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Manufacturer Collusion: Strategic Implications of the Channel Structure*

Markus Reisinger† Tim Paul Thomes‡

July 2017

Abstract

We investigate how the structure of the distribution channel affects tacit collusion between manufacturers. When selling through a common retailer, we find—in contrast to the conventional understanding of tacit collusion that firms act to maximize industry profits—that colluding manufacturers strategically induce double marginalization so that retail prices are above the monopoly level. This lowers industry profits but increases the profit share that manufacturers appropriate from the retailer. Comparing common distribution with independent (exclusive) distribution, we show that the latter facilitates collusion. Despite this result, common retailing leads to lower welfare because a common retailer monopolizes the downstream market. For the case of independent retailing, we also demonstrate that contract offers that are observable to the rival retailer are not necessarily beneficial for collusive purposes.

Keywords: tacit collusion; contract observability; common retailing; independent (exclusive) retailing; two-part tariffs; wholesale price contracts

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1 Introduction

Large manufacturers which sell their products through retailers are often long-term competitors. An example is the automobile industry, where in many countries few big producers control a large share of the market over a long time horizon. For example, General Motors, Ford, Chrysler, and Toyota have supplied around 60% of the US market during the last ten years with relatively stable shares (Plunkett 2012).[1] Almost without exception, car producers sell to final consumers via authorized non-integrated dealers.[2]

A similar pattern applies to the market for beauty products, cosmetics and toiletries. This market is dominated by few established players, such as Estée Lauder, L'Oreal, Procter & Gamble, and Unilever.[3] In contrast to the automobile industry, these companies typically follow a strategy of running a strong wholesale business with retailers carrying the products of multiple competing manufacturers.[4]

The existing literature has pointed out that the channel structure has important effects on manufacturers' profits (see, e.g., O'Brien and Shaffer 1997 or Cachon and Kök 2010 on common (multi-brand) retailing, and Bonanno and Vickers 1988 or Rey and Stiglitz 1995 on independent (exclusive) retailing).[5] This literature takes a static perspective, that is, it examines the strategic implications of different forms of the structure in a one-shot game. It therefore neglects the effects that the distribution channel may have on repeated interaction between manufacturers. Likewise, the literature on long-term cooperation and collusion between manufacturers has ignored channel considerations. Most papers assume that firms sell directly to final consumers, whereas papers explicitly considering the vertical relationship between manufacturers and retailers (e.g., Nocke and White 2007, or Jullien and Rey 2007) focus on vertical integration or the effects of contracts within the channel. However, in most industries (i) dynamic considerations play an important role, implying that manufacturers likely base their pricing decisions not only on current but also on past prices, and (ii) manufacturers sell their products via retailers to final consumers, implying that the channel structure affects pricing decisions.

[1] Similar or even bigger numbers can be found in Europe, where domestic producers control a large part of the market in most countries.

[2] As reported by Maxton and Wormald (2004), the average number of brands per dealer is around 1.2 in Europe and 2.4 in the US.

[3] For example, in the haircare segment, which accounts for about 24% of the industry's total revenue (Panteva 2011), L'Oreal and Procter & Gamble together have a market share well above 40% (Trefis Analysis 2011).

[4] As pointed out by Panteva (2011), mass merchandisers, supermarkets, drugstores and department stores account for the lion's share of the industry's sales at the retail level.

[5] We provide an overview of the relevant literature in the next section.

In fact, several empirical studies provide evidence consