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# Cartel Stability in Times of Low Interest Rates <sup>\*</sup>

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## Abstract

We study how the interest rate affects the stability of cartels, considering two channels. (i) Time value of money: a low interest rate implies a high discount factor and increases the value of future profits resulting in more stable cartels. (ii) Production cost: Production costs depend on the cost of capital. A low interest rate implies low production costs, allowing a firm to serve a large market share by undercutting the cartel price, resulting in a more profitable deviation from a collusive agreement, destabilizing a cartel. Taking into account these opposing effects, we show that in competitive markets, stability is U-shaped with the interest rate: collusion is most stable when interest rates are very low or very high. Empirical evidence from 615 firms convicted by the European Commission between 1999 and 2016 supports our theoretical findings.

**Keywords:** Antitrust, Collusion, Interest Rate, Survival Analysis

**JEL:** C41, D43, K21, L40

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# 1 Introduction

Low interest rates mark the last decade. Since the financial crisis, central banks have kept interest rates down to stimulate the economy. Nowadays, inflation is back, and central banks are fighting it with increasing interest rates. In this paper, we analyze a possible side-effect of monetary policy: we study how the interest rate affects the formation and stability of cartels.

When interest rates are low, a dollar tomorrow has about the same value as a dollar today. Accordingly, future values are only discounted slightly. Firms value additional profits from collusion over a long period more than a large one-time gain by deviating from the collusive agreement. Technically, collusion's net present value increases when interest rates are low. Following this argument, high interest rates discourage the formation of cartels and destabilize them.

However, production typically requires capital; the interest rate determines the cost of capital and thereby affects production costs. Lower production costs enable a firm to serve a large market share itself. Deviating from a collusive agreement becomes more profitable the higher the market share a firm ends up with after the deviation. If the cost of capital is high and it does not pay for a firm to serve a higher market share than it already does under the collusive agreement, it has no incentive to deviate. Therefore, competition may be weak in times of high interest rates because firms lack the resources to compete for the entire market.

Our setup builds on heterogeneous consumers and two horizontally differentiated firms. The higher the firms' marginal production cost, the smaller the set of consumers they compete for. Thus, in our setup, competition is less fierce with higher marginal production costs. Firms' marginal costs of production depend on the interest rate. Each period, firms set their price. Firms discount future values using the interest rate. We derive the condition for a stable cartel based on the optimal punishment strategy. To study the interplay of the two effects, we propose a continuous measure of a cartel's stability based on its profitability.

The literature typically assumes a dichotomous stability measure: if the interest rate is below a threshold, firms collude; otherwise, they compete. We show that generally, the threshold depends on the interest rate through the capital's cost in the production function.

We find that stability is U-shaped with the interest rate. A U-shape means that stability decreases for low interest rate values while it increases for high interest rate values. Thus, when interest rates are low, the effect of the time value of money dominates, and stability decreases with the interest rate. When interest rates are high,

the interest rate's effect on production costs dominates and stability increases with the interest rate.

We empirically test our prediction of the U-shape using a dataset collected by Hellwig and Hüscherlath (2018) and find empirical evidence in support of our results. The dataset contains 615 firms active in 114 cartels convicted by the European Commission between 1999 and 2016. We follow Hellwig and Hüscherlath (2018) and use survival analysis to estimate a cartel's duration. Precisely, we estimate how a firm's duration of participation depends on the interest rate using a Weibull model. Using the appropriate test by Lind and Mehlum (2010), we find significant evidence for the U-shape in line with our theory.<sup>1</sup>

We conclude that a cartel's stability and the likelihood of its formation depend on the capital market. The interest rate affects collusion non-monotonically. In times of low real interest rates, we expect the cartels' stability to be weakened when real interests increase. Thus, the last decade's expansionary monetary policy may have stabilized cartels and facilitated new ones, leading to market inefficiencies.

## 1.1 Related Literature

Our paper relates to frameworks studying collusion with differentiated products. Similar to us, Chang (1991) and Häckner (1996) study a stage game à la Hotelling and find that product differentiation increases the likelihood of a cartel. Deneckere (1983, 1984) studies differentiated products with Cournot and Bertrand competition and finds a non-monotonic relation between cartel stability and product differentiation.<sup>2</sup>

Moreover, several papers have studied the effect of the business cycle on cartel stability, focusing on demand cycles. Rotemberg and Saloner (1986) argue that collusion is counter-cyclical; Haltiwanger and Harrington (1991) and Bagwell and Staiger (1997) argue to the contrary. Fabra (2006) shows that collusion tends to be counter-cyclical when capacity constraints bind while it is pro-cyclical for sufficiently large capacities.<sup>3</sup>

Another branch of the literature studies how cartel stability depends on the production cost. Most work focuses on collusion between firms with heterogeneous costs (e.g., Bae (1987), Rothschild (1999), or Miklós-Thal (2011)).<sup>4</sup> Klein and Schinkel (2019)

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<sup>1</sup>As common in the empirical literature, there exist, however, several problems regarding the data's quality. There is a selection bias since only convicted cartels are collected in the dataset. Furthermore, a cartel's duration may be underestimated due to insufficient evidence.

<sup>2</sup>Collie (2006) introduces quadratic production costs.

<sup>3</sup>The theoretical literature lacks an explanation for the formation of new cartels. An exception is Bos and Harrington (2010), who present a theoretical model with endogenous cartel formation in a market with many firms.

<sup>4</sup>For more on collusion with heterogeneous firms, see Harrington (1989) and Harrington (1991).

present a theoretical framework including costly collusion. In their setup, industries with lower homogeneous marginal production costs tend to collude more.<sup>5</sup>

None of those papers discuss the interest rate's effect explicitly. All study a cartel's stability employing a critical discount factor. The lower the interest rate, the higher the discount factor, i.e., cartels become more stable. By contrast, Dal Bó (2007) studies fluctuations in the discount factor that may arise from uncertain interest rates. Cartel prices and profits decrease with the discount factor's volatility and increase with its expected value. In our setup, cartel prices are not affected by the discount factor but by the interest rate's effect on the production costs: higher costs are handed over to consumers.

Bagliano et al. (2000) and Schinkel (2018) focus on the loan market and show that a counter-cyclical monetary policy may favor collusion among banks, affecting the transmission of policy rates into market rates. Like us, the latter distinguishes between the effect of interest rates on the cost of capital and the time value. However, our setup applies to various industries.

Some empirical work includes the interest rate in the study of collusion. Levenstein and Suslow (2016) analyze 247 cartels accused of price-fixing brought to the US Department of Justice between 1961 and 2013. They argue in line with the abovementioned literature: interest rates are inversely related to a firm's discount factor and incorporate it as a control in their estimations. In their dataset, lower interest rates indeed stabilize cartels and facilitate the formation of new cartels.

By contrast, Hellwig and Hüschelrath (2018) find the opposite. They study 615 firms active in 114 cartels convicted by the European Commission between 1999 and 2016. In their dataset, low interest rates destabilize cartels.

Our theory explains the seemingly contradictory empirical evidence. We use the data collected by Hellwig and Hüschelrath (2018) and incorporate the interest rate's U-shape, finding empirical evidence for our theoretical prediction.<sup>6</sup>

The following section illustrates the main idea. Next, we derive our theoretical model to study cartels' stability in more detail. Then, we present some empirical evidence. Finally, we conclude.

## 2 A Short Illustration

This section briefly describes the main idea and illustrates how cartel stability may increase or decrease with the interest rate  $r$ .

<sup>5</sup>Busse (2002) presents some empirical work on the cost side using data from the airline industry. She shows that higher leveraged firms tend to start a price war.

<sup>6</sup>Recent empirical work by Marvão et al. (2023) confirms the interest rate's non-monotonic effect.

Consider two symmetric firms that make a profit  $\pi_c(r)$  each, in each period if they compete. If they collude, they make a profit  $\pi_a(r)$  per period. If a firm deviates from the collusive agreement, the defector makes the profit  $\pi_d(r)$  in this period.

Profits depend on the interest rate  $r$  because the interest rate affects the cost of capital, affecting the marginal production costs. They are continuous and differentiable. As common, profits are ordered  $\pi_d(r) \geq \pi_a(r) \geq \pi_c(r)$ ; thus, collusion does not form an equilibrium in a finite game. Therefore, we assume that firms interact with each other in infinitely many periods.

Let us, for simplicity, assume a grim trigger strategy: Firms continue to collude if both have adhered to the collusive agreement. However, if one firm deviates, firms compete forever. Formally, a cartel is stable if

$$\sum_{\tau=0}^{\infty} \frac{\pi_a(r)}{(1+r)^\tau} \geq \pi_d(r) + \sum_{\tau=1}^{\infty} \frac{\pi_c(r)}{(1+r)^\tau},$$

which simplifies to

$$r \leq \frac{\pi_a(r) - \pi_c(r)}{\pi_d(r) - \pi_a(r)}.$$

When the interest rate is below the threshold on the right-hand side, collusion is stable; otherwise, it is not. However, we observe that the right-hand side also depends on the interest rate.

To study a cartel's stability, let us define  $\tilde{S}(r) = (\pi_a(r) - \pi_c(r)) / (\pi_d(r) - \pi_a(r)) - r$ .  $\tilde{S}$  measures the cartel's profitability.<sup>7</sup> When  $\tilde{S}(r) \geq 0$ , a cartel is profitable and thus stable; otherwise, not.

Let us assume that profit functions satisfy<sup>8</sup>

$$0 \geq \frac{\partial \pi_c}{\partial r} \geq \frac{\partial \pi_a}{\partial r} \geq \frac{\partial \pi_d}{\partial r}.$$

Higher interest rates increase capital costs and, thereby, marginal production costs, resulting in lower profits. The second inequality follows because the cost pass-through is higher in a competitive market than for colluding firms; competing firms set prices closer to marginal costs; therefore, collusive profits are more affected by a change in the marginal cost, respectively, the interest rate. Finally, the last inequality follows because the defector ends up with a higher demand after deviation, making a cost change more pronounced in its profit function.

<sup>7</sup>We explain this measure in more detail in the next section.

<sup>8</sup>Lemma 3 in the appendix shows that all our assumptions in this section are satisfied in the Hotelling setup.

The additional profit from deviating  $\pi_d(r) - \pi_a(r)$  decreases: a firm has less incentive to deviate from the collusive agreement. However, the gains from collusion  $\pi_a(r) - \pi_c(r)$  decrease, too.

Let us assume there exists  $\bar{r} < \infty$ , where  $\pi_d(\bar{r}) = \pi_a(\bar{r})$ , i.e., firms do not gain anything by deviating. If  $\pi_a(\bar{r}) > \pi_c(\bar{r})$ ,  $\tilde{S} \rightarrow \infty$  for  $r \rightarrow \bar{r}$ , resulting in increasing cartel stability with the interest rate. Otherwise,  $\pi_a(\bar{r}) = \pi_c(\bar{r})$ , and stability still increases if  $\partial\pi_d/\partial r = \partial\pi_a/\partial r < \partial\pi_c/\partial r$ , at  $r = \bar{r}$ : At  $\bar{r}$ , a defector's profit function becomes equivalent to the profit function of a cartel participant. However, the profit function of a competing firm remains different.

Thus, we have illustrated how cartel stability may increase with the interest rate.

Finally, note that in a competitive market, stability may also decrease with the interest rate. Let a competitive market be defined by a defector doubling its profits  $\pi_d(r) \rightarrow 2\pi_a(r)$  and competing firms pricing at marginal costs, resulting in a full pass-through,  $\partial\pi_c/\partial r \rightarrow 0$ . Thus,  $\tilde{S}(r) = 1 - \pi_c/\pi_a - r$ , and decreases with  $r$ .

The next section presents a model to give more structure to the profit functions and study how the interest rate affects cartel stability in more detail. Moreover, we use an optimal punishment strategy instead of the grim trigger strategy because the grim trigger is generally not optimal.

### 3 The Model

In this section, we first describe the stage game, where we build on a differentiated duopoly in the spirit of Hotelling (1929) with fixed locations and a log-concave distribution of consumers. We derive the demand function, followed by an analysis of the firms' pricing strategies if costs are high, i.e., when firms are local monopolists. Moreover, we derive prices and profits for competing and colluding firms.

We assume a uniform distribution to derive stable collusion if the stage game is infinitely often repeated, following Abreu (1986) using an optimal punishment strategy. In the appendix, we show that our results also hold for more general distributions when firms use a grim trigger strategy à la Friedman (1971), which relates more to our short illustration.<sup>9</sup>

Finally, we show that a cartel's stability is U-shaped with the interest rate.

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<sup>9</sup>Readers only interested in the case of optimal punishment may skip the section of competing firms.

### 3.1 The Stage Game

**Demand.** There is a unit mass of consumers symmetrically distributed between two firms. The cumulative distribution function  $F(x)$  is twice continuously differentiable and strictly log-concave on its compact support. Without loss of generality, let  $F$ 's support be  $[-1, 1]$ . We denote the density as  $f(x) = F'(x)$ , which we assume to be strictly positive on its support.<sup>10</sup> The distribution reflects heterogeneous consumers' preferences. Whenever many consumers are indifferent between the two firms,  $f(0)$  is high. A consumer located near the support's boundary strongly prefers one firm; price differences are less relevant for those consumers.

Consumer  $x \in [-1, 1]$  has utility  $U - p_i - t|x_i - x|$  if she buys the good at firm  $i$  at price  $p_i$ , where  $x_i \in \{-1, 1\}$  is the firm's location.  $U$  is the utility of having the good in monetary units, and  $t > 0$  is the transportation cost, measuring the intensity of competition. If consumer  $x$  does not buy the good, we normalize her utility to 0. We denote the firm at the support's lower bound as firm  $i$ , i.e.,  $x_i = -1$ , and its competitor as firm  $j$  with  $x_j = 1$ . Accordingly, the participation constraint for a consumer to buy at firm  $i$  is  $U - p_i - t(x + 1) \geq 0 \Leftrightarrow x \leq (U - p_i - t)/t$ .

Consumer  $x$  prefers buying at firm  $i$  instead of firm  $j$  if  $U - p_i - t(x + 1) \geq U - p_j - t(1 - x) \Leftrightarrow x \leq (p_j - p_i)/2t$ . Firm  $i$ 's demand consists of the consumers participating in the market and preferring to buy its product instead of buying at firm  $j$ , i.e., all consumer  $x \leq \min\{(U - p_i - t)/t, (p_j - p_i)/2t\}$ . Because the cumulative distribution function is strictly increasing, we can write firm  $i$ 's demand function as

$$D_i(p_i, p_j) = \min \left\{ F \left( \frac{U - p_i - t}{t} \right), F \left( \frac{p_j - p_i}{2t} \right) \right\}.$$

**Local Monopolists.** Firms have marginal costs  $c(r) \geq 0$ , depending on the interest rate  $r \geq 0$ . We assume a higher interest rate increases marginal costs, formally,  $c'(r) > 0$ , and that the first and second derivatives are finite.<sup>11</sup>

First, consider firms are local monopolists and serve less than the entire market, i.e.,  $F((U - p_i - t)/t) \leq F((p_j - p_i)/2t)$ . In this case, Firm  $i$  maximizes  $(p_i - c(r))F((U - p_i - t)/t)$ , resulting in the optimal price  $p_m$  implicitly given by

$$p_m = c(r) + t \frac{F \left( \frac{U - p_m - t}{t} \right)}{f \left( \frac{U - p_m - t}{t} \right)}.$$

<sup>10</sup>Formally, the distribution is log-concave if  $f^2(x) - F(x)f'(x) > 0$  and symmetric if  $f(x) = f(-x)$ .

<sup>11</sup>If capital is required in the production process, the minimum cost to produce a certain outcome depends on the interest rate. For example, with the Cobb-Douglas production function, the minimum cost of increasing the quantity depends positively on the interest rate and satisfies our assumptions.



By  $F$ 's log-concavity, the right-hand side decreases with  $p_m$ , while the left-hand side of the equation strictly increases; therefore,  $p_m$  is uniquely defined. Local monopoly pricing  $p_i = p_j = p_m$  forms an equilibrium if  $F((U - p_m - t)/t) \leq F(0) \Leftrightarrow p_m \geq U - t$ , which implies that firms serve less than the total market.

**Competition.** Next, consider competing firms, i.e.,  $F((U - p_i - t)/t) \geq F((p_j - p_i)/2t)$ . Firm  $i$ 's best response function for any  $p_j$  is implicitly given by

$$p_i^*(p_j) = \begin{cases} \sigma, & \text{if } p_j < c(r) - 2t; \\ c(r) + 2t \frac{F\left(\frac{p_j - p_i^*(p_j)}{2t}\right)}{f\left(\frac{p_j - p_i^*(p_j)}{2t}\right)}, & \text{if } c(r) - 2t \leq p_j \leq c(r) + 2t + \frac{2t}{f(1)}; \\ p_j - 2t, & \text{if } p_j > c(r) + 2t + \frac{2t}{f(1)}, \end{cases} \quad (1)$$

where  $\sigma = [p_j + 2t, \infty)$ . If firm  $j$ 's price is quite low, firm  $i$  would have to price below marginal cost to attract a customer, resulting in a loss. Thus, firm  $i$  avoids any demand by setting a high price, resulting in zero profits. On the other hand, if firm  $j$ 's price is very high, firm  $i$  sets a price to serve the entire demand.<sup>12</sup>

For the intermediary case, we find that the best response increase with the marginal cost  $c(r)$ .<sup>13</sup> This implies, that the targeted demand decreases with the marginal cost. If costs are high, it becomes less attractive for a firm to serve a large market share by itself. Thus, the higher the marginal cost, the smaller the set of consumers for which firms actually compete. I.e. in our setup, competition is less fierce the higher the marginal cost of production.

By  $F$ 's log-concavity,  $p_i^*(p_j)$  is uniquely determined for intermediary values of  $p_j$ . There exists a unique equilibrium with  $p_i = p_j = p_c := c(r) + t/f(0)$  resulting in firms' profits  $t/2f(0)$  if  $p_c \leq U - t$ .

To summarize, if costs are high, firms are local monopolists and choose  $p_m$ ; firms compete and set  $p_c$  if costs are low. However, for  $p_m \leq U - c(r) \leq p_c$ , multiple equilibria exist, described by the knife-edge case in the demand function, formally,  $F((U - p_i - t)/t) = F((p_j - p_i)/2t) \Leftrightarrow p_i + p_j = 2U - 2t$ . Note that only the symmetric equilibrium is continuous in the model's parameters; thus, let us focus on the symmetric equilibrium.<sup>14</sup>

With this, we have derived the competing equilibrium and summarize the profit function in the following lemma.

<sup>12</sup>Note that the best reply is continuous for  $p_j \geq -2t$ .

<sup>13</sup>Formally,  $dp_i^*(p_j)/dc(r) = f^2(\cdot)/(2f^2(\cdot) - F(\cdot)f'(\cdot)) \geq 0$ .

<sup>14</sup>For more on this see Bacchiega et al. (2023).

**Lemma 1.** *Competing firms make a profit of*

$$\pi_c := \begin{cases} \frac{t}{2f(0)}, & \text{if } p_c \leq U - t; \\ \frac{U-t-c(r)}{2}, & \text{if } p_m \leq U - t < p_c; \\ t \frac{F^2\left(\frac{U-p_m-t}{t}\right)}{f\left(\frac{U-p_m-t}{t}\right)}, & \text{if } U - t < p_m. \end{cases}$$

**Collusion.** Instead of competing, firms can collude and set prices to maximize their joint profits

$$\max_{p_i, p_j} (p_i - c(r))D_i(p_i, p_j) + (p_j - c(r))D_j(p_j, p_i).$$

Prices  $p_i = p_j = p_a := U - t$  are the highest prices at which the entire market is covered. If firms agree on prices  $p_a$ , their resulting profit is  $\pi_a := (U - t - c(r))/2$ .

If costs are high, colluding firms may want to exclude some customers from the market, resulting in the equivalent outcome as with two local monopolists. Formally, cartel prices are  $p_a$  if  $p_a \geq p_m \Leftrightarrow c(r) \leq U - t - t/2f(0)$  and  $p_m$  else. The following lemma summarizes the profit function of colluding firms.

**Lemma 2.** *Colluding firms make a profit of*

$$\pi_a := \begin{cases} \frac{U-t-c(r)}{2}, & \text{if } p_m \leq U - t; \\ t \frac{F^2\left(\frac{U-p_m-t}{t}\right)}{f\left(\frac{U-p_m-t}{t}\right)}, & \text{if } U - t < p_m. \end{cases}$$

Note that the profit function of a competing firm in Lemma 1 is equivalent to the profit function of a colluding firm in Lemma 2 if  $p_c \geq U - t \Leftrightarrow c(r) \geq U - t - t/f(0)$ . The necessity of an agreement, thus, only arises if production costs  $c(r)$  are low.

**Deviation.** If costs are below  $U - t - t/f(0)$ , collusion is not an equilibrium of the stage game. Firm  $i$  undercuts its competitor's price to increase its market share. The deviation price is determined by the best response in equation (1), formally  $p_d := p_i^*(p_j)$ , resulting in a profit of

$$\pi_d(p_j) := \begin{cases} 0, & \text{if } p_j < c(r) - 2t; \\ 2t \frac{F^2\left(\frac{p_j-p_d}{2t}\right)}{f\left(\frac{p_j-p_d}{2t}\right)}, & \text{if } c(r) - 2t \leq p_j \leq c(r) + 2t + 2t/f(1); \\ p_j - 2t - c(r), & \text{if } p_j > c(r) + 2t + 2t/f(1), \end{cases}$$

which is a continuous function.

There are no gains from deviation if the marginal cost is above  $U - t - t/f(0)$ : the competitive outcome is equivalent to the collusive outcome in the stage game. At the other extreme, if  $p_a - p_d \geq 2t$ , i.e., the marginal cost is below  $U - 3t - 2t/f(1)$ , the deviating firm can capture the entire market by undercutting the collusive price  $p_a = U - t$ .

Let us define  $\underline{r} := c^{-1}(U - 3t - 2t/f(1))$  and  $\bar{r} := c^{-1}(U - t - t/f(0))$ . Thus, for  $r \in [\underline{r}, \bar{r}]$ , no firm can serve the total demand by deviating because costs are too high, yet costs are not high enough for firms to stop competing.

Note that for  $r \in [\underline{r}, \bar{r}]$ , a deviating firm conquers a larger share of the market, the lower the marginal cost is. With low marginal costs, the defector reaches consumers located near its competitor. However, those consumers have a strong preference for the competitor and only buy at the defector's price cut is substantial enough. In other words, if there is a marginal cost reduction, the firm reaches more customers by deviating optimally, yet the additional customers have a lower willingness to pay.

Therefore, the marginal cost  $c(r)$  affects the defector's profit more strongly if  $c(r)$  is already high.

This concludes the analysis of the stage game.

### 3.2 The Supergame

Let us assume that the stage game is infinitely often repeated. In each period, firms set their price simultaneously. Following Abreu (1986) and Häckner (1996)'s optimal punishment strategy, firms collude playing prices  $p_a$ . If a firm deviates, firms set the price  $p_P$  as a punishment, resulting in a profit of  $\pi_P = (p_P - c(r))/2$ . If both firms have played  $p_P$ , collusion is restored. Otherwise, a firm continues playing  $p_P$ .

Two conditions have to be satisfied in a subgame perfect equilibrium.

First, a firm deviating from the collusive agreement makes an additional profit of  $\pi_d(U - t) - \pi_a$  in today's period. However, in the next period, the firm forgoes an additional profit of  $\pi_a - \pi_P$ , which it would have gotten if it did not deviate, i.e., a firm does not deviate if

$$\pi_d(U - t) - \pi_a \leq (\pi_a - \pi_P)/(1 + r). \quad (2)$$

Second, the punishment strategy has to be credible. Thus, given any firm has deviated, the firm should have no incentive to deviate from the punishment strategy. By deviating from the punishment path, a firm could get the additional profit of  $\pi_d(p_P) - \pi_P$ . However, collusion is not restored, and therefore, the firm forgoes an additional profit of  $\pi_a - \pi_P$  in the following period. Thus, firms have no incentive to deviate from

the strategy in the punishment phase if

$$\pi_d(p_P) - \pi_P \leq (\pi_a - \pi_P)/(1+r). \quad (3)$$

**Proposition 1.** *Let consumers be  $\mathbb{U}[-1, 1]$  with  $F(x) = (1+x)/2$ . The optimal punishment price is  $p_P^* = 5t + 2c(r) - U$ , resulting in a stable cartel if*

$$r \leq \begin{cases} \frac{U-t-c(r)}{U-5t-c(r)}; & \text{if } c(r) < U - 7t \\ \frac{19t+c(r)-U}{U-3t-c(r)}; & \text{if } c(r) \in [U - 7t, U - 3t]. \end{cases} \quad (4)$$

*Proof.* Using the uniform distribution, we can simplify  $\pi_c = t$  and equation (2)

$$\pi_d(p_j) = \begin{cases} 0, & \text{if } p_j < c(r) - 2t; \\ \frac{(p_j+2t-c(r))^2}{16t}, & \text{if } c(r) - 2t \leq p_j \leq 6t + c(r); \\ p_j - 2t - c(r), & \text{if } p_j > 6t + c(r), \end{cases}$$

which is a continuous and differentiable function.

To simplify notation let us define the discount factor as  $\delta = 1/(1+r)$  and let  $\delta_1(p_P)$  be the function, such that (2) holds with equality and note that  $\delta_1(p_P)$  increases with  $p_P$ . Similarly, let  $\delta_2(p_P)$  be the function, such that (3) holds with equality.

Next, note that  $\delta_1(p_P) \leq \delta_2(p_P)$  whenever  $\pi_d(p_P) - \pi_P \geq \pi_d(U-t) - \pi_a$ , because  $\pi_a \geq \pi_P$  for any valid punishment price. Direct calculations yield that  $\pi_d(p_P) - \pi_P$  is twice differentiable, convex, takes the values of zero at  $p_P = c + 2t$  and goes to infinity if  $p_P \rightarrow \pm\infty$ ;  $\pi_d(U-t) - \pi_a$  is constant.

Thus, there exist two solution for  $\pi_d(p_P) - \pi_P = \pi_d(U-t) - \pi_a$ ,  $p_P = U-t = p_a$  and  $p_P = 5t + 2c(r) - U$ . For  $p_P \leq 5t + 2c(r) - U$ ,  $\delta_1(p_P) \leq \delta_2(p_P)$ . Moreover,  $\delta_2(c+2t) = 0$  and decreases for  $p_P \leq c + 2t$ . Because  $5t + 2c(r) - U \leq c + 2t \Leftrightarrow U - c(r) \geq 3t$ , we get that  $p_P = 5t + 2c(r)$  is the punishment price leading to the lowest discount factor satisfying (2) and (3), which concludes the proof.  $\square$

Inequality (4) determines if a cartel is stable or not. Let us define

$$S(r) := \begin{cases} \frac{U-t-c(r)}{U-5t-c(r)} - r, & \text{if } c(r) < U - 7t; \\ \frac{19t+c(r)-U}{U-3t-c(r)} - r, & \text{if } c(r) \in [U - 7t, U - 3t], \end{cases}$$

thus, whenever  $S(r) \geq 0$ , a cartel is stable.  $S(r)$  measures the profitability of a cartel, the higher  $S$ , the more profitable the cartel.

The literature typically assumes that a firm's decision to collude is dichotomous: if a cartel is profitable, collude; otherwise, don't.<sup>15</sup> Accordingly, firms fully collude even if a cartel is only marginally profitable. We assume, by contrast, that the likelihood to collude increases continuously in the profitability of a cartel. The more money is to be made by colluding, the more tempted firms are to engage in the infringement.

Approximating the binary outcome of collusion or no collusion in a continuous way seems reasonable: for example, consider an economy existing of many two-firm industries as presented. Industries differ in their parameters, e.g., the willingness to pay  $U$  or the transportation costs  $t$ . In such a setup, our proposed measure considers the number of cartels in the entire economy.<sup>16</sup>

Similarly, if the antitrust authority does not have perfect knowledge of an industry's parameters,  $S$  reflects the antitrust authorities' belief that there is a cartel.

Alternatively, one can also argue that managers may have different beliefs about convictions by the antitrust authorities or different moral costs to violate cartel law. Thus, even if condition (4) holds, it may be unlikely that managers with high moral standards breach the law, yet the likelihood increases the more money can be made with a cartel.

Therefore, we take  $S$  as our stability measure for a cartel. The more profitable a cartel is, the more stable it is. With this, we establish our main result.

**Proposition 2.** *Let consumers be  $\mathbb{U}[-1, 1]$  with  $F(x) = (1+x)/2$  and the cost function satisfy  $c'(r) + 3c''(r) \geq 0$ . A cartel's stability, measured by  $S(r)$ , is U-shaped with the interest rate  $r$  in a competitive market, i.e., decreases for low  $r$  and increases for high  $r$  if  $t \leq 9c'(r)$ .*

*Proof.* First, note that  $S(r)$  is a continuous and differentiable function.  $S(\underline{r}) = 3 - r$  and

$$\frac{\partial S(r)}{\partial r} := \begin{cases} \frac{4t}{(U-5t-c(r))^2}c'(r) - 1, & \text{if } c(r) < U - 7t; \\ \frac{16t}{(U-3t-c(r))^2}c'(r) - 1, & \text{if } c(r) \in [U - 7t, U - 3t], \end{cases}$$

resulting in  $c'(\underline{r})/t - 1$  at  $r = \underline{r}$ .

