (19).

Price Competition

From (13) and (17) it is clear that for values of the discount factor below $\underline{\delta}_t$, collusion is impossible because the gain from deviation is larger than the gain from tacit agreement even if collusive per-period profits are held constant over the cycle. For values of the discount factor in $[0, \underline{\delta}_t)$, equity holders cannot collude and set the prices $\mathbf{p}^B_t$. As the competitive price also depends on the demand level when the good is differentiated, the price path is procyclical in the punishment phase. Only the competitive (punishment) price for a homogeneous good $\mathbf{p}_t = c$ is acyclic. These results are summarized in figure 2.

Figure 2: Price Path in Dependence of the Discount Factor



I : heterogeneous: strictly procyclical, homogeneous: acyclical pricing

II : strictly anticyclical pricing

III : mixed pricing

IV : strictly procyclical pricing

As figure 1 shows, in a singly peaked cycle for every period after which demand rises (e. g. t'), there is a period with the same level of demand after which demand falls (e. g. t''). Due to discounting, the profit stream from an implicit agreement is larger in starting periods where demand is still rising. As the gain from deviation is the same in both periods t' and t'', the period t^* in which perfect collusion is impossible for the first time because of a discount factor lower than the critical threshold for perfect collusion, $\underline{\delta}_t^{\bar{K}}$ must lie in the phase of falling demand. With cyclical fluctuations, the critical phase for collusion is in a recession.

This result is contrary to the finding of „price wars during booms" by *Rotemberg*, *Saloner* (1986). The difference in the pricing behavior is due to the fact that the agents in our model know the pattern of demand whereas in *Rotemberg*, *Saloner* (1986) and *Stenbacka* (1994) the demand level develops stochastically. As shown by *Haltiwanger*, *Harrington* (1991), with a repeated cyclical structure, the decision about compliance with or deviation from tacit collusion does not depend on the actual level of demand (as with stochastic shocks) but on its increase or decrease. Our analysis shows that this is also true if firms are leveraged and products are differentiated.

Case 2: Firms are Bankrupt in the Case of Punishment

If the periodic repayment b is higher than the per-period profit from price competition at the peak of the cycle, $b > \pi_{\hat{t}}^B(\mathbf{p}^B)$, firms will go bankrupt if a deviation occurs. This is also true if the good is homogeneous. Thus, the optimal pricing strategy derived in this section also applies in the latter case.

Equityholders still decide whether to collude or deviate comparing the respective profit streams. Analogously to (13), their inclination to collude is now given by

$$V^b(t, \pi_1^K, ..., \pi_{\hat{t}}^K, \delta) \equiv \delta \; [K(t+1, \delta) - b/(1-\delta)] - \pi_t^A + \pi_t^K. \qquad (20)$$

Index b denotes cases where firms are bankrupt after a defection. Due to insolvency in the punishment phase, repayments do not cancel. Comparison with the corresponding incentive of firms that always solvent (13) shows the impact of leverage on the intensity of competition. As by assumption the repayment exceeds the profits from price competition even for the highest level of demand, the reduction of collusive gains are higher in the case of bankruptcy. The inclination to participate in an implicit agreement declines with rising indebtedness. This is true irrespective of the value of the discount factor and hence regardless of the intensity of collusion. Thus, the critical thresholds of the discount factor are higher here compared to situations where firms are always solvent.

In sum, the arguments given for situations where firms are never bankrupt continue to hold qualitatively, but due to the lower additional stream of net profits from the tacit agreement, all critical thresholds of the discount factor, for cyclical pricing as well as for price competition, are lower if firms are insolvent after a breakdown of collusion. The critical values given in figure 2 are shifted to the right by an increase in the debt level.

Case 3: Firms are Bankrupted by Punishment Only if Demand is Very Low

Again, an intermediate case is possible where firms are bankrupt only in periods of low demand, i.e. if demand is lower than some critical level θ^{**}.[13] If the implicit agreement breaks down, equity holders gain per-period profits from price competition as long as demand level is still higher than this critical value. If the demand falls further, firms are insolvent and debtholders take over. The formal analysis is the same as in the case of solvency considered in the first case, but the profit stream from the punishment phase has to be replaced by the sum of discounted per-period profits from the periods where firms are solvent and the stream of discounted repayments due in all later periods.

As repayments are higher than per-period profits from price competition in periods where firms are insolvent, the reduction of the future collusive profit stream is now stronger than in the case of solvency, but less severe compared to a situation where firms are bankrupt immediately after a defection. The effect of limited liability of equity holders is hence the same as in the case of uncorrelated stochastic shocks. Consequently, the critical values of the discount factors separating the different pricing strategies are lower than in the case of bankruptcy immediately after a breakdown of the collusive agreement, but higher than in situations where firms are always solvent.

As in the case of uncorrelated demand shocks, the degree of product differentiation is decisive for the solvency of firms in price competition. Given that firms are less

[13] Here, cases 1 and 2 are again contained as special cases. Case 1 results, if the critical demand level for solvency in price competition θ^{**} is lower than the smallest value of the demand parameter θ_1, whereas case 2 results, if θ^{**} is larger than $\hat{\theta}$, the parameter value at the peak of the demand cycle.

likely to be bankrupt if goods are highly differentiated, the stability of collusion and hence the critical values of the discount factor separating the intervals of pro- and anticyclical pricing (cf. figure 2) are higher with a higher degree of heterogeneity. Again, a greater degree of product differentiation can facilitate collusion if firms are indebted.

The above analysis showed that the collusion is also destabilized by debt if demand develops cyclically as long as firms face bankruptcy due to punishment at least for low demand levels. Hence, the effect of leverage is qualitatively identical for all demand patterns considered here. In markets with demand cycles, however, pricing is anticyclical only if equity holders place a low value on future profits. If they are more patient, procyclical pricing is optimal. Thus, the optimal collusive pricing strategy of leveraged firms is qualitatively identical to the optimal price path derived by *Haltiwanger*, *Harrington* (1991) for unleveraged firms producing a homogeneous good. The cyclicity of pricing, however, is more pronounced the higher the debt level.

5 Demand Cycles with Stochastic Shocks

Until now, we considered uncorrelated shocks and cyclical fluctuations separately. Analysis of simultaneous cyclical and stochastic demand changes would necessitate a great number of case differentiations in addition to those concerning the insolvency of firms in price competition. Seeing as a unified framework is to complicated to yield clear results, we will only briefly outline such a setup.

To this end, we model demand development as a sum of a trend and a stochastic process as customary in time series analysis (see, e.g., *Harvey* 1993) and assume an *i.i.d.* stochastic shock on the demand level of every period of the repeated cycle. The level of demand for variety i in period t resulting from both the realization of the stochastic shock and the cyclic trend gives an equity holder's expectation of the demand for his product. If the expected values of the demand levels in the model with additional stochastic shocks are equal to the levels in the model with deterministic cyclical development, it is sufficient to replace the per-period demand in the above model by its expected value to account for the stochastic shocks. The expected value of the profit stream is then also equal to the profit stream without additional shocks. The current shock realization only changes the possible gain from deviation. As in the model with purely stochastic shocks by *Rotemberg*, *Saloner* (1986), equity holders have to react to the changing incentive to deviate by lowering the collusive price if the current demand realization is high. On the other hand, they can tacitly agree on a higher price than without the additional shock if the actual value of the shock is low. If the demand level results from a cyclical development with stochastic shocks, the pricing decision is a combination of the strategy for cyclical development of demand and the strategy for markets with uncorrelated stochastic shocks. Therefore, the finding of less intense collusion between leveraged firms and a more pronounced cyclicity of pricing remains unchanged in the model combining both kinds of demand fluctuations. This again proves the robustness of *Haltiwanger*, *Harrington*'s (1991) conclusions with respect to leverage and product differentiation.

6 Conclusion

Our analysis determined the impact of outside finance on the pricing decisions of firms in long run competition. Comparison with *Wanzenried*'s (2003) results reveals that leverage is advantageous in short-run price competition, but lowers firms profits in long-run interaction, irrespective of the demand fluctuations. Debt is hence an other example for the " 'topsy-turvy principle' of supergame theory" (*Shapiro* 1989, p. 365).

The effect of limited liability, i.e. bankruptcy and the resulting inability of equity holders to repay debt, proves decisive for the effect of leverage on the competitive pressure in infinitely repeated competition with stochastic demand shocks as well as with cyclical demand development. The basic effect of limited liability derived by *Maksimovic* (1988) also holds for price competition and is robust to demand fluctuations: Equity holders running the firms decide on whether to adhere to or defect from a tacit agreement comparing the profit streams resulting in both cases. If firms are always solvent, repayments are due irrespective of whether equity holders compete, collude or deviate. Hence, the debt level does not change their incentive to collude. If, however, firms are insolvent in non-cooperative price competition, they cannot meet the repayments in the punishment phase. In this case, obligations from debt do not cancel in the comparison of profits from continued collusion against those from defection and the ensuing punishment. Thus, the potential costs of cheating, i.e. the forgone future profits from the tacit agreement, are lower the higher the repayment is. Consequently, collusion is less stable the higher the leverage. The degree of product differentiation is thus decisive for the effect of debt: If the good is sufficiently differentiated, even profits from non-cooperative price competition are sufficient to serve the liabilities. Then, firms are solvent even if they do not collude in the product market. If the product is fairly homogeneous, however, non-cooperative profits are insufficient to meet the financial obligations. Hence, debt reduces firms' ability to collude only if the degree of product differentiation is not to high. The latter effect was not considered in the earlier model of demand fluctuations by *Stenbacka* (1994).

The development of demand, however, determines equity owners' optimal collusive pricing strategies. If market demand is subject to uncorrelated shocks, a high level of current demand results in a high potential gain from defection, whereas the future gain from continued collusion remains unchanged. Hence, if the demand realization is higher than a certain critical level, equity holders are forced to reduce per-period profits from deviation by lowering prices. These price reductions stabilize the implicit agreement. As collusion is more difficult if debt levels are high, the critical demand realization leading to such price reductions is lower the higher the leverage is. The anticyclicity of prices increases with the firms' indebtedness. The same reasoning applies if market demand develops cyclically: In this case, the inclination to collude depends on the slope and not on the level of demand. As the potential punishment for defection is lower in times of falling demand, the incentive to cheat on the tacit agreements is higher in such periods. If owners place sufficiently high value on future profits, collusion has to be stabilized by lower prices only in periods of falling demand. Pricing is then procyclical. Additional price reductions in periods preceding a fall in demand are necessary only if owners do not place high value on future profits. In this case, they set prices anticyclically. Again, the incentive to collude declines with the debt level. Consequently, the cyclicity of pricing is more pronounced in markets where firms are highly indebted. Thus, the basic insights by *Rotemberg*, *Saloner* (1986) and *Haltiwanger*, *Harrington* (1991) continue to hold if products are differentiated and firms are leveraged.

Irrespective of demand development, obligations from debt destabilize a potential price-fixing conspiracy. Hence, high levels of debt, as needed for example to finance new areas of business or large innovation projects, need not raise concern of the competition authorities.

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