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Collusion under different pricing schemes

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Abstract

We analyze collusive outcomes under different pricing schemes in a differentiated product market in which customers have elastic demand. Starting with a situation in which firms can set two-part tariffs to price discriminate, we consider two policy interventions that ban price discrimination: Firms must set (a) linear prices or (b) fixed fees. We find that collusion at maximum prices becomes harder to sustain under linear prices. By contrast, the analysis shows that the fixed fees policy facilitates collusion at maximum prices. The results have important implications for competition policy.

1 | INTRODUCTION

We analyze the impact of different pricing structures on firms' ability to maintain collusion. We examine the effects of nonlinear pricing and the outcomes of related regulatory policies designed to address the practice, which is common in many industries. Examples of businesses that employ nonlinear pricing include amusement parks, gas, media markets, mobile telecommunications, and electricity. In these industries, the pricing structures typically consist of (at least) two components: a fixed (entry) fee, which is independent of the quantity demanded, and a linear per-unit price.

The question of whether price discrimination helps to fight collusion has received considerable attention from both an academic and a practical point of view (see some motivating examples below). The literature has analyzed this issue in terms of cases of first- and third-degree price discrimination (see below). Generally speaking, these types of price discrimination are found to be good for competition and make collusion more difficult to sustain. However, the question of the impact of second-degree price discrimination on firms' ability to sustain collusion remains unanswered. This article addresses this gap.¹

We investigate whether and how the possibility of coordinating on multiple price components instead of agreeing upon one single (linear or fixed) collusive price influences firms' ability to sustain collusion. To derive policy recommendations, we also examine the effects on total welfare and customer surplus. To this end, building on the setup by Yin (2004) who models two-part tariff competition in duopoly, we analyze the incentives to collude under different pricing schemes in a differentiated products setup (à la Hotelling, 1929) with variable demand. Total demand is elastic, as local demand—the demand of a single customer—decreases in the price and in the distance to the respective firm (i.e., considering transport costs). We start by analyzing collusive incentives in the case in which firms can price discriminate and coordinate on two-part tariffs. Turning to the situations in which price discrimination is prohibited, we find that the comparison with regard to the sustainability of collusion at monopoly prices crucially depends on the type of policy intervention—that is, whether authorities order the use of linear or fixed fees only. The scope for collusion is largest when firms use fixed fees only, whereas collusion is most difficult to sustain when firms set linear prices only.

What renders collusion particularly less attractive under linear pricing compared with nonlinear pricing is the higher additional benefit from reducing the linear price: Not only does the reduction enlarge a deviating firm's market share, but it increases inframarginal demand at the same time. Due to a lower linear collusive price, this effect is less

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pronounced under two-part tariffs. Moreover, this effect is even less pronounced under fixed fees, which explains why collusion at monopoly prices is easiest to sustain in that scenario.

Our analysis has important implications for customer and total welfare—and, hence, for competition policy. In any case, banning price discrimination turns out to be the right thing to do. Our model predicts that when authorities follow a consumer standard, banning fixed fees is optimal. In this case, consumer surplus is always higher under linear pricing than under two-part tariffs—independent of whether firms collude or compete. By contrast, when authorities are interested in maximizing social welfare, our analysis shows that linear prices should be banned. Again, independent of whether the market is collusive or competitive, welfare is always highest under fixed fees.

1.1 | Motivating cases

Competition authorities have been debating whether to ban price discrimination and what the effects of such a ban on collusion are. When firms use two-part tariffs as a type of second-degree price discrimination,² a ban can come in two different forms: banning linear prices or banning fixed prices. Indeed, such regulatory interventions have been proposed in markets in which price discrimination and collusion are important aspects. For example, in the United Kingdom, the “big six” energy suppliers faced investigations over price-fixing allegations.³ At the same time, the Office of Gas and Electricity Markets (Ofgem) introduced several restrictions on the retail residential energy market.⁴ A central proposal by Ofgem was that Ofgem itself would set a standardized (uniform) fixed (or “standing”) charge for all standard tariffs, and that suppliers would then compete on a single unit rate for each standard tariff (Littlechild, 2014). Such an intervention thus equates to banning of fixed fees.

Another prominent example is the market for (mobile) telecommunication services. Numerous investigations across the world have documented price fixing in this market. Examples include the case of mobile phone service providers in Hong Kong in 2000 (Chen & Lin, 2002) and a convicted mobile phone cartel in France (de Mesnard, 2009).⁵ Moreover, the different pricing components and subscription plans, which are important in this market, appear to play crucial roles in these collusive cases. As Larsen (2010) points out in his extensive study of (allegedly) collusive behavior regarding text messaging in the United States, firms set supracompetitive pay-per-use (PPU) prices for those customers who did not opt for a monthly text plan, or exceed their monthly limit of text messages. Indeed, the author suggests that “[a]s a first step, the FCC [Federal Communications Commission] should set a price cap on PPU rates closer to the marginal cost of the service” (p. 242). In other words, competition in the linear price component would be restricted.⁶

Furthermore, in an investigation in South Korea, the country’s three largest wireless carriers were accused of collusion and other unfair practices. In June 2017, the government announced measures to lower mobile expenses by increasing the monthly discount rate for new mobile phone subscribers from 20% to 25%. Additionally, the government ordered carriers to exempt the basic monthly subscription fee (11,000 won, approximately \$9.90 USD) for elderly and low-income household members.⁷ Similar to the Ofgem example, such an intervention means that firms can no longer compete in fixed fees.

1.2 | Related literature

Although price discrimination and nonlinear tariffs are important features of antitrust concerns, the literature on the impact of different pricing schemes on collusion is sparse.⁸ Concerning the relationship between third-degree price discrimination and collusion, Liu and Serfes (2007) investigate the impact of the availability of customer-specific information for market segmentation in a linear-city model on the sustainability to collude. A higher degree of market segmentation accompanied by a more diversified pricing structure is possible as the quality of customer information increases. The authors show that collusion is harder to sustain as the firms’ ability to segment customers improves.

A related study to Liu and Serfes (2007) is Colombo (2010). The author allows for different degrees of product differentiation (i.e., firms are not located at the extremes of the linear city), and analyzes perfect (or first-degree) price discrimination. With perfect price discrimination, firms may set prices based on the exact location of a customer in so-called delivered pricing.⁹ The author finds that collusion is easier to sustain the lower transport costs are,¹⁰ and that colluding on discriminatory prices is harder than on a uniform price.¹¹

For third-degree price discrimination, Helfrich and Herweg (2016) find that price discrimination helps to fight collusion not only under best-response asymmetries (lower static Nash equilibrium profits under price discrimination)

as in Liu and Serfes (2007), but also under best-response symmetries (higher static Nash equilibrium profits under price discrimination).

In their contribution, Fong and Liu (2011) analyze intertemporal price discrimination in an overlapping generations model and show that, in comparison to uniform pricing, loyalty rewards of different forms facilitate collusion. In contrast to our model, firms in Fong and Liu (2011) can set linear prices only. If they can discriminate, they may set two different linear prices in a given period for first-time and repeat customers. In our model, firms can set both a linear and a fixed tariff component at the same point in time.

The rest of this article is organized as follows: Section 2 presents the setup and derives demand functions. Section 3 analyzes the case of price discrimination when firms set two-part tariffs. In Section 4, we then consider the implications of two policy interventions to ban price discrimination: linear prices only (Section 4.1) and fixed fees only (Section 4.2). We discuss extensions in Section 5. The last section concludes.

2 | THE MODEL

We consider a model of horizontal product differentiation à la Hotelling (1929) with two symmetric firms¹² located at the extremes of the linear city of unit length, where locations are denoted by $L_i = i - 1$ and $i \in \{1, 2\}$.¹³ Fixed and marginal costs are equal to zero.¹⁴ Firms discount future profits by the common discount factor δ per period. We compare the incentives to collude in three different pricing scenarios:

- (i) a two-part-tariff scenario (denoted by T) in which firms compete in tariffs which are made up of a fixed component $f_{i,T}$ and a variable part $p_{i,T}$ charged per unit sold (see Section 3),
- (ii) a linear-price scenario (denoted by L) in which firms compete in prices $p_{i,L}$ per unit purchased (see Section 4.1), and
- (iii) a fixed-fee scenario (denoted by F) in which firms compete in fixed fees $f_{i,F}$, that is, customers pay a flat (subscription) fee independent of actual usage (see Section 4.2).

Customers of mass one are uniformly distributed along the line. Each customer buys either from firm 1 or from firm 2. Building on Yin (2004), who models two-part tariff competition in duopoly, we allow individual demands to be elastic.¹⁵ Let $\mathcal{L} = \{L, T\}$ and $\mathcal{F} = \{F, T\}$. A customer who is located at x and purchases a quantity q receives the following utility when buying from firm i in pricing scenario $k \in \{F, L, T\}$:

$$U(q; x, p_{i,k}, f_{i,k}) = q - \frac{q^2}{2} - q(\mathbb{1}_{\mathcal{L}} p_{i,k} + \tau |L_i - x|) - \mathbb{1}_{\mathcal{F}} f_{i,k},$$

where τ is the transport-cost parameter, and

$$\mathbb{1}_{\mathcal{L}}(k) = \begin{cases} 1 & \text{if } k \in \mathcal{L}, \\ 0 & \text{if } k \notin \mathcal{L} \end{cases}$$

as well as

$$\mathbb{1}_{\mathcal{F}}(k) = \begin{cases} 1 & \text{if } k \in \mathcal{F}, \\ 0 & \text{if } k \notin \mathcal{F}. \end{cases}$$

We note that the quantity demanded depends on transport costs. In the product differentiation interpretation of the model, this means that mismatch costs occur for each unit purchased. Then, $q\tau|L_i - x|$ represents the total disutility suffered by a customer with preferred product characteristics of x when consuming a product that is not ideal. Note that the larger are q and/or $|L_i - x|$, the greater the disutility.

Customers maximize their utility when deciding on the quantity they want to purchase. This implies that a customer has the following local demand at firm i

$$\begin{aligned} \max_q U(q; x, p_{i,k}, f_{i,k}) &\Rightarrow \frac{\partial U}{\partial q} = 1 - q - \mathbb{1}_{\mathcal{L}} p_{i,k} - \tau |L_i - x| = 0 \\ &\Rightarrow q(x, p_{i,k}, f_{i,k}) = \begin{cases} 1 - \mathbb{1}_{\mathcal{L}} p_{i,k} - \tau |L_i - x| & \text{if } U(q; x, p_{i,k}, f_{i,k}) \geq 0 \\ 0 & \text{else.} \end{cases} \end{aligned}$$

Customer heterogeneity with respect to product preferences is also reflected in the individual demand, which decreases as the difference between preferences and actual product characteristics grows.

The marginal customer who is indifferent between buying from firm i and firm j (with $j \in \{1, 2\}, j \neq i$) is located at

$$\tilde{x}(p_{i,k}, f_{i,k}; p_{j,k}, f_{j,k}) = \frac{1}{2} - \frac{\mathbb{1}_{\mathcal{L}}(p_{i,k} - p_{j,k})}{2\tau} - \frac{\mathbb{1}_{\mathcal{F}}(f_{i,k} - f_{j,k})}{\tau(2 - \mathbb{1}_{\mathcal{L}}(p_{i,k} + p_{j,k}) - \tau)}. \quad (1)$$

Now if the indifferent customer \tilde{x} is located in between both firms, i.e., $0 \leq \tilde{x} \leq 1$, aggregate demand of firm i in scenario k is given by

$$Q_{i,k}(p_{i,k}, f_{i,k}; p_{j,k}, f_{j,k}) = \int_0^{\tilde{x}(p_{i,k}, f_{i,k}; p_{j,k}, f_{j,k})} (1 - \mathbb{1}_{\mathcal{L}} p_{i,k} - \tau x) dx.$$

Firm i 's profit is then given as

$$\pi_{i,k}(p_{i,k}, f_{i,k}; p_{j,k}, f_{j,k}) = \mathbb{1}_{\mathcal{L}} p_{i,k} Q_{i,k}(p_{i,k}, f_{i,k}; p_{j,k}, f_{j,k}) + \mathbb{1}_{\mathcal{F}} f_{i,k} \tilde{x}(p_{i,k}, f_{i,k}; p_{j,k}, f_{j,k}). \quad (2)$$

The first term of the profit function is the revenue generated by charging a variable price per unit purchased, whereas the second term is the profit from charging a fixed fee.

We will analyze an infinitely repeated stage game that has the following decision structure:

Step 1. Firms decide on their prices.

Step 2. Customers observe firms' prices and make their purchase decisions.

With regard to firms' price-setting decision, we assume that firms use grim-trigger strategies (Friedman, 1971). This means that they start by setting the collusive prices, and continue to do so as long as no firm deviated from the collusive path in any of the previous periods. If there was deviation, then firms set the competitive prices forever.¹⁶

Before analyzing the three different pricing regimes and their impact on collusion, a note on the sustainability of collusion seems in order.¹⁷ We will derive the critical discount factor for the different pricing scenarios. Given the use of grim-trigger strategies, we can compute critical discount factors according to the well-known formula

$$\delta \geq \bar{\delta} := \frac{\pi^d - \pi^c}{\pi^d - \pi^*}, \quad (3)$$

where π^c , π^d , and π^* denote collusive profits, deviation profits, and competitive (punishment) profits, respectively. All things equal, a lower punishment/deviation profit and/or a higher collusive profit facilitate collusion, whereas the opposite is true for a higher punishment/deviation profit and/or a lower collusive profit.

Our focus here is on the situation in which the market is covered, that is, when all customers along the line buy from one of the two firms. Hence, we make the following assumption with regard to customers' transport costs:

Assumption 1. Transport costs are not too high: $0 < \tau \leq 2/5 =: \bar{\tau}$.

The assumption guarantees that the whole market is served under any of the pricing scenarios to be considered. For larger transport costs, firms prefer not to serve the customers located around the center of the unit line. As a result, firms are local monopolists, and the notion of collusion has no bite. Note that the assumption regarding transport costs is standard in the literature (see Yin, 2004).

Let us briefly comment on the definitions of total welfare and customer surplus, which we compare later as well. We assume that total welfare denoted by Υ puts equal weights on firm profits denoted by π and customer surplus denoted by Λ . Thus, given firm symmetry (in equilibrium), it is calculated as

$$\Upsilon = 2\pi + \Lambda,$$

where customer surplus amounts to

$$\Lambda = 2 \int_0^{\frac{1}{2}} U(x; p, f) dx.$$

3 | PRICE DISCRIMINATION

In this section, we analyze the scenario with (second-degree) price discrimination. Customers whose locations are not known by the firms choose their level of demand. Due to the fixed fee, the average cost for each unit purchased will vary between customers at different locations, that is, price discrimination comes in the form of a quantity discount here.

3.1 | Punishment

The results in the competitive stage are due to Yin (2004) for the situation with a fully covered market. Dropping subscript i , the following prices and profits result:

$$p_T^* = \frac{\tau}{4},$$

$$f_T^* = \frac{3\tau}{4} - \frac{9\tau^2}{16},$$

and

$$\pi_T^* = \frac{\tau}{2} - \frac{11\tau^2}{32}.$$

3.2 | Collusion

Under collusive pricing, firms share the market equally and set a linear price knowing that they can extract parts of the corresponding customer surplus via the fixed fee. Straightforward calculations lead to the following result.

Lemma 1. *In the two-part-tariff scenario, the collusive prices and profits are given by*

$$\bar{p}_T^c = \frac{\tau}{4},$$

$$\bar{f}_T^c = \frac{(4 - 3\tau)^2}{32},$$

and

$$\bar{\pi}_T^c = \frac{1}{4} - \frac{\tau}{4} + \frac{5\tau^2}{64}.$$

In all pricing scenarios, an increase in differentiation leads to lower monopoly profits. This is due to the fact that customer surplus is lowered, which means that there is less to extract from customers for firms.¹⁸

With regard to linear prices, we can state the following result.

Observation 1. Linear prices under competition and collusion are identical, that is, $p_T^* = \bar{p}_T^c$.

The interpretation is that firms determine market shares via the fixed fee in a first step; then, they monopolize their market.¹⁹ This observation will prove helpful in explaining our results with regard to the sustainability of monopoly prices below. As market shares are identical in both scenarios, this results in the same linear price. In contrast, the optimal fixed fee is larger without competition because firms are able to extract all surplus of the indifferent customer.

3.3 | Deviation

Next assume that firm i 's competitor follows the collusive agreement by setting \bar{p}_T^c and \bar{f}_T^c . When deriving the optimal deviating prices, we have to distinguish between the cases in which firm i (a) serves the whole market, or (b) shares the market with the other firm. For relatively large values of the transport-cost parameter, it is optimal to leave some market share to the competitor when deviating. This is because covering the whole market would require a steep downward adjustment of the price. Below a certain cut-off value for the transport-cost parameter, which we denote by $\tilde{\tau}_T$, the optimal deviation leads to a market share equal to one.

Define $A := \sqrt{61 - 83\tau + 28\tau^2}$ and $\tilde{\tau}_T := 14/19 - 2\sqrt{30}/19 \approx 0.1603$. Then, we have:

Lemma 2. *Under two-part tariffs, the optimal deviation from the collusion yields the following prices and profits:*

$$p_T^d = \begin{cases} \frac{\tau}{2} & \text{if } 0 < \tau \leq \tilde{\tau}_T \\ \frac{8 - 5\tau - A}{3} & \text{if } \tilde{\tau}_T < \tau \leq \bar{\tau}, \end{cases}$$

$$f_T^d = \begin{cases} \frac{1}{2} - 2\tau + \frac{11\tau^2}{8} & \text{if } 0 < \tau \leq \tilde{\tau}_T \\ \frac{197}{9} - \frac{268\tau}{9} + \frac{181\tau^2}{18} - \frac{25A}{9} + \frac{35\tau A}{18} & \text{if } \tilde{\tau}_T < \tau \leq \bar{\tau}, \end{cases}$$

and

$$\pi_T^d = \begin{cases} \frac{1}{2} - \frac{3\tau}{2} + \frac{7\tau^2}{8} & \text{if } 0 < \tau \leq \tilde{\tau}_T \\ \frac{(-8 + 5\tau + A)(58 - 86\tau + 31\tau^2 - 8A + 5\tau A)}{27\tau} & \text{if } \tilde{\tau}_T < \tau \leq \bar{\tau}. \end{cases}$$

Proof. See the Appendix. □

3.4 | Critical discount factor

We are now able to calculate the critical discount factor according to condition (3). We summarize our findings from straightforward calculations as follows.

Proposition 1. *When firms set two-part tariffs, the critical discount factor is given by*

$$\bar{\delta}_T = \begin{cases} \frac{4 - 17\tau}{8 - 26\tau} & \text{if } 0 < \tau \leq \tilde{\tau}_T \\ \frac{60928 - 124176\tau + 83856\tau^2 - 18745\tau^3 - 7808A + 10624\tau A - 3584\tau^2 A}{2(30464 - 62304\tau + 42576\tau^2 - 9737\tau^3 - 3904A + 5312\tau A - 1792\tau^2 A)} & \text{if } \tilde{\tau}_T < \tau \leq \bar{\tau}. \end{cases}$$

Furthermore, $\bar{\delta}_T$ is decreasing in τ .

We find a positive relationship between the degree of differentiation and the sustainability of collusion. Generally speaking, there are two opposing effects: On the one hand, collusion tends to be facilitated at higher levels of differentiation, because deviation becomes less profitable. On the other hand, collusion tends to be more difficult to sustain, because more differentiated products result in less severe punishment (higher competitive profits), and because collusive profits decrease. From the case with constant demand in which there is only one price (see, e.g., Chang, 1991), we know that the facilitating effect dominates, and collusion becomes easier to sustain.

Given the importance of the fixed fee for securing market shares in the present situation, this result carries over.

3.5 | Total welfare and customer surplus

Given equilibrium prices and Observation 1, total welfare, which is solely affected by transport costs and the linear price, is the same under competition and collusion:

$$\Upsilon_T^* = \tilde{\Upsilon}_T^c = \frac{1}{2} - \frac{\tau}{4} + \frac{\tau^2}{96}.$$

Customer surplus under punishment and collusion is given as

$$\Lambda_T^* = \frac{1}{2} - \frac{5\tau}{4} + \frac{67\tau^2}{69}$$

and

$$\bar{\Lambda}_T^c = \frac{\tau}{4} - \frac{7\tau^2}{48},$$

respectively.

4 | BANNING PRICE DISCRIMINATION

When there is a ban on price discrimination, we distinguish between two policy interventions: (a) linear pricing and (b) fixed prices only.

4.1 | Linear pricing

The results presented in this section are borrowed from Rothschild (1997).

4.1.1 | Punishment

Competitive equilibrium prices and profits can be derived as

$$p_L^* = \frac{2 + 3\tau - \sqrt{4 - 4\tau + 13\tau^2}}{4}$$

and

$$\pi_L^* = \frac{(2 + 3\tau - \sqrt{4 - 4\tau + 13\tau^2})(2 - 4\tau + \sqrt{4 - 4\tau + 13\tau^2})}{32}.$$

4.1.2 | Collusion

The monopoly price equals

$$\bar{p}_L^c = \frac{1}{2} - \frac{\tau}{8}.$$

The resulting collusive profit of each firm is given by

$$\bar{\pi}_L^c = \frac{(4 - \tau)^2}{128}.$$

4.1.3 | Deviation

Given that the competitor sticks to collusion and sets the optimal collusive price p_L^c , we can derive the price set by a deviating firm i . Define $B := \sqrt{592 - 392\tau + 637\tau^2}$ and $\tilde{\tau}_L := (4\sqrt{249} - 16)/233 \approx 0.2022$. Then, the optimal deviating price and the resulting profit are given by

$$p_L^d = \begin{cases} \frac{1}{2} - \frac{9\tau}{8} & \text{if } 0 < \tau \leq \tilde{\tau}_L \\ \frac{40 + 14\tau - B}{72} & \text{if } \tilde{\tau}_L < \tau \leq \bar{\tau} \end{cases}$$

and

$$\pi_L^d = \begin{cases} \frac{1}{4} - \frac{\tau}{4} - \frac{45\tau^2}{64} & \text{if } 0 < \tau \leq \tilde{\tau}_L \\ \frac{(40 + 14\tau - B)(208 + 952\tau - 539\tau^2 + 20B + 7\tau B)}{497664\tau} & \text{if } \tilde{\tau}_L < \tau \leq \bar{\tau}. \end{cases}$$

4.1.4 | Critical discount factor

Using the profits in the collusive, deviating, and punishment phases together with (3), the critical discount factor under linear pricing is given by

$$\bar{\delta}_L = \begin{cases} \frac{16 - 24\tau - 91\tau^2}{2(16 - 20\tau + 5\tau^2 - 14\tau\sqrt{4 - 4\tau + 13\tau^2})} & \text{if } 0 < \tau \leq \tilde{\tau}_L \\ \frac{3520 + 17520\tau - 12876\tau^2 + 15893\tau^3 - 592B + 392\tau B - 637\tau^2 B}{3520 - 44688\tau + 49332\tau^2 - 376795\tau^3 + 108864\tau^2\sqrt{13\tau^2 - 4\tau + 4} - 592B + 392\tau B - 637\tau^2 B} & \text{if } \tilde{\tau}_L < \tau \leq \bar{\tau}. \end{cases}$$

As shown by Rothschild (1997), the critical discount factor first increases in the transport-cost parameter, and then decreases.

4.1.5 | Total welfare and customer surplus

Total welfare under punishment and collusion, respectively, is given by

$$\Upsilon_L^* = \frac{1}{4} - \frac{\tau}{2} - \frac{31\tau^2}{48} + \frac{(2 + 3\tau)\sqrt{4 - 4\tau + 13\tau^2}}{16}$$

and

$$\bar{\gamma}_L^c = \frac{3}{8} - \frac{3\tau}{16} + \frac{13\tau^2}{384}.$$

With regard to customer surplus in the punishment case, it amounts to

$$\Lambda_L^* = \frac{1}{4} - \frac{5\tau}{8} + \frac{11\tau^2}{12} + \frac{(1+2\tau)\sqrt{4-4\tau+13\tau^2}}{8}.$$

Under monopoly prices, we have

$$\bar{\Lambda}_L^c = \frac{1}{8} - \frac{\tau}{16} + \frac{7\tau^2}{384}.$$

4.1.6 | Impact of a ban

The following proposition lists the consequences of introducing a linear-pricing regime after banning price discrimination.

Proposition 2. *For any value $\tau \in (0, \bar{\tau}]$, it holds that*

- (i) $\pi_L^* < \pi_T^*$ and $\bar{\pi}_L^c < \bar{\pi}_T^c$,
- (ii) $\bar{\delta}_T < \bar{\delta}_L$,
- (iii) $\Upsilon_L^* < \Upsilon_T^*$ and $\bar{\Upsilon}_L^c < \bar{\Upsilon}_T^c$, as well as
- (iv) $\Lambda_T^* < \Lambda_L^*$ and $\bar{\Lambda}_T^c < \bar{\Lambda}_L^c$.

Punishment profits are higher with two-part tariffs compared with linear pricing, although intuition would first point in the opposite direction: Typically, competitive pressure tends to be higher when firms have more instruments available. However, here firms use the fixed fee to compete for the indifferent customer under two-part tariffs (see Observation 1). Competition for the marginal customer via the linear component is more intense than via the fixed fee. Cutting the linear price to steal market share is more attractive, because it comes with a silver lining of increased inframarginal demand. Moreover, the smaller price applies only to an individual demand smaller than one, whereas cutting a fixed fee by the same amount would apply to an individual demand equal to one. This comparison continues to hold even though the lower linear fee results in higher surplus under two-part tariffs than under linear pricing, which increases competition in the fixed component. Put differently, the cost of avoiding competition in the linear fee is less than the benefit.²⁰

When firms collude, the (strictly) largest industry profit is obtained when two-part tariffs are used, because in this scenario, firms have more instruments available to extract customer surplus.

Given that both critical discount factors are the same (equal to one half, see Figure 1) when there is no differentiation, and that an increase in differentiation results in a lower critical discount factor under two-part tariffs, the following is clear: the critical discount factor under two-part tariffs lies below that under linear pricing for small to intermediate degrees of differentiation. Moreover, incentives to steal demand via a reduction in the linear price (which, as argued above, is more rewarding than stealing demand via the fixed part) are lower under two-part tariffs. This is due to the fact that the above-mentioned effects are less pronounced, because the linear part under collusive two-part tariffs is lower. Hence, the scope for boosting inframarginal demand decreases, and previous demand, which is served at a lower deviating price now, is relatively high. This is also true for the comparison of the cases of competition and deviation.²¹ This is why the stabilizing effect of lower deviation incentives under two-part tariffs—together with higher collusive profits—outweighs the destabilizing effect of higher punishment profits.

Note that the differences in social welfare are solely driven by the differences in the linear prices, where $0 < p_T^* < p_L^*$ and $0 < \bar{p}_T^c < \bar{p}_L^c$. As a consequence, social welfare is lower when firms set linear prices compared with the situation in which they set two-part tariffs. In the latter scenario, there is less distortion, because the lower price is closer to the socially optimal of zero (i.e., the marginal costs).

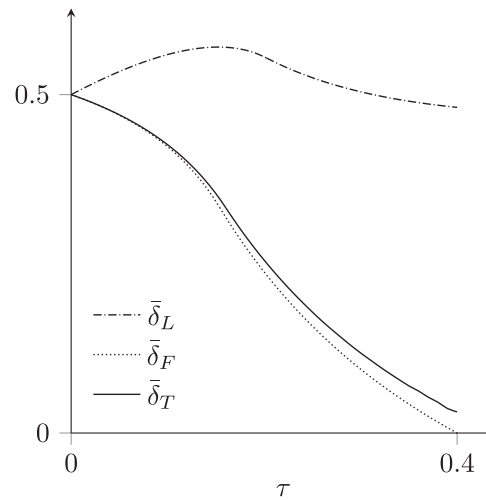


FIGURE 1 Comparison of the critical discount factors in the three pricing scenarios

With regard to customer surplus, we can conclude that the higher surplus generated in the two-part-tariff scenario both under competition and collusion benefits firms and not customers.

4.2 | Fixed fees

Under fixed fees only, local demand at a firm solely depends on customers' locations.

4.2.1 | Punishment

Using symmetry, and proceeding in the standard way, we arrive at the following result.

Lemma 3. *In the punishment scenario with fixed fees, firms set an equilibrium fixed fee of*

$$f_F^* = \tau - \frac{\tau^2}{2}$$

and make a profit of

$$\pi_F^* = \frac{\tau}{2} - \frac{\tau^2}{4}.$$

Given that local demand is fixed, we have the standard effect of an increase in differentiation: More differentiation softens competition. This results in an incentive to increase fees to extract more surplus from each customer, because switching suppliers becomes more costly. As mentioned above, profits are always larger under fixed fees compared with linear pricing. Similar to the effects that emerge under linear pricing, as differentiation vanishes ($\tau \rightarrow 0$), competition becomes tougher, and profits converge to zero.

4.2.2 | Collusion

In the fixed-fee scenario, firms can fully extract the surplus of the indifferent customer at the center to maximize joint profits. We then have:

Lemma 4. *With fixed fees, collusive prices and profits are given by*

$$\bar{f}_F^c = \frac{(2 - \tau)^2}{8}$$

and

$$\bar{\pi}_F^c = \frac{(2 - \tau)^2}{16}.$$

4.2.3 | Deviation

We now turn to the optimal deviating strategy. Given that the other firm sets the collusive fixed fee, we again have to distinguish between the case in which the deviator finds it profitable to serve the whole market, or that in which the deviator instead leaves some market share to the other firm. Define $\tilde{\tau}_F := 2/13 \approx 0.1538$. We then have:

Lemma 5. *With fixed fees, deviation prices and profits are given by*

$$f_F^d = \begin{cases} \frac{1}{2} - \frac{3\tau}{2} + \frac{5\tau^2}{8} & \text{if } 0 < \tau \leq \tilde{\tau}_F \\ \frac{(2 - \tau)(2 + 3\tau)}{16} & \text{if } \tilde{\tau}_F < \tau \leq \bar{\tau} \end{cases}$$

and

$$\pi_F^d = \begin{cases} \frac{1}{2} - \frac{3\tau}{2} + \frac{5\tau^2}{8} & \text{if } 0 < \tau \leq \tilde{\tau}_F \\ \frac{(2 - \tau)(2 + 3\tau)^2}{256\tau} & \text{if } \tilde{\tau}_F < \tau \leq \bar{\tau}. \end{cases}$$

Proof. See the Appendix. □

4.2.4 | Critical discount factor

Using expression (3), and performing straightforward calculations, we can state:

Proposition 3. *When firms set fixed fees, the critical discount factor is given by*

$$\bar{\delta}_F = \begin{cases} \frac{2 - 9\tau}{2(2 - 7\tau)} & \text{if } 0 < \tau \leq \tilde{\tau}_F \\ \frac{2 - 5\tau}{2 + 11\tau} & \text{if } \tilde{\tau}_F < \tau \leq \bar{\tau}. \end{cases}$$

Furthermore, $\bar{\delta}_F$ is decreasing in τ .

The observation that the critical discount factor decreases in the degree of product differentiation is related to the case of unit demand where the effect of an increased level of product differentiation on deviation—which is less profitable as customers incur higher transport costs—outweighs the opposing, sustainability-decreasing effects on competitive and collusive profits. Due to a linear price of zero in the present setup (i.e., constant local demand), the same relationship is obtained here.

4.2.5 | Total welfare and customer surplus

Because, by definition, the linear price is equal to zero (and, hence, equal to marginal costs²²) under fixed prices, there is no distortion from a social welfare point of view as long as fixed fees are mere transfers, which are assumed here:

$$\Upsilon_F^* = \bar{\Upsilon}_F^c = \frac{1}{2} - \frac{\tau}{4} + \frac{\tau^2}{24}.$$

For the punishment phase, customer surplus amounts to

$$\Lambda_F^* = \frac{1}{2} - \frac{5\tau}{4} + \frac{13\tau^2}{24}.$$

Under collusive pricing, customer surplus is given as

$$\bar{\Lambda}_F^c = \frac{\tau}{4} - \frac{\tau^2}{12}.$$

4.2.6 | Impact of a ban

We can now compare the outcomes from the case with price discrimination with the outcomes in a scenario in which firms can only charge fixed fees.

Proposition 4. *For any value $\tau \in (0, \bar{\tau}]$, it holds that*

- (i) $\pi_T^* < \pi_F^*$ and $\bar{\pi}_T^c < \bar{\pi}_F^c$,
- (ii) $\bar{\delta}_F < \bar{\delta}_T$,
- (iii) $\Upsilon_T^* < \Upsilon_F^*$ and $\bar{\Upsilon}_T^c < \bar{\Upsilon}_F^c$, as well as
- (iv) $\Lambda_F^* < \Lambda_T^*$ and $\bar{\Lambda}_T^c < \bar{\Lambda}_F^c$.

Competitive profits are lower with two-part tariffs compared with fixed fees. Under two-part tariffs, when competing for market shares via the fixed fee, firms anticipate that they can earn additional profits by adjusting the linear price once market shares are set. This additional source of income induces firms to compete more intensely for market shares by lowering the fixed fees, resulting in relatively lower profits under two-part tariffs. Again, collusive profits are higher with two instruments at hand.

Collusion at monopoly prices can be sustained for a greater range of discount factors under fixed fees only. Now that the focus is only on the fixed component, the above-mentioned, opposing effects are reinforced, resulting in an even lower incentive to deviate from collusion.

Because there is no distortion from the linear fee, social welfare is higher under fixed fees than under two-part tariffs.

With regard to customer surplus, we can conclude that the higher surplus generated under competitive fixed fees benefits firms and not customers. The opposite is true for the case of collusion.

4.3 | Summary and implications

Table 1 summarizes the results from the analysis so far.

Note that the comparison of collusive profits between the fixed-price scenario and linear pricing is not clear cut, a priori intuition from the above analysis. Under linear pricing, firms are unable to extract all surplus from the indifferent customer, because they can only set a linear price.²³ When firms only charge a fixed fee, they can fully extract the indifferent customer's surplus. The implicit linear price of zero in this case results in a higher customer surplus and, hence, larger collusive profits.

Interestingly, we find that the ranking of the critical discount factors is the same for all values of the transport-cost parameter. A graphical illustration of the critical discount factors is given in Figure 1.²⁴

TABLE 1 Comparison of the three regimes under competitive and collusive pricing

	Competition	Collusion
Profits	$\pi_L^* < \pi_T^* < \pi_F^*$	$\bar{\pi}_L^c < \bar{\pi}_F^c < \bar{\pi}_T^c$
Critical discount factors	–	$\bar{\delta}_F < \bar{\delta}_T < \bar{\delta}_L$
Social welfare	$\Upsilon_L^* < \Upsilon_T^* < \Upsilon_F^*$	$\bar{\Upsilon}_L^c < \bar{\Upsilon}_T^c < \bar{\Upsilon}_F^c$
Customer surplus	$\Lambda_F^* < \Lambda_T^* < \Lambda_L^*$	$\bar{\Lambda}_T^c < \bar{\Lambda}_F^c < \bar{\Lambda}_L^c$

Based on Table 1, we can deliver some policy implications depending on the overarching goal of the policymaker or competition authority. When the primary consideration is customer surplus (or a consumer surplus standard), which appears to be the case, for example, in the US and in the EU, then the message is clear: Fixed fees should be banned. From the table, we can see that banning fixed fees appears to be a safe policy independent of whether the market is competitive or collusive. In the case in which the market is originally competitive, that is, $\delta < \bar{\delta}_T$, it continues to be competitive even after introducing a ban on price discrimination (by ordering linear prices, that is). At the same time, customer surplus will increase, because $\Lambda_T^* < \Lambda_L^*$.

Now in the case in which the market is originally collusive, that is, $\delta \geq \bar{\delta}_T$, there are two scenarios. If the market continues to be collusive, then customer surplus will rise, because $\bar{\Lambda}_T^c < \bar{\Lambda}_L^c$ holds. In the second scenario, collusion can no longer be maintained. In this case, customer surplus increases, because $\bar{\Lambda}_T^c < \bar{\Lambda}_L^c < \Lambda_L^*$.

Consider now a competition authority or a government favoring a total welfare standard. This seems to be true, for example, in Australia, Canada, and New Zealand. Again, the message is clear: Linear fees should be banned. In this case, the level of social welfare under fixed fees only is independent of whether the market is initially competitive or collusive. In any case, the level is always highest under fixed fees only compared with the alternative scenario with two-part tariffs, that is, $\Upsilon_T^* = \bar{\Upsilon}_T^c < \Upsilon_F^* = \bar{\Upsilon}_F^c$.

5 | EXTENSIONS

In this section, we briefly discuss three extensions to the base model. We first analyze less-than-maximum collusive prices. We then comment on the situation in which firms are free to choose the pricing regime. Last, we analyze the case of positive marginal costs.

5.1 | Partial collusion

So far we have only considered the possibility of collusion at monopoly prices. However, firms may set a lower collusive price to reduce the incentive to deviate from collusion in those cases in which the actual discount factor is below the critical discount factor.²⁵ This is particularly important for the case in which firms' pricing decisions are not subject to regulatory intervention. As we have seen, collusion at two-part tariffs results in highest profits, but collusion under a fixed-fee regulatory intervention can be sustained for a greater range of the discount factor. Therefore, colluding firms may find it optimal to switch to nondiscriminatory pricing even if this is not mandated by authorities.

In the appendix, we demonstrate the formal derivation of the optimal partial collusive price when firms have to use fixed fees. We illustrate our general results making use of a numerical example in Figure 2, which gives the collusive profits for the case with $\tau = 0.25$. Two observations from the exercise are in order. First, collusive profits under linear pricing are always lowest, but collusive profits under fixed fees only can be higher than under two-part tariffs when we consider partial collusion.

Second, as the figure shows, the insight with regard to the sustainability of collusive profits in the three different pricing scenarios from the main part continues to hold here. Consider the case with a given (supracompetitive) profit, which is feasible in all pricing scenarios (e.g., $\bar{\pi}_L^c$). The horizontal line indicates that, in line with the order of the critical discount factors (see Table 1), such a profit can be maintained for the greatest range of discount factors when firms only set fixed fees, whereas the range of discount factors is most narrow under linear pricing.

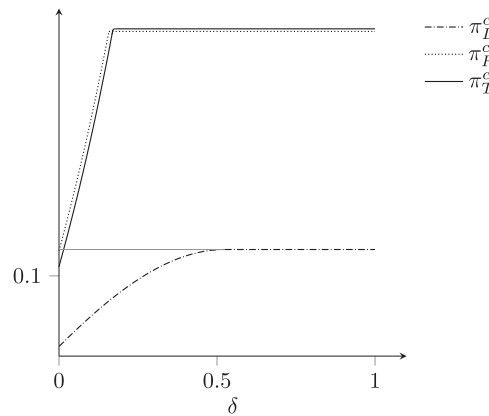


FIGURE 2 Collusive profits in the three scenarios (for $\tau = 0.25$)

5.2 | Unrestricted pricing

For the analysis so far, we have assumed that firms cannot choose the type of pricing structure themselves but are restricted due to regulation. Let us briefly comment on the effects of letting firms freely choose their tariff structure. We consider the case in which they can decide on the pricing strategy when they collude. Note that when a deviating firm cannot be forced to stick to a certain pricing structure, using a two-part tariff is optimal. At the same time, firms use two-part tariffs in the competitive equilibrium.²⁶ Therefore, we consider the following grim-trigger strategy: Firms start by setting the collusive linear and/or fixed prices and continue to do so as long as no firm has deviated in any of the previous periods. If at least one firm deviated in any of the previous periods, firms compete in two-part tariffs forever.

When comparing the resulting, new critical discount factors in the three different pricing scenarios to our previous results (see Table 1), the following two observations are immediate: First, when firms collude on two-part tariffs, the critical discount factor remains unchanged. Second, when firms collude on linear prices, two terms change in the derivation of the critical discount factor: the deviation profit and the punishment profit. Because both profits tend to be higher, the critical discount factor increases. As a consequence, collusion at monopoly prices tends to be more difficult to sustain. Hence, the order of the critical discount factors does not change for these two pricing scenarios. Together with the observation that collusive prices are lowest under linear pricing, we can conclude that firms never opt to collude on linear prices only.

For the case in which firms collude on fixed fees, the effect on the critical discount factor is less clear cut. On the one hand, deviation profits increase, that is, collusion at monopoly prices tends to be more difficult to sustain. On the other hand, punishment is harsher, that is, collusion is facilitated.

Figure 3 illustrates the comparison. We first point out that under fixed fees, the facilitating effect of a harsher punishment is outweighed by the destabilizing effect of a more profitable deviation, that is, the critical discount factor increases compared with the previous analysis. As a consequence, the critical discount factor moves closer to the one under two-part tariffs. There are two scenarios: For low and intermediate values of the transport cost, monopoly prices are still easier to sustain under fixed fees. For high values of the transport cost, the monopoly profit under fixed fees is not much higher than the punishment profit under two-part tariffs, that is, collusion becomes less attractive. As a result, collusion at monopoly prices is easier to sustain under two-part tariffs.

As far as the highest possible collusive profit under unrestricted pricing is concerned, it is clear that for high transport costs, firms would always collude on two-part tariffs. In this case, collusion is easier to sustain, and monopoly profits are higher. The situation is less clear cut for low and intermediate values of the transport-cost parameter. Under fixed fees, it is true that collusion at monopoly prices is easier to sustain, but firms may still make supracompetitive, less-than-maximum profits under two-part tariffs (see Section 5.1). Because the punishment profit is the same for both pricing scenarios, the comparison of the collusive profits is more involved.²⁷

Let us consider the example from Figure 2 again, that is, $\tau = 0.25$. In this case, we have $\bar{\delta}_F \approx 0.1699 < \bar{\delta}_T \approx 0.1787$. Moreover, $\bar{\pi}_F^c \approx 0.1914$. Because $\bar{\pi}_T^c(\bar{\delta}_F) \approx 0.1875$, we can conclude that when firms are not restricted in their pricing pattern, using fixed fees only can still be the best option. This is due to the fact that the lower monopoly profits can be sustained for a broader range of the discount factor, and can be strictly larger than those from partial collusion under two-part tariffs.

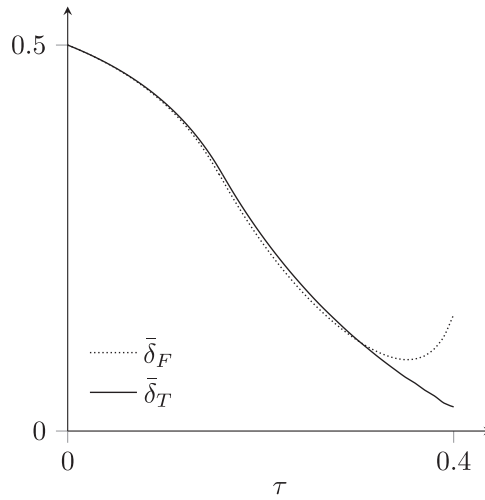


FIGURE 3 Comparison of the critical discount factors for fixed fees and two-part tariffs under unrestricted pricing

5.3 | Positive marginal costs

So far we have assumed that marginal costs are zero. Clearly, this means that the welfare comparison is biased toward the regulatory regime with fixed fees, as by definition firms set the socially optimal linear price. At the same time, firms do not make a loss with each unit supplied under fixed fees. We are, therefore, interested in whether the results from the main section continue to hold for positive marginal costs. We do not present the formal results here, but report the general insights from this case.²⁸

Starting with the critical discount factors, we point out that the result from the main analysis continues to hold qualitatively when introducing a (symmetric) positive marginal cost of production c for the firms (with $c \leq 1/2$). As marginal costs increase, collusion becomes easier to sustain under fixed fees and two-part tariffs for any given value of the transport-cost parameter.²⁹ Under linear pricing, collusion first becomes more difficult to sustain before it is facilitated by the introduction of positive marginal costs. The critical discount factors for the cases in which $c = 0.1$ and $c = 0.2$ are displayed in Figure 4. As can be seen from the figure, the general pattern with regard to the order of the

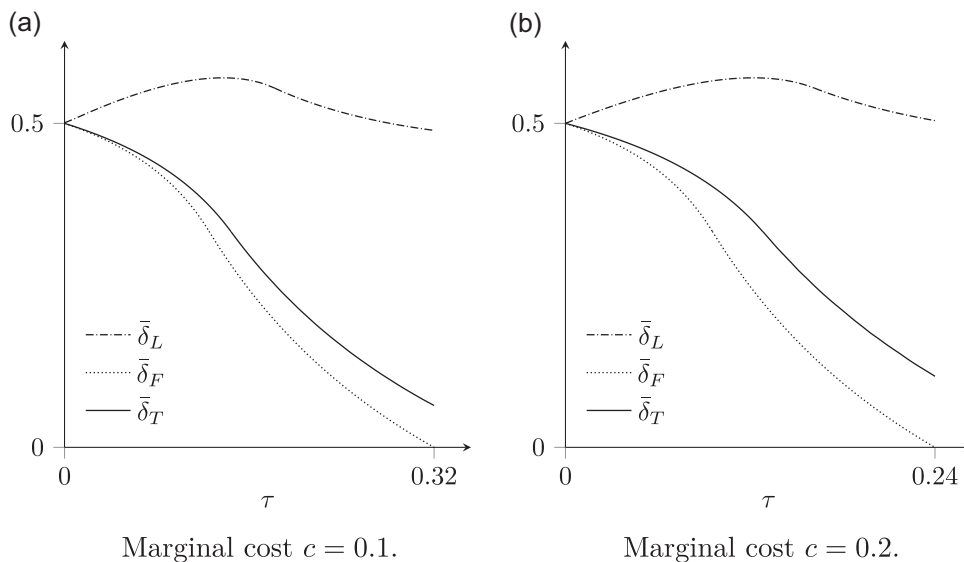


FIGURE 4 Critical discount factors with positive marginal costs. (a) Marginal cost $c = 0.1$ and (b) marginal cost $c = 0.2$

critical discount factors indeed does not change: Collusion at monopoly prices can be sustained for the greatest range of discount factors under fixed fees, whereas full collusion is most difficult to maintain under linear pricing.

With regard to the implications of the two policy interventions, we stress that, again, the policymaker's standard is crucial when deciding whether to opt for one type of intervention or the other. As before, when the authority has a customer standard, it is optimal to ban fixed fees: Independent of the type of market, customers are better off under linear pricing, and collusion may no longer be sustainable.

When the policymaker is interested in maximizing total welfare, there is some slight change compared with the findings in the main part. As before, when marginal costs are rather low, linear prices should be banned independent of the market type. When marginal costs are higher, total welfare is highest under two-part tariffs—again, independent of whether the market is competitive or collusive. This means that banning linear prices is no longer welfare enhancing here, because selling units below cost then results in a welfare loss due to substantial overconsumption. Moreover, allowing price discrimination based on two-part tariffs has the additional benefit that it also makes collusion at monopoly prices more difficult to sustain.

6 | CONCLUSION

Motivated by collusive behavior and regulatory interventions in different industries in which customers face multiple price components, we analyze the outcomes and firms' ability to collude under three different pricing regimes. Our analysis shows that monopoly prices are easiest to sustain with fixed fees. Collusion at monopoly prices can be sustained for the smallest range of the discount factor under linear pricing, as compared with the other two pricing scenarios. We argue that a planner focusing on customer surplus should ban fixed fees. By contrast, banning linear fees tends to maximize total welfare.

The present analysis provides a better understanding of recent antitrust cases. It also has implications for competition policy in a more general context. Consumer protection agencies and policymakers often criticize firms' elaborate pricing schedules contending that they are designed to price discriminate between customers. Authorities often demand that firms reduce the number of pricing components. However, this article highlights that—in contrast to other forms of price discrimination—the implications of such changes are not clear cut. Thus, authorities must be very specific with regard to their regulatory policies. It is true that having fewer instruments to price discriminate among customers at one's disposal can reduce prices customers have to pay in a static context. Indeed, when moving from two-part tariffs to linear prices, we find that customer rents increase. However, undesired anti-competitive consequences may result. Collusion is easier to sustain, and firms end up generating higher supracompetitive profits in a dynamic setting when moving to a simpler pricing regime. This is true when firms must abolish linear prices, and charge fixed fees only. A conclusion from these observations is that it is important for competition authorities to carefully assess what measures achieve the simplification of pricing structures.

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ENDNOTES

¹ Both academics and practitioners have intensely discussed the merits of a ban on wholesale second-degree price discrimination in vertically related industries, but not for the market we analyze in this article.

² Two-part tariffs or nonlinear pricing can be considered a form of second-degree price discrimination (see Varian, 1989) in the sense that all customers are offered the same schedule of price-quantity combinations. When customers are heterogeneous in their demand, they self-select different quantities and, hence, end up paying different per-unit prices. A typical example of two-part tariffs is the use of quantity discounts that take different forms (e.g., loyalty discounts and rebates).

- ³ See, for example, <https://www.ft.com/content/ab44af16-1cbb-11e4-88c3-00144feabdc0> (accessed June 21, 2020) and <https://www.bbc.com/news/business-26734203> (accessed June 21, 2020).
- ⁴ For an overview and a critical evaluation of Ofgem's policy, see Littlechild (2014).
- ⁵ On a more general note, Nunn and Sarvary (2004) empirically analyze the mobile telecommunications industry, using price and quantity data from 10 countries around the world. They find that "market power in different countries may originate from [...] collusive pricing among cellular operators" (p. 377).
- ⁶ Competition in linear prices pretty much came to an end due to the European Commission's recent abolishment of roaming charges in Europe. Most users of mobile services now pay a fixed fee. Until mid-2017, users typically were charged on a PPU basis on top of their fixed fee when they traveled abroad. This type of charging is no longer allowed.
- ⁷ See <https://pulsenews.co.kr/view.php?year=2017&no=536955> (accessed June 21, 2020).
- ⁸ There is a large body of literature on the use of two-part tariffs in monopoly starting with Oi (1971). As far as the formal treatment of competition with nonlinear prices is concerned, Armstrong and Vickers (2001) as well as Rochet and Stole (2002) analyze nonlinear pricing in a setting with both horizontal and vertical heterogeneity, whereas Laffont, Rey, and Tirole (1998) focus on competition in two-part tariffs in the context of access pricing. To isolate the effect of different pricing schemes, we build our analysis on Yin (2004) who focuses on a duopoly model with horizontal product differentiation.
- ⁹ This is a special case of the analysis in Liu and Serfes (2007) with maximally differentiated firms. Further contributions investigating the implications of delivered pricing on collusion are, among others, Jorge and Pires (2008) and Miklós-Thal (2008). In a similar vein, Thisse and Vives (1992) make an early contribution by analyzing collusion in the context of basing point pricing, which also implies individual prices based on customers' locations.
- ¹⁰ In the standard setting with unit demand and without firms' ability to discriminate between customers, lower transport costs make it harder for firms to sustain collusion at maximum prices (Chang, 1991).
- ¹¹ Note that in his setup, firms always punish and deviate using discriminatory prices. This is different from the present setup in which punishment and deviation profits depend on the pricing instruments available to the firms for most of the analysis.
- ¹² We make use of this setup in line with almost all of the contributions mentioned in the Introduction. This allows us to put our results in a broader perspective (see Section 6). A different approach with exogenous asymmetry and two-part tariffs in a homogeneous-product setup is suggested by Griva and Vettas (2015). However, we prefer to use a setup with symmetric firms, because collusive outcomes are less straightforward with asymmetric firms.
- ¹³ Clearly, some comparative statics on firms' location choices would be interesting, but a formal analysis given the type of variable demand we use is beyond the scope of the present article. Note that the effects are a priori not clear cut. First, from the insights in Chang (1991) and Häckner (1996) (see also footnote 16 below), there is a tendency that outcomes regarding the impact of a lower degree of differentiation (closer locations) on collusion qualitatively hold compared with a decrease in transport costs. However, we point out that closer locations have an additional effect in our setup: Apart from intensifying price competition (which is the only effect under unit demand), there is also a positive demand effect.
- ¹⁴ We will relax the assumption of zero marginal costs in Section 5.3.
- ¹⁵ More precisely, we use the shipping model with linear demand which is discussed in Section 3.2 in Yin (2004). As the results in Yin (2004) hold generally (in particular also for a shopping model [Section 3.1]), we conjecture that our results are not driven by the choice of setup either. We use this specific setup, because it allows us to derive tractable results, and because it has been used for the case of collusion under linear pricing before (see Rothschild, 1997). Gu and Wenzel (2009, 2012) take a different approach to modeling elastic demand in this type of scenario. In contrast to the present model, all customers have the same elastic demand in that setup, and the effects of different degrees of demand elasticity can be analyzed.
- ¹⁶ Another form of punishment is the use of optimal penal codes (Abreu, 1986). We are confident that our results do not qualitatively change in light of the results derived in Häckner (1996) for unit demand. Häckner (1996) uses optimal punishments and compares his results to those of Chang (1991) who uses grim-trigger strategies. Häckner (1996) concludes that "the relationship between cartel stability and product differentiation is fairly robust to changes in the punishment mechanism for the class of models characterized by Bertrand competition and horizontal differentiation" (p. 613). Competition in our setup is mainly driven by the fixed fee, which is why we expect the main insights from our analysis to also hold under optimal penal codes.
- ¹⁷ Note that we do not analyze how the price structure affects the design of an optimal leniency policy. Models addressing leniency programs typically rely on a number of parameters and assumptions. For example, one would have to assume an investigation probability, which—following the observations from real-life cartels in Harrington (2006)—could be higher for markets in which fewer pricing instruments are used. To ensure comparability with the above-mentioned contributions, we restrict our focus to the regulation of pricing and price components.
- ¹⁸ Note that the results for the collusive scenarios are first derived under the assumption that collusion can be maintained, that is, the incentive-compatibility constraint is not binding here. In Section 5.1, we analyze the case in which such full collusion is not sustainable.

- ¹⁹ Indeed, we arrive at the same result when we assume that firms set fixed fees and linear prices sequentially. In a different context in which two products exhibit demand complementarity, Young (1991) also reports that collusion only affects the fixed fee and not the per-unit charge.
- ²⁰ This also explains why firms make higher competitive profits under fixed fees only, compared with the case with linear pricing (see Table 1).
- ²¹ Recall that the difference in linear prices under competition and collusion is larger for linear pricing than for two-part tariffs where this difference is zero (Observation 1).
- ²² See Section 5.3 for the case with positive marginal costs.
- ²³ Under linear pricing, even the indifferent customer is left with a positive surplus. This is because the firms optimize against a linear demand function. Furthermore, it can be shown that optimal collusion involves serving the customer located at the center only if $\tau \leq 2/3$, which holds under Assumption 1.
- ²⁴ The order of the critical discount factors also holds for an alternative setup with horizontally differentiated firms located along the circular city (Salop, 1979). In particular, the number of firms does not affect the order.
- ²⁵ In the standard setup with constant demand, Chang (1991) shows that a price above the competitive price can be sustained as long as firms are (slightly) differentiated. See also Rasch and Wambach (2009) for a similar analysis.
- ²⁶ This can be seen from the best-response functions in the two-part-tariff regime in which the competitor sets a linear price and a fixed fee equal to zero, respectively.
- ²⁷ In terms of Figure 2, it is not obvious that the two relevant lines intersect.
- ²⁸ The formal results are available from the authors upon request.
- ²⁹ Note that in this case, the upper bound for the transport cost needs to be adjusted to $2(1 - 2c)/5$.
- ³⁰ Given a lower collusive fixed fee, a deviating firm may abstain from serving the whole market even for $\tau < \bar{\tau}_F$. For this to be true, it can be shown that the discount factor must be sufficiently small ($\delta \leq 1/3$), such that the δ -adjusted fixed fee is low enough. Contact authors for details.

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APPENDIX A

A.1 Proof of Lemma 2

For the proof, it is helpful to rewrite the profit function of the deviating firm as a function of the linear prices of both firms, the fixed fee of the firm that sticks to collusion, and the expression for marginal customer. Consider firm 1 without loss of generality. Maximization is then over p_1 and \tilde{x} . The idea is that the deviating firm can choose the optimal market size and, given the market size, the optimal linear price. Solve the condition for the indifferent customer for firm 1's fixed fee. The profit function of firm 1 is then given by

$$\pi_{1,T}^d(p_1, \tilde{x}; \bar{p}_T^c, \bar{f}_T^c) = p_1 \int_0^{\tilde{x}} (1 - p_1 - \tau x) dx + \left(\frac{(1 - p_1 - \tau \tilde{x})^2}{2} - \frac{(1 - \bar{p}_T^c - \tau(1 - \tilde{x}))^2}{2} + \bar{f}_T^c \right) \tilde{x}.$$

Differentiating with respect to p_1 gives

$$\frac{\partial \pi_{1,T}^d}{\partial p_1} = -p_1 \tilde{x} + \frac{\tau \tilde{x}^2}{2},$$

differentiating the profit function with respect to \tilde{x} leads to

$$\frac{\partial \pi_{1,T}^d}{\partial \tilde{x}} = \frac{1}{2} - \frac{p_1^2}{2} + p_1 \tau \tilde{x} + \frac{\tau}{2} - \frac{\tau^2}{2} - 4\tau \tilde{x} + \frac{5\tau^2 \tilde{x}}{2}.$$

Solving for p_1 and \tilde{x} leads to

$$p_{1,T}^d = \frac{8 - 5\tau - A}{3}$$

and

$$\tilde{x}_T^d = \frac{16 - 10\tau - 2A}{3\tau}.$$

Given these two critical values, we now check whether second-order conditions are satisfied, that is, whether they constitute a maximum of the profit function. The Hessian of the profit function is given by

$$H(p_1, \tilde{x}) = \begin{bmatrix} -\tilde{x} & -p_1 + \tau\tilde{x} \\ -p_1 + \tau\tilde{x} & p_1\tau - 4\tau + \frac{5\tau^2}{2} \end{bmatrix}.$$

The determinant of the Hessian is given by

$$D(p_1, \tilde{x}) = -p_1^2 + p_1\tau\tilde{x} + 4\tau\tilde{x} - \frac{5\tau^2\tilde{x}}{2} - \tau^2\tilde{x}^2.$$

It follows that the pair $(p_{1,T}^d, \tilde{x}_T^d)$ is a local maximum if $D(p_{1,T}^d, \tilde{x}_T^d) > 0$ and $\partial^2\pi_{1,T}^d/\partial p_1^2|_{p_1=p_{1,T}^d, \tilde{x}=\tilde{x}_T^d} < 0$. Substituting the critical values into the determinant and simplifying gives

$$D(p_{1,T}^d, \tilde{x}_T^d) = \frac{A(8 - 5\tau - A)}{3}.$$

Observe that $D(p_{1,T}^d, \tilde{x}_T^d)$ is a function of τ only, define it $D(p_{1,T}^d, \tilde{x}_T^d) =: K(\tau)$. $K(\tau)$ has three roots, one at $\tau = 1/2 - \sqrt{5}/2 \approx -0.618$, a second one at $\tau = 83/56 + \sqrt{57}/56 \approx 1.617$, and a third one at $\tau = 83/56 - \sqrt{57}/56 \approx 1.347$. As none of these roots is in the range of τ as defined by Assumption 1, it follows that $K(\tau)$ does not have any roots in the relevant range. Substituting a valid value into $K(\tau)$ leads to $K(0.1) \approx 0.537$. It follows that $D(p_{1,T}^d, \tilde{x}_T^d) > 0$. The second condition follows immediately, $\partial^2\pi_{1,T}^d/\partial p_1^2 = -\tilde{x} < 0$ as $\tilde{x} \in [0, 1]$.

The resulting optimal fixed fee $f_{1,T}^d$ follows from substituting the collusive values of firm j , $p_{1,T}^d$, and \tilde{x}_T^d into expression (1), and solving for f_1 . Re-substituting the optimal values into the profit function leads to the deviation profit for large τ .

Clearly, \tilde{x}_T^d cannot exceed 1. Solving $\tilde{x}_T^d \leq 1$ for τ leads to

$$\tau \leq \frac{14}{19} - \frac{2\sqrt{30}}{19} = \tilde{\tau}_T.$$

For $\tau > \tilde{\tau}_T$, the optimal deviating values are given by $p_{1,T}^d$ and $f_{1,T}^d$. For $\tau \leq \tilde{\tau}_T$, the optimal linear price is derived by substituting $\tilde{x} = 1$ into the first-order condition and solving for p_1 , leading to

$$p_{1,T}^d = \frac{\tau}{2}.$$

The optimal fixed fee is calculated by setting $\tilde{x} = 1$, substituting firm j 's collusive values and the optimal linear price of firm i into equation (1) and solving for f_i which gives

$$f_{1,T}^d = \frac{1}{2} - 2\tau + \frac{11\tau^2}{8}.$$

The respective profit follows immediately.

A.2 Proof of Lemma 5

The optimal deviation fixed fee set by firm 1 when the other firm sets pricing according to the collusive agreement is determined by maximizing the profit function $\pi_{1,F}^d(f_1; \bar{f}_F^c)$ over f_1 . The partial derivative is given by

$$\frac{\partial \pi_{1,F}^d}{\partial f_1} = \frac{4 - 16f_1 + 4\tau - 3\tau^2}{8\tau(2 - \tau)}.$$

Observe that the second-order condition is satisfied due to Assumption 1. Solving the first-order condition for f_1 leads to $f_{1,F}^d = (2 - \tau)(2 + 3\tau)/16$. Given $f_{1,F}^d$, we have to ensure that the market share of the deviating firm does not exceed 1, that is, $\tilde{x}(f_{1,F}^d, \bar{f}_F^c) \leq 1 \Leftrightarrow \tau \geq 2/13$. Thus, for $\tau \geq 2/13$, the optimal deviation fixed fee is $f_{1,F}^d$. For $\tau \leq 2/13$, the optimal fixed fee is set such that the indifferent customer is at location $x = 1$: $\tilde{x}(f_1, \bar{f}_F^c) = 1 \Rightarrow f_{1,F}^d = 1/2 - 3\tau/2 + 5\tau^2/8$. Plugging the respective fixed fees into the profit function (2) leads to the deviation profit.

A.3 Partial collusion

We demonstrate the formal derivation of the optimal collusive price under partial collusion for the case in which firms must use fixed fees. The other pricing regimes can be analyzed in an analogous fashion but are less tractable.

We start by deriving the optimal deviation under partial collusion. To this end, suppose that the competitor sticks to collusion and sets a fixed fee of $f_F^c \leq \bar{f}_F^c$. Consider the case in which $\tau > \tilde{\tau}_F$, which means that a deviating firm does not want to serve the whole market under collusion at monopoly prices. Now if the collusive fixed fee has to be adjusted downwards to sustain collusion, a deviating firm is even less interested in capturing the whole market. Then, maximizing the deviating firm's profit function yields the following optimal deviation fixed fee:

$$\max_{f_F^d} \pi_F^d(f_F^d; f_F^c) = f_F^d \left(\frac{1}{2} - \frac{f_F^d - f_F^c}{\tau(2 - \tau)} \right) \Rightarrow f_F^d(f_F^c) = \frac{f_F^c}{2} + \frac{\tau(2 - \tau)}{4}.$$

Given this fixed fee, the profit amounts to

$$\pi_F^d(f_F^c) = \frac{(2f_F^c + \tau(2 - \tau))^2}{16\tau(2 - \tau)}.$$

In order for collusion to be maintained when firms play grim-trigger strategies, it must hold that

$$\frac{\pi_F^c(f_F^c)}{1 - \delta} \geq \pi_F^d(f_F^c) + \frac{\delta \pi_F^*}{1 - \delta} \Leftrightarrow \frac{f_F^c}{2(1 - \delta)} \geq \frac{(2f_F^c + \tau(2 - \tau))^2}{16\tau(2 - \tau)} + \frac{\delta \pi_F^c}{1 - \delta}.$$

Solving this inequality for f_F^c gives the following optimal δ -adjusted collusive fixed fee, such that collusion can be just maintained:

$$f_F^c(\delta) = \frac{\tau(2 - \tau)(-1 + 3\delta)}{2(1 - \delta)}.$$

Note that $\partial f_F^c / \partial \delta > 0$, $f_F^c(0) = f_F^*$, and $f_F^c(\bar{\delta}_F) = \bar{f}_F^c$.³⁰ The resulting maximally sustainable collusive profit is then given as

$$\pi_F^c(\delta) = \frac{\tau(2 - \tau)(-1 + 3\delta)}{4(1 - \delta)}.$$

It holds that $\partial \pi_F^c / \partial \delta > 0$, $\pi_F^c(0) = \pi_F^*$, and $\pi_F^c(\bar{\delta}_F) = \bar{\pi}_F^c$ (see also Figure 2).

The derivation of the respective optimal partial prices under two-part tariffs is more involved. This has to do with the fact that the participation constraint usually is satisfied for an indefinitely large number of combinations of the linear price and the fixed fee. From these combinations, we focus on those that maximize the collusive profit. The maximization problem is given as follows:

$$\begin{aligned}
 & \max_{p_T^c, f_T^c} \pi_T^c(p_T^c, f_T^c; p_T^c, f_T^c) \\
 & \text{s.t. } \frac{\pi_T^c(p_T^c, f_T^c; p_T^c, f_T^c)}{1 - \delta} \geq \pi_T^d(p_T^d, f_T^d; p_T^c, f_T^d) + \frac{\delta \pi_T^*}{1 - \delta}, \\
 & U\left(q; \frac{1}{2}; p_T^c, f_T^c\right) \geq 0.
 \end{aligned}$$

We abstain from presenting the respective expressions, but point out that firms find it profitable to set a strictly positive linear fee. For the case in which firms can only set linear prices, the derivation of less-than-monopoly collusive profits works analogously.