For  $c(r) < U - 7t$ , we can derive  $\partial S(r)/\partial r \geq 0 \Leftrightarrow c(r) \in [U - 5t - 2\sqrt{tc'(r)}, U - 5t + 2\sqrt{tc'(r)}]$ . Similarly, for  $c(r) \in [U - 7t, U - 3t]$ , we get  $\partial S(r)/\partial r \geq 0 \Leftrightarrow c(r) \in$

<sup>15</sup>An exception is Emons (2020) analyzing a leniency program's efficiency when firms choose their degree of collusion.

<sup>16</sup>Formally, let for example  $t$  be distributed according to the cumulative distribution function  $G$ . Thus, the number of cartels in the economy is  $\int_{t \in T} \mathbb{1}(S(r; t) \geq 0) dG(t)$ , where  $\mathbb{1}(\cdot)$  is the indicator function.

$[U - 3t - 4\sqrt{tc'(r)}, U - 3t + 4\sqrt{tc'(r)}]$ . Thus,  $S$  increases with  $r$  in the two intervals. Next, note that the intervals overlap,  $U - 5t + 2\sqrt{tc'(r)} \geq U - 3t - 4\sqrt{tc'(r)} \Leftrightarrow t \leq 9c'(r)$ . Hence,  $S$  decreases with low  $r$ , i.e., for  $c(r) + 2\sqrt{tc'(r)} \leq U - 5t$  and increasing otherwise, resembling a U-shape. Note that the left hand side of the inequality is monotone increasing with  $r$  if  $c'(r)\sqrt{c'(r)} + \sqrt{tc''(r)} \geq 0$ . Using  $t \leq 9c'(r)$  results in the sufficient restriction of the cost function.  $\square$

Remind that by a U-shape we mean that the stability decreases for low  $r$  and increases for high  $r$ . Whether  $S$  is convex or not depends on the second derivative of the marginal cost function  $c''(r)$ . Nonetheless, there is a smooth transition from decreasing to increasing because  $S$  is continuous and differentiable.

To generate the U-shape with uniformly distributed consumers, we rely on two assumptions. The cost function is not too concave with  $r$ ,  $c'(r) + 3c''(r) \geq 0$ , and the market is sufficiently competitive,  $t \leq 9c'(r)$ . Alternatively, the interest rate has to affect the marginal cost of production sufficiently strong.

The U-shape results from two opposing effects. On the one hand, a higher interest rate leads to stronger discounting, decreasing future values. Additional future values from colluding are, thus, lower, making deviation relatively more attractive, resulting in lower cartel stability. On the other hand, a high interest rate increases marginal costs of production. With high production costs, it does not pay for firms to serve a large market share on their own. Thus, a firm deviating from a collusive agreement increases its market share only by a little, making deviation less profitable when costs are high.

In our setup, the effect of the time value of money dominates for low interest rates, while the effect on the production cost dominates for high interest rates: When interest rates are low, production costs are low, and a firm may profitably capture a large share of the market by undercutting the cartel price. Thus, a firm reaches consumers close to its competitor, i.e., consumers with a low value for the defector's product. These consumers are less valuable to the firm than consumers with a higher valuation of its product. With an increase in the interest rate or a cost increase, the firm thus loses its least valued customers. The production cost effect is, therefore, less pronounced for low interest rates, yet amplifies for higher levels of the interest rate.

## 4 Empirical Evidence

This section empirically tests if the interest rate indeed affects cartel stability in a non-monotonic way, as predicted in the last section. A cartel's stability can be measured in different ways; we quantify the interest rate's effect on a firm's participation duration in a cartel using survival analysis. Next, we present the data.

## 4.1 Data

We use the dataset constructed by Hellwig and Hüschelrath (2018). It contains 615 firms participating in 114 cartels convicted by the European Commission between 1999 and 2016. The earliest cartel started its infringement in the second quarter of 1969, and the latest cartel in the dataset ended in 2012's second quarter. This gives us an unbalanced panel with 16'431 firm-quarter observations.

The dataset contains information about the infringement, firms' industries, and the cartels' spatial scope. Some cartel members entered after its start or left before the cartel ended. Hellwig and Hüschelrath (2018) analyzed the effect on cartel stability of late entries and early exits. Furthermore, the dataset contains information on the reason why an investigation started. Using this information, Hellwig and Hüschelrath (2018) classified a cartel's natural break-up if the European Commission started its investigation after the cartel ended or in the case of a leniency applicant if the cartel ended at least a year earlier.

During the relevant period, the European Commission introduced three leniency programs to uncover illegal cartels. The first version was released in the third quarter of 1996 and was inspired by the 1993 US Department of Justice's Corporate Leniency Policy. It was amplified in 2002's first quarter, whereby the main improvement was that reductions in fines became stricter aligned to the cooperation, and first applicants received automatic immunity, resulting in less uncertainty in the law's interpretation. This was also the goal of the revision in 2006's fourth quarter, where a leniency applicant's duty was clarified. For each revision, we construct a dummy variable equal to zero before its introduction and one afterward.

We use the long-term interest rate in the Euro area from OECD.<sup>17</sup> The time series refers to government bonds maturing in ten years. The interest rate is implied by the bond's trade price on the financial market, not the interest rate at which loans were issued. It starts in the first quarter of 1970, and to the best of our knowledge, it is the longest available time series for the Euro area. Firms borrowing may pay an individual risk premium; unfortunately, we do not observe this for the firms in our dataset.<sup>18</sup>

Firms' decisions are based on the real interest rate and not on the nominal rates. We use the Euro area's inflation rate from the World Bank,<sup>19</sup> which starts in 1970 and is yearly available. Under the assumption that market participants expected the actual inflation rate, we can calculate the real interest rate by subtracting the inflation rate

<sup>17</sup>The time series is indexed as IRLTLT01EZM156N and is also available at FRED.

<sup>18</sup>Alternatively, we use the Bank of England Official Bank Rate starting in 1975 to measure the interest rate; results are similar.

<sup>19</sup><https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=XE>

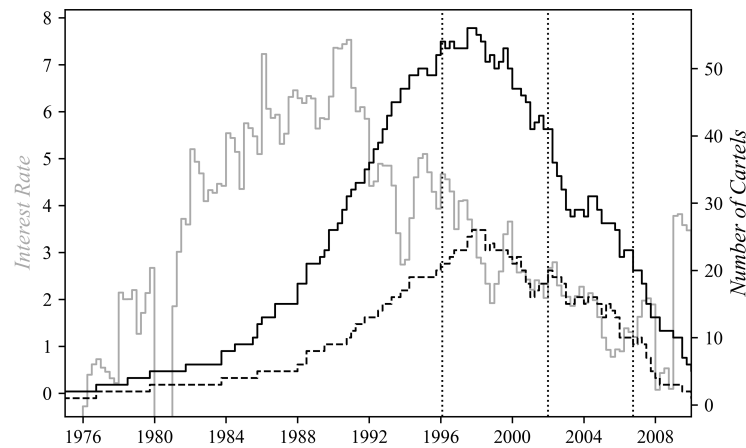


Figure 1: Real interest rate and number of active cartels. The solid black line refers to the total number of firms, and the dashed line refers to the ones only active in cartels with a natural break-up. The vertical lines indicate leniency programs.

from the nominal interest rate.<sup>20</sup> Alternatively, we have used nominal values instead of real ones and got similar results, yet less significant.

Figure 1 shows the real interest rate and the number of active cartels. The vertical lines indicate the leniency program's introduction and revisions. The figure suggests that the leniency program and its revisions successfully decreased the number of cartels. Marvão and Spagnolo (2014) present a detailed analysis of the leniency program's effectiveness. We could only speculate on the increasing cartel activity until 1995. However, we tested our results additionally on a subset starting in 1995's first quarter, and results were similar, although less significant.

Real GDP per capita in the Euro Area measured by the World Bank is, unfortunately, only yearly available.<sup>21</sup> We use it to control for changes in demand resulting from a change in income.<sup>22</sup> Additionally, to control for Europe's general economic situation, we use the economic sentiment indicator available at Eurostat. The indicator is a weighted average of replies' balances to selected questions addressed to firms in different industries in the Eurozone.<sup>23</sup> It starts in the first quarter of 1985 and is measured monthly; we use a quarter's average.

<sup>20</sup>Levenstein and Suslow (2016) use last year's inflation, which reflects a naive forecast. Following this approach, our results become less significant.

<sup>21</sup>We use constant 2010 thousand USD.

<sup>22</sup>Alternatively, we use the Production and Sales (MEI) from OECD statistics, which is quarterly available. The results are similar.

<sup>23</sup>The time series is seasonally adjusted and scaled to a long-term mean of 100.



## 4.2 Empirical Results

We focus on a firm's participation duration in a cartel. Similar to Hellwig and Hüschelrath (2018), we focus on a firm's natural leave. We are interested in how long it takes a firm to leave a cartel after it has entered. The firm's exit, respectively, the event, is a random variable  $T$ . The probability that the event has not happened before period  $t$  is  $P(T \geq t) = \mathcal{S}(t)$ , where  $\mathcal{S}$  is the survival function.

More precisely, we assume a Weibull model,<sup>24</sup>

$$\mathcal{S}(t|x_{i,t}) = \exp(-\exp(\beta^\top x_{i,t})t^\kappa),$$

implying a hazard function

$$\frac{d\mathcal{S}(t|x_{i,t})/dt}{\mathcal{S}(t|x_{i,t})} = h(t|x_{i,t}) = \kappa \exp(\beta^\top x_{i,t})t^{\kappa-1}.$$

The hazard function can be interpreted as the probability that the event happens at  $t$  if it has not happened before.  $\kappa$  is the distribution's shape parameter. If  $\kappa > 1$ , the baseline hazard  $h(t|0) = \kappa t^{\kappa-1}$  increases monotonically over time; it becomes more likely that the event happens over time.

Depending on the covariates, the hazard function increases or decreases. If  $\beta^\top x_{i,t} > 0$ , the hazard function is larger than the baseline hazard, and thus, it is more likely for the firm  $i$  to experience the event, i.e., to leave the cartel.

We control for the cartel's infringement, i.e.,  $x_i$  contains the information if a cartel fixed prices, market shares, or both. Furthermore, we control in which industry the cartel was active and whether it was active in the entire EU, only in some countries, or worldwide. We also include the number of cartel members, which may change over time. Additionally, we include controls for the exit or entry of other cartel members within six months. Finally, we control for the leniency program's introduction and its revisions.

The event we are studying is a firm's natural leave. Some firms in our dataset may be forced to leave a cartel due to an investigation resulting in a cartel break-up. Those firms did not experience the event, yet the cartel ended. The data is, thus, right censored. Let  $\zeta_i = 0$  if the observation is censored and 1 otherwise. An uncensored observation's contribution to the likelihood is the information that the event did not happen until  $t$  and the event happening at  $t$ , formally  $\mathcal{S}(t|x_{i,t})h(t|x_{i,t})$ . If the data is censored, its contribution is the information that the event has not happened until  $t$ ,

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<sup>24</sup>In the appendix, we consider alternative specifications of the survival function, yielding robust findings.

|                            | (1)                | (2)                | (3)                | (4)                |
|----------------------------|--------------------|--------------------|--------------------|--------------------|
| Interest Rate              | 0.63**<br>(0.19)   | 0.76***<br>(0.21)  | 0.70**<br>(0.23)   | 0.78***<br>(0.23)  |
| Interest Rate <sup>2</sup> | -0.15***<br>(0.03) | -0.14***<br>(0.03) | -0.16***<br>(0.03) | -0.15***<br>(0.03) |
| GDP p.c.                   |                    | 0.26***<br>(0.06)  |                    | 0.19**<br>(0.07)   |
| Economic Indicator         |                    |                    | 0.03**<br>(0.01)   | 0.02*<br>(0.01)    |
| Observations               | 16'264             | 16'264             | 15'631             | 15'631             |

Table 1: Duration Models. Robust standard errors in parentheses and significance levels indicated by \* for  $p < 0.05$ , \*\* for  $p < 0.01$ , and \*\*\* for  $p < 0.001$ . All models include a constant and controls for infringement, industries, spacial scope, members, members' entry and exit, and leniency programs. All coefficients are reported in Table 2.

formally  $\mathcal{S}(t|x_{i,t})$ . The likelihood function is accordingly

$$\mathcal{L} = \prod h(t|x_{i,t})^{\zeta_i} \mathcal{S}(t|x_{i,t}).$$

We estimate parameters  $\beta$  and  $\kappa$ , maximizing the likelihood function. All coefficients are reported in the appendix in Table 2, of which we present a subset in Table 1.

We use a second-order polynomial to model the interest rate's non-monotonic effect. This is flexible enough to allow for the structures imposed by Proposition 2, precisely, the U-shape between stability and the interest rate. Moreover, we control for demand as well as for production factors.

The results are significant, and signs are as predicted by our theory. The interest rate affects stability non-monotonically; precisely, stability is U-shaped with the interest rate. We follow Lind and Mehlum (2010) and use the appropriate test for the duration's hump-shape. Precisely, we test if the slope at the lower bound of the sample is positive while the slope at the upper bound of the sample is negative. We can reject the alternative at the 99% significance level.

The rest of our estimates are qualitatively similar to Hellwig and Hüschelrath (2018). More interestingly, Hellwig and Hüschelrath (2018) and Levenstein and Suslow (2016) use different datasets and include a linear term for the interest rate in their studies. They find opposing results: in Hellwig and Hüschelrath (2018), stability increases with the interest rate, while in Levenstein and Suslow (2016), it goes down.

According to Proposition 2, both effects may arise. On the one hand, low interest rates increase the time value of money, resulting in more patient players stabilizing cartels. On the other hand, low interest rate lowers production costs, thereby increasing a firm's profit when it deviates from the collusive agreement, destabilizing cartels.

The second effect directly affects a firm’s balance sheet by increasing outside capital. Levenstein and Suslow (2016) control for firms’ outside capital.<sup>25</sup> Consequently, the second effect is silenced; their estimates are, thus, in line with our theory.

According to our estimates, cartel stabilization is the lowest when interest rates are around 3%. Estimates are, however, very noisy. Confidence intervals range from around 2% up to over 7%. Current real interest rates are, nonetheless, below our estimate. Accordingly, cartels become less stable if the real interest rates increase. The estimates should, however, be taken with caution.

Some remarks are in order. The dataset only contains convicted cartels; thus, there is an obvious selection bias that we are not able to address. Furthermore, a firm’s duration in a cartel may be underestimated because of a lack of evidence. We relied on aggregate data, whereas we neglected firm-specific risk premia. We, therefore, abstain from interpreting any estimated coefficient’s size, which is generally challenging in the used models. Nonetheless, our results are in line with the literature and support our theory.<sup>26</sup>

## 5 Conclusion

We have shown that the interest rate affects a cartel’s stability non-monotonically. More precisely, stability is U-shaped with the interest rate in competitive markets.

Two opposing effects are at work. On the one hand, the time value of money implied by the interest rate makes future profits from colluding more valuable when interest rates are low, increasing cartel stability. On the other hand, a low interest rate decreases a firm’s production cost. Thus, firms can capture a larger market share by deviating, resulting in more profitable deviations from the collusive agreement. Cartel stability is, therefore, weakened when the interest rate is low. The first effect dominates for relatively low interest rates; otherwise, the second effect dominates.

Our results are driven by the fact that in our setup, higher marginal costs result in less fierce competition. Firms compete for a smaller set of consumers when the marginal production cost is high, resulting in higher market power. This may not be the case in different setups, for example with a representative agent, respectively, homogeneous consumers. When consumers’ preferences are not heterogeneous, respectively, not horizontally differentiated, firms may not gain any market power when costs increase.

We used a dataset collected by Hellwig and Hüschelrath (2018) containing 615 firms participating in 114 cartels convicted by the European Commission between 1999 and

<sup>25</sup>They rely on industry averages due to the lack of firm-specific data.

<sup>26</sup>For a detailed discussion of the sample bias and related problems for empirical work on cartels, see Harrington (2006).

2016 to test our theoretical prediction. Using a Weibull model, we estimate the interest rate's effect on a firm's participation duration in a cartel.

Interestingly, Hellwig and Hüschelrath (2018) and Levenstein and Suslow (2016) find opposing linear effects of the interest rate on cartel stability. According to our theory, both findings are possible. By incorporating the interest rate's non-monotonic effect, we find supporting evidence for our predicted U-shape in the former datasets. Future empirical work should consider using a quadratic effect of the interest rate or controlling for the interest rate's effect on the production cost.

We conclude that the interest rate affects cartel stability non-monotonically. Last decade's unusually low interest rates have favored collusion by increasing cartel stability and the likelihood of cartel formation, thus leading to market inefficiencies.

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## A Appendix

### A.1 Alternative Supergame

Alternatively to an optimal punishment strategy, we study collusion using a grim trigger strategy. First, note that equation (2) simplifies to

$$\pi_d(U - t) = \begin{cases} U - 3t - c(r), & \text{if } c(r) < U - 3t - 2t/f(1); \\ 2t \frac{F^2\left(\frac{U-t-p_d}{2t}\right)}{f\left(\frac{U-t-p_d}{2t}\right)}, & \text{if } c(r) \geq U - 3t - 2t/f(1). \end{cases}$$

Next, note that  $\pi_d$  is continuous and differentiable with  $c(r)$ .<sup>27</sup> With this, we have the following functional form of the different profit functions.

**Lemma 3.** *If consumers are symmetrically log-concave distributed and  $r \leq \bar{r}$ ,*

- (i)  $\pi_c$  is constant with  $c(r)$ ;
- (ii)  $\pi_a$  decreasing with  $c(r)$  at a constant rate, i.e., is linear;
- (iii)  $\pi_d$  decreases with  $c(r)$  at an increasing rate, i.e., is convex;
- (iv)  $\pi_c = \pi_a = \pi_d$  at  $r = \bar{r}$ .

<sup>27</sup>Continuity follows from the continuity of  $p_d$ . Differentiability follows from  $dp_d/dc(r) = f^2(\cdot)/(2f^2(\cdot) - F(\cdot)f'(\cdot))$  and  $d\pi_d/dc(r) = [F(\cdot)(F(\cdot)f'(\cdot) - 2f^2(\cdot))/f^2(\cdot)][dp_d/dc(r)]$ , simplifying to  $-F(\cdot)$  for  $r \in [\underline{r}, \bar{r}]$ .

*Proof.* (i), (ii), and (iv) follow immediately. For (iii), first consider  $c(r) \geq U - 3t - 2t/f(1)$ , and start with  $dp_d/dc(r) = f^2(\cdot)/(2f^2(\cdot) - F(\cdot)f'(\cdot)) \geq 0$ . Using this, we get  $d\pi_d/dc(r) = -F((U - t - p_d)/2t) \in [-1, -1/2]$ . Finally,  $d^2\pi_d/dc(r)^2 = (dp_d/dc(r))f((U - t - p_d)/2t)/2t \geq 0$ . Because  $\pi_d$  is continuous, differentiable and decreases linearly for  $c(r) < U - 3t - 2t/f(1)$ , (iii) follows.  $\square$

By definition, profits are ordered by  $\pi_d \geq \pi_a \geq \pi_c$ , and by Lemma 3, the difference between the profits decreases with  $r$ .

Competitive firms price close to marginal cost and thus pass-on any change in their marginal cost to consumers. Therefore, profits are not affected. Colluding firms price at the consumers willingness to pay, and do not pass-on changes in their marginal cost to consumers. Therefore, their profits are stronger affected than competitive firms' profits. The defector ends up with a higher demand, making its profit even stronger affected by a marginal cost change.

According to the grim trigger strategy, firms set collusive prices  $p_a$  as long as both set this price in the last period. If one of the two deviates, firms play the competitive price forever. Formally, the cartel is stable if

$$\sum_{\tau=0}^{\infty} \pi_a/(1+r)^\tau \geq \pi_d + \sum_{\tau=1}^{\infty} \pi_c/(1+r)^\tau,$$

which simplifies to

$$r \leq \frac{\pi_a - \pi_c}{\pi_d - \pi_a}.$$

Similar to the main text, let  $\tilde{S}(r) = (\pi_a - \pi_c)/(\pi_d - \pi_a) - r$ , thus, whenever,  $\tilde{S}(r) \geq 0$ , a cartel is stable.

Let us first focus on  $c(r) < U - 3t - 2t/f(1)$ , thus, we can simplify  $\tilde{S}(r) = (U - t - t/f(0) - c(r))/(U - 5t - c(r)) - r$  and get  $\partial\tilde{S}/\partial r = c'(r)t(4 - 1/f(0))/(U - 5t - c(r))^2 - 1$ . Similar to the main text, we find that  $\tilde{S}$  increases with  $r$  for  $c(r) \in [U - 5t - \sqrt{(4t - t/f(0))c'(r)}, U - 5t + \sqrt{(4t - t/f(0))c'(r)}]$ . Note that the upper bound of the interval  $U - 5t + \sqrt{(4t - t/f(0))c'(r)} \geq U - 3t - 2t/f(1) \Leftrightarrow t \leq c'(r)(4 - 1/f(0))/(4 - 4/f(1))^2$ , thus, in a competitive market the interest rate decreases for low interest rates, i.e.,  $c(r) \leq U - 5t + \sqrt{(4t - t/f(0))c'(r)}$  and increases otherwise.

Note that  $\tilde{S} \rightarrow \infty$  for  $r \rightarrow \bar{r}$ ; thus, for high interest rates, stability increases. Moreover, note that  $\underline{r} \rightarrow \bar{r}$  if the market becomes perfectly competitive, i.e.,  $t \rightarrow 0$ . Since  $\tilde{S}$  increases at  $\bar{r}^{28}$  and below  $\underline{r}$  in a competitive market and everything is smooth,

<sup>28</sup>This follows from  $S'$  differentiability, which is implied because all profit functions are differentiable.

we conjecture that  $\tilde{S}$  also increases with  $r$  for  $r \in [\underline{r}, \bar{r})$ , resulting in an overall U-shape of  $\tilde{S}$  with the interest rate in competitive markets.

## A.2 Empirical Results

Our results are generally in line with Hellwig and Hüschelrath (2018), although we use real instead of nominal terms to control for macroeconomic factors. Moreover, we control for each leniency program's revision. The main insight of Hellwig and Hüschelrath (2018) is robust to these changes: firms' entry and exit create a dynamic within the cartel. For a detailed discussion, we refer the reader to their paper.

Table 2 presents the estimates from the main text's Weibull model. Estimates are similar to Hellwig and Hüschelrath (2018). Moreover, the estimates yield significant support for our theory. In Table 3, we restrict the data to a subsample after 1995. Results are similar yet less significant. In Table 4, we present estimates with an alternative measure for GDP. Following Hellwig and Hüschelrath (2018), we use the Production and Sales (MEI) data for the Euro Area from OECD, which is quarterly available. Estimates are again similar to the main results.

Alternatively to the Weibull model, we estimate an exponential duration model in Table 5. This basically assumes  $\kappa = 0$ , i.e., the survival function and hazard rate are

$$\begin{aligned}\mathcal{S}(t|x_{i,t}) &= \exp(-\exp(\beta^\top x_{i,t})t) \\ h(t|x_{i,t}) &= \exp(\beta^\top x_{i,t}).\end{aligned}$$

This has the advantage of estimating one less parameter. However, the model loses some flexibility: the baseline hazard is constant over time.

Table 6 presents the results of a Cox regression model. Similar to the duration models above, this assumes a proportional hazard rate

$$h(t|x_{i,t}) = h_0(t) \exp(\beta^\top x_{i,t}).$$

However, the Cox model uses a different approach to estimate the coefficient vector  $\beta$ . Let  $\mathcal{C}_t$  be the set of active cartels. Thus, firms in  $\mathcal{C}_t$  are at risk of leaving the cartel. The Cox model relates the firms leaving at time  $t$  to all the firms at risk. Accordingly, the maximum likelihood function is

$$\mathcal{L} = \prod \left( \frac{\exp(\beta^\top x_{i,t})}{\sum_{j \in \mathcal{C}_t} \exp(\beta^\top x_{j,t})} \right)^{\zeta_i}.$$



By contrast to the other proportional hazard models, the baseline hazard is not estimated. The results are similar to the above.

The proportional hazard models discussed assume that the covariates act multiplicatively on the hazard rate. Alternatively, the covariates may act multiplicatively on duration. We present some models with accelerated failure time. Above, in a proportional hazard model,  $\beta^\top x_{i,t} > 0$  increased the probability that a firm leaves a cartel given that it has not left it before. Alternatively, in the accelerated failure-time models,  $\beta^\top x_{i,t} > 0$  increases a firm's duration of staying in a cartel. Thus, the estimates' signs should be the opposite as before to be in line with our theory.

We assume a generalized gamma distribution. The survival function is

$$\mathcal{S}(t|x_{i,t}) = \begin{cases} 1 - I(\gamma, u) & \text{if } \kappa > 0; \\ 1 - \Phi(z) & \text{if } \kappa = 0; \\ I(\gamma, u) & \text{if } \kappa < 0 \end{cases}$$

where  $\sigma$  is an ancillary parameter estimated additionally to  $\beta$ ,  $I(\cdot)$  is the incomplete gamma function and with  $\gamma = \kappa^{-2}$ ,  $u = \gamma \exp(|\kappa|z)$  and

$$z = \text{sign}(\kappa) \frac{\log(t) - \beta^\top x_{i,t}}{\sigma}.$$

This model nests the lognormal model if  $\kappa = 0$ . Moreover, it nests the Weibull distribution for accelerated failure-time if  $\kappa = 1$ . Accordingly, it also nests the exponential distribution for accelerated failure-time if  $\kappa = 1$  and  $\sigma = 1$ .

Table 7 presents the results. The estimates are significant and in line with our theory. Moreover, we can reject  $\kappa = 1$  on the 0.01 significance level. Therefore, we can reject the Weibull and exponential distribution for accelerated failure-time.

All estimates are in line with our theory. We, therefore, abstain from testing which model fits the data best since all models yield significant results in line with our theoretical prediction: Cartel stability is U-shaped with the interest rate.

Table 2: Duration Models

|                                       | (1)                | (2)                 | (3)                | (4)                 |
|---------------------------------------|--------------------|---------------------|--------------------|---------------------|
| <i>Infringement (base: Multiple)</i>  |                    |                     |                    |                     |
| Price Fixing                          | 0.78***<br>(0.15)  | 0.74***<br>(0.16)   | 0.75***<br>(0.16)  | 0.72***<br>(0.16)   |
| Market Sharing                        | -0.10<br>(0.26)    | -0.05<br>(0.27)     | -0.06<br>(0.27)    | -0.05<br>(0.27)     |
| <i>Industry (base: Manufacturing)</i> |                    |                     |                    |                     |
| Agriculture, Forestry, And Fishing    | 1.22***<br>(0.32)  | 1.19***<br>(0.30)   | 1.25***<br>(0.32)  | 1.23***<br>(0.31)   |
| Wholesale and Retail Trade            | -0.55<br>(0.47)    | -0.62<br>(0.47)     | -0.59<br>(0.46)    | -0.63<br>(0.46)     |
| Transportation and Storage            | 0.30<br>(0.21)     | 0.32<br>(0.21)      | 0.32<br>(0.21)     | 0.33<br>(0.21)      |
| Financial and Insurance Activities    | 0.42<br>(0.47)     | 0.41<br>(0.48)      | 0.46<br>(0.48)     | 0.45<br>(0.48)      |
| Others                                | -1.35<br>(0.71)    | -1.39<br>(0.71)     | -1.36<br>(0.71)    | -1.38<br>(0.71)     |
| <i>Spacial Scope (base: EU-wide)</i>  |                    |                     |                    |                     |
| Worldwide                             | 0.60***<br>(0.18)  | 0.58**<br>(0.18)    | 0.55**<br>(0.18)   | 0.56**<br>(0.18)    |
| Some Countries                        | -0.39**<br>(0.15)  | -0.38*<br>(0.15)    | -0.40**<br>(0.15)  | -0.39**<br>(0.15)   |
| Members                               | -0.13***<br>(0.02) | -0.14***<br>(0.02)  | -0.14***<br>(0.02) | -0.14***<br>(0.02)  |
| Entry                                 | -0.56*<br>(0.25)   | -0.56*<br>(0.25)    | -0.53*<br>(0.25)   | -0.53*<br>(0.25)    |
| Exit                                  | 0.85***<br>(0.15)  | 0.77***<br>(0.15)   | 0.78***<br>(0.15)  | 0.74***<br>(0.15)   |
| Leniency Program 96                   | 0.82***<br>(0.23)  | 0.00<br>(0.34)      | 0.22<br>(0.31)     | -0.12<br>(0.36)     |
| Leniency Program 02                   | 0.38**<br>(0.15)   | -0.08<br>(0.18)     | 0.65***<br>(0.18)  | 0.25<br>(0.22)      |
| Leniency Program 06                   | 0.20<br>(0.17)     | -0.28<br>(0.20)     | 0.07<br>(0.18)     | -0.23<br>(0.20)     |
| Interest Rate                         | 0.63**<br>(0.19)   | 0.76***<br>(0.21)   | 0.70**<br>(0.23)   | 0.78***<br>(0.23)   |
| Interest Rate <sup>2</sup>            | -0.15***<br>(0.03) | -0.14***<br>(0.03)  | -0.16***<br>(0.03) | -0.15***<br>(0.03)  |
| GDP p.c.                              |                    | 0.26***<br>(0.06)   |                    | 0.19**<br>(0.07)    |
| Economic Indicator                    |                    |                     | 0.03**<br>(0.01)   | 0.02*<br>(0.01)     |
| Constant                              | -5.74***<br>(0.42) | -14.13***<br>(2.04) | -8.02***<br>(0.91) | -13.59***<br>(2.35) |
| ln( $\kappa$ )                        | 0.24***<br>(0.05)  | 0.24***<br>(0.05)   | 0.25***<br>(0.05)  | 0.25***<br>(0.05)   |
| Observations                          | 16'264             | 16'264              | 15'631             | 15'631              |

Robust standard errors in parentheses

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Table 3: Duration Models Subsample

|                                       | (1)                | (2)                | (3)                | (4)                |
|---------------------------------------|--------------------|--------------------|--------------------|--------------------|
| <i>Infringement (base: Multiple)</i>  |                    |                    |                    |                    |
| Price Fixing                          | 0.76***<br>(0.15)  | 0.74***<br>(0.15)  | 0.74***<br>(0.15)  | 0.74***<br>(0.15)  |
| Market Sharing                        | -0.06<br>(0.27)    | -0.05<br>(0.27)    | -0.05<br>(0.27)    | -0.05<br>(0.27)    |
| <i>Industry (base: Manufacturing)</i> |                    |                    |                    |                    |
| Agriculture, Forestry, And Fishing    | 1.14***<br>(0.32)  | 1.14***<br>(0.31)  | 1.19***<br>(0.32)  | 1.19***<br>(0.31)  |
| Wholesale and Retail Trade            | -0.61<br>(0.47)    | -0.63<br>(0.47)    | -0.62<br>(0.46)    | -0.64<br>(0.46)    |
| Transportation and Storage            | 0.30<br>(0.21)     | 0.31<br>(0.21)     | 0.32<br>(0.21)     | 0.32<br>(0.21)     |
| Financial and Insurance Activities    | 0.32<br>(0.48)     | 0.32<br>(0.48)     | 0.36<br>(0.48)     | 0.36<br>(0.48)     |
| Others                                | -1.39*<br>(0.70)   | -1.40*<br>(0.70)   | -1.39*<br>(0.70)   | -1.40*<br>(0.70)   |
| <i>Spacial Scope (base: EU-wide)</i>  |                    |                    |                    |                    |
| Worldwide                             | 0.59**<br>(0.18)   | 0.59**<br>(0.18)   | 0.57**<br>(0.18)   | 0.57**<br>(0.18)   |
| Some Countries                        | -0.38**<br>(0.15)  | -0.38*<br>(0.15)   | -0.38**<br>(0.15)  | -0.38**<br>(0.15)  |
| Members                               | -0.14***<br>(0.02) | -0.14***<br>(0.02) | -0.14***<br>(0.02) | -0.14***<br>(0.02) |
| Entry                                 | -0.50*<br>(0.25)   | -0.50*<br>(0.25)   | -0.48<br>(0.25)    | -0.48<br>(0.25)    |
| Exit                                  | 0.80***<br>(0.15)  | 0.77***<br>(0.15)  | 0.76***<br>(0.15)  | 0.74***<br>(0.15)  |
| Leniency Program 96                   | -0.62<br>(0.33)    | -0.70*<br>(0.34)   | -0.65<br>(0.35)    | -0.71*<br>(0.35)   |
| Leniency Program 02                   | 0.30<br>(0.15)     | 0.13<br>(0.20)     | 0.53**<br>(0.19)   | 0.38<br>(0.24)     |
| Leniency Program 06                   | 0.20<br>(0.17)     | 0.01<br>(0.22)     | 0.11<br>(0.18)     | -0.02<br>(0.22)    |
| Interest Rate                         | 0.61*<br>(0.27)    | 0.62*<br>(0.27)    | 0.55<br>(0.28)     | 0.57*<br>(0.28)    |
| Interest Rate <sup>2</sup>            | -0.16**<br>(0.05)  | -0.14*<br>(0.06)   | -0.14*<br>(0.06)   | -0.13*<br>(0.06)   |
| GDP p.c.                              |                    | 0.10<br>(0.08)     |                    | 0.08<br>(0.08)     |
| Economic Indicator                    |                    |                    | 0.02*<br>(0.01)    | 0.02<br>(0.01)     |
| Constant                              | -4.03***<br>(0.51) | -7.63**<br>(2.80)  | -6.00***<br>(1.07) | -8.40**<br>(2.85)  |
| ln( $\kappa$ )                        | 0.23***<br>(0.05)  | 0.23***<br>(0.05)  | 0.24***<br>(0.05)  | 0.24***<br>(0.05)  |
| Observations                          | 10'975             | 10'975             | 10'975             | 10'975             |

Robust standard errors in parentheses

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Table 4: Duration Models Alternative GDP

|                                       | (1)                | (2)                 | (3)                | (4)                 |
|---------------------------------------|--------------------|---------------------|--------------------|---------------------|
| <i>Infringement (base: Multiple)</i>  |                    |                     |                    |                     |
| Price Fixing                          | 0.78***<br>(0.15)  | 0.73***<br>(0.16)   | 0.75***<br>(0.16)  | 0.73***<br>(0.16)   |
| Market Sharing                        | -0.10<br>(0.26)    | -0.07<br>(0.27)     | -0.06<br>(0.27)    | -0.06<br>(0.27)     |
| <i>Industry (base: Manufacturing)</i> |                    |                     |                    |                     |
| Agriculture, Forestry, And Fishing    | 1.22***<br>(0.32)  | 1.30***<br>(0.29)   | 1.25***<br>(0.32)  | 1.29***<br>(0.30)   |
| Wholesale and Retail Trade            | -0.55<br>(0.47)    | -0.66<br>(0.47)     | -0.59<br>(0.46)    | -0.64<br>(0.47)     |
| Transportation and Storage            | 0.30<br>(0.21)     | 0.33<br>(0.21)      | 0.32<br>(0.21)     | 0.33<br>(0.21)      |
| Financial and Insurance Activities    | 0.42<br>(0.47)     | 0.44<br>(0.48)      | 0.46<br>(0.48)     | 0.45<br>(0.48)      |
| Others                                | -1.35<br>(0.71)    | -1.36<br>(0.71)     | -1.36<br>(0.71)    | -1.36<br>(0.71)     |
| <i>Spacial Scope (base: EU-wide)</i>  |                    |                     |                    |                     |
| Worldwide                             | 0.60***<br>(0.18)  | 0.55**<br>(0.18)    | 0.55**<br>(0.18)   | 0.55**<br>(0.18)    |
| Some Countries                        | -0.39**<br>(0.15)  | -0.41**<br>(0.15)   | -0.40**<br>(0.15)  | -0.41**<br>(0.15)   |
| Members                               | -0.13***<br>(0.02) | -0.14***<br>(0.02)  | -0.14***<br>(0.02) | -0.14***<br>(0.02)  |
| Entry                                 | -0.56*<br>(0.25)   | -0.54*<br>(0.25)    | -0.53*<br>(0.25)   | -0.53*<br>(0.25)    |
| Exit                                  | 0.85***<br>(0.15)  | 0.77***<br>(0.15)   | 0.78***<br>(0.15)  | 0.76***<br>(0.15)   |
| Leniency Program 96                   | 0.82***<br>(0.23)  | 0.16<br>(0.33)      | 0.22<br>(0.31)     | 0.08<br>(0.34)      |
| Leniency Program 02                   | 0.38**<br>(0.15)   | 0.09<br>(0.17)      | 0.65***<br>(0.18)  | 0.36<br>(0.23)      |
| Leniency Program 06                   | 0.20<br>(0.17)     | -0.24<br>(0.21)     | 0.07<br>(0.18)     | -0.13<br>(0.21)     |
| Interest Rate                         | 0.63**<br>(0.19)   | 0.88***<br>(0.23)   | 0.70**<br>(0.23)   | 0.82***<br>(0.24)   |
| Interest Rate <sup>2</sup>            | -0.15***<br>(0.03) | -0.16***<br>(0.03)  | -0.16***<br>(0.03) | -0.16***<br>(0.03)  |
| GDP                                   |                    | 0.07***<br>(0.02)   |                    | 0.04<br>(0.02)      |
| Economic Indicator                    |                    |                     | 0.03**<br>(0.01)   | 0.01<br>(0.01)      |
| Constant                              | -5.74***<br>(0.42) | -11.78***<br>(1.60) | -8.02***<br>(0.91) | -10.59***<br>(1.79) |
| ln( $\kappa$ )                        | 0.24***<br>(0.05)  | 0.25***<br>(0.05)   | 0.25***<br>(0.05)  | 0.25***<br>(0.05)   |
| Observations                          | 16'264             | 16'166              | 15'631             | 15'631              |

Robust standard errors in parentheses  
\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Table 5: Duration Models with Exponential Distribution

|                                       | (1)                | (2)                 | (3)                | (4)                 |
|---------------------------------------|--------------------|---------------------|--------------------|---------------------|
| <i>Infringement (base: Multiple)</i>  |                    |                     |                    |                     |
| Price Fixing                          | 0.61***<br>(0.14)  | 0.56***<br>(0.15)   | 0.57***<br>(0.14)  | 0.54***<br>(0.15)   |
| Market Sharing                        | -0.12<br>(0.25)    | -0.08<br>(0.27)     | -0.08<br>(0.27)    | -0.07<br>(0.27)     |
| <i>Industry (base: Manufacturing)</i> |                    |                     |                    |                     |
| Agriculture, Forestry, And Fishing    | 0.75*<br>(0.31)    | 0.72*<br>(0.28)     | 0.75*<br>(0.30)    | 0.74*<br>(0.29)     |
| Wholesale and Retail Trade            | -0.65<br>(0.46)    | -0.72<br>(0.46)     | -0.68<br>(0.45)    | -0.72<br>(0.45)     |
| Transportation and Storage            | 0.14<br>(0.20)     | 0.16<br>(0.20)      | 0.16<br>(0.20)     | 0.17<br>(0.20)      |
| Financial and Insurance Activities    | 0.17<br>(0.42)     | 0.17<br>(0.42)      | 0.19<br>(0.43)     | 0.18<br>(0.43)      |
| Others                                | -1.32*<br>(0.67)   | -1.33*<br>(0.67)    | -1.31*<br>(0.66)   | -1.32*<br>(0.66)    |
| <i>Spacial Scope (base: EU-wide)</i>  |                    |                     |                    |                     |
| Worldwide                             | 0.51**<br>(0.17)   | 0.50**<br>(0.17)    | 0.48**<br>(0.17)   | 0.48**<br>(0.17)    |
| Some Countries                        | -0.34*<br>(0.14)   | -0.33*<br>(0.14)    | -0.35*<br>(0.14)   | -0.34*<br>(0.14)    |
| Members                               | -0.12***<br>(0.02) | -0.12***<br>(0.02)  | -0.12***<br>(0.02) | -0.12***<br>(0.02)  |
| Entry                                 | -0.77**<br>(0.24)  | -0.78**<br>(0.24)   | -0.75**<br>(0.24)  | -0.76**<br>(0.24)   |
| Exit                                  | 0.94***<br>(0.14)  | 0.88***<br>(0.15)   | 0.88***<br>(0.15)  | 0.85***<br>(0.15)   |
| Leniency Program 96                   | 0.89***<br>(0.23)  | 0.08<br>(0.34)      | 0.32<br>(0.31)     | -0.02<br>(0.35)     |
| Leniency Program 02                   | 0.35*<br>(0.15)    | -0.11<br>(0.18)     | 0.59**<br>(0.18)   | 0.19<br>(0.22)      |
| Leniency Program 06                   | 0.28<br>(0.16)     | -0.18<br>(0.19)     | 0.16<br>(0.17)     | -0.14<br>(0.20)     |
| Interest Rate                         | 0.67***<br>(0.20)  | 0.80***<br>(0.22)   | 0.75**<br>(0.23)   | 0.83***<br>(0.23)   |
| Interest Rate <sup>2</sup>            | -0.15***<br>(0.03) | -0.14***<br>(0.03)  | -0.17***<br>(0.03) | -0.15***<br>(0.04)  |
| GDP p.c.                              |                    | 0.25***<br>(0.06)   |                    | 0.19**<br>(0.07)    |
| Economic Indicator                    |                    |                     | 0.02**<br>(0.01)   | 0.02*<br>(0.01)     |
| Constant                              | -4.89***<br>(0.36) | -13.06***<br>(1.99) | -6.92***<br>(0.88) | -12.46***<br>(2.31) |
| Observations                          | 16'264             | 16'264              | 15'631             | 15'631              |

Robust standard errors in parentheses

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Table 6: Cox Regression

|                                       | (1)                | (2)                | (3)                | (4)                |
|---------------------------------------|--------------------|--------------------|--------------------|--------------------|
| <i>Infringement (base: Multiple)</i>  |                    |                    |                    |                    |
| Price Fixing                          | 0.69***<br>(0.15)  | 0.63***<br>(0.16)  | 0.65***<br>(0.16)  | 0.62***<br>(0.16)  |
| Market Sharing                        | -0.14<br>(0.29)    | -0.05<br>(0.28)    | -0.08<br>(0.29)    | -0.05<br>(0.28)    |
| <i>Industry (base: Manufacturing)</i> |                    |                    |                    |                    |
| Agriculture, Forestry, And Fishing    | 1.08**<br>(0.35)   | 1.06**<br>(0.34)   | 1.09**<br>(0.36)   | 1.08**<br>(0.34)   |
| Wholesale and Retail Trade            | -0.52<br>(0.45)    | -0.60<br>(0.45)    | -0.58<br>(0.44)    | -0.62<br>(0.44)    |
| Transportation and Storage            | 0.30<br>(0.20)     | 0.33<br>(0.21)     | 0.33<br>(0.21)     | 0.35<br>(0.21)     |
| Financial and Insurance Activities    | 0.37<br>(0.43)     | 0.36<br>(0.43)     | 0.41<br>(0.44)     | 0.40<br>(0.44)     |
| Others                                | -1.25<br>(0.66)    | -1.33<br>(0.69)    | -1.19<br>(0.65)    | -1.26<br>(0.67)    |
| <i>Spacial Scope (base: EU-wide)</i>  |                    |                    |                    |                    |
| Worldwide                             | 0.58**<br>(0.18)   | 0.54**<br>(0.18)   | 0.54**<br>(0.18)   | 0.53**<br>(0.18)   |
| Some Countries                        | -0.37**<br>(0.14)  | -0.40**<br>(0.15)  | -0.39**<br>(0.14)  | -0.40**<br>(0.15)  |
| Members                               | -0.12***<br>(0.02) | -0.12***<br>(0.02) | -0.12***<br>(0.02) | -0.12***<br>(0.02) |
| Entry                                 | -0.76**<br>(0.27)  | -0.75**<br>(0.27)  | -0.72**<br>(0.27)  | -0.72**<br>(0.27)  |
| Exit                                  | 0.77***<br>(0.15)  | 0.67***<br>(0.16)  | 0.68***<br>(0.16)  | 0.64***<br>(0.16)  |
| Leniency Program 96                   | 0.78***<br>(0.23)  | -0.12<br>(0.35)    | 0.16<br>(0.31)     | -0.22<br>(0.36)    |
| Leniency Program 02                   | 0.42**<br>(0.15)   | -0.08<br>(0.18)    | 0.71***<br>(0.19)  | 0.27<br>(0.23)     |
| Leniency Program 06                   | 0.19<br>(0.18)     | -0.33<br>(0.21)    | 0.07<br>(0.19)     | -0.27<br>(0.22)    |
| Interest Rate                         | 0.65***<br>(0.19)  | 0.79***<br>(0.21)  | 0.73***<br>(0.22)  | 0.81***<br>(0.22)  |
| Interest Rate <sup>2</sup>            | -0.15***<br>(0.03) | -0.14***<br>(0.03) | -0.17***<br>(0.03) | -0.15***<br>(0.03) |
| GDP p.c.                              |                    | 0.28***<br>(0.06)  |                    | 0.21**<br>(0.07)   |
| Economic Indicator                    |                    |                    | 0.03**<br>(0.01)   | 0.02*<br>(0.01)    |
| Observations                          | 16'264             | 16'264             | 15'631             | 15'631             |

Robust standard errors in parentheses

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Table 7: Duration Models with Generalized Gamma Distribution

|                                       | (1)                | (2)                | (3)                | (4)                |
|---------------------------------------|--------------------|--------------------|--------------------|--------------------|
| <i>Infringement (base: Multiple)</i>  |                    |                    |                    |                    |
| Price Fixing                          | -0.62***<br>(0.13) | -0.55***<br>(0.13) | -0.54***<br>(0.14) | -0.51***<br>(0.14) |
| Market Sharing                        | 0.29<br>(0.23)     | 0.28<br>(0.25)     | 0.33<br>(0.25)     | 0.33<br>(0.26)     |
| <i>Industry (base: Manufacturing)</i> |                    |                    |                    |                    |
| Agriculture, Forestry, And Fishing    | -0.67*<br>(0.30)   | -0.63*<br>(0.29)   | -0.57<br>(0.33)    | -0.58<br>(0.32)    |
| Wholesale and Retail Trade            | 0.65<br>(0.39)     | 0.74<br>(0.40)     | 0.68<br>(0.36)     | 0.73<br>(0.37)     |
| Transportation and Storage            | -0.16<br>(0.20)    | -0.19<br>(0.20)    | -0.22<br>(0.22)    | -0.22<br>(0.22)    |
| Financial and Insurance Activities    | -0.22<br>(0.34)    | -0.22<br>(0.34)    | -0.17<br>(0.38)    | -0.17<br>(0.38)    |
| Others                                | 1.16*<br>(0.48)    | 1.21*<br>(0.49)    | 1.25**<br>(0.48)   | 1.26**<br>(0.48)   |
| <i>Spacial Scope (base: EU-wide)</i>  |                    |                    |                    |                    |
| Worldwide                             | -0.57***<br>(0.17) | -0.54**<br>(0.17)  | -0.54**<br>(0.17)  | -0.55**<br>(0.18)  |
| Some Countries                        | 0.32**<br>(0.12)   | 0.30*<br>(0.12)    | 0.32*<br>(0.12)    | 0.30*<br>(0.13)    |
| Members                               | 0.10***<br>(0.02)  | 0.11***<br>(0.02)  | 0.10***<br>(0.02)  | 0.10***<br>(0.02)  |
| Entry                                 | 0.43*<br>(0.18)    | 0.43*<br>(0.19)    | 0.39*<br>(0.18)    | 0.39*<br>(0.18)    |
| Exit                                  | -0.89***<br>(0.20) | -0.86***<br>(0.21) | -0.94***<br>(0.25) | -0.91***<br>(0.26) |
| Leniency Program 96                   | -0.63***<br>(0.17) | 0.06<br>(0.25)     | 0.00<br>(0.23)     | 0.25<br>(0.26)     |
| Leniency Program 02                   | -0.31*<br>(0.14)   | 0.12<br>(0.18)     | -0.64***<br>(0.17) | -0.32<br>(0.21)    |
| Leniency Program 06                   | -0.38<br>(0.26)    | 0.02<br>(0.27)     | -0.42<br>(0.38)    | -0.15<br>(0.38)    |
| Interest Rate                         | -0.53**<br>(0.17)  | -0.66***<br>(0.20) | -0.72**<br>(0.24)  | -0.78**<br>(0.24)  |
| Interest Rate <sup>2</sup>            | 0.12***<br>(0.03)  | 0.12***<br>(0.03)  | 0.15***<br>(0.04)  | 0.14***<br>(0.04)  |
| GDP p.c.                              |                    | -0.23***<br>(0.05) |                    | -0.15*<br>(0.06)   |
| Economic Indicator                    |                    |                    | -0.03***<br>(0.01) | -0.03**<br>(0.01)  |
| Constant                              | 4.37***<br>(0.32)  | 11.71***<br>(1.83) | 7.31***<br>(0.99)  | 11.64***<br>(2.20) |
| $\ln(\sigma)$                         | -0.06<br>(0.08)    | -0.06<br>(0.09)    | -0.02<br>(0.09)    | -0.02<br>(0.09)    |
| $\kappa$                              | 0.41<br>(0.22)     | 0.37<br>(0.22)     | 0.16<br>(0.29)     | 0.19<br>(0.29)     |
| Observations                          | 16'264             | 16'264             | 15'631             | 15'631             |

Robust standard errors in parentheses

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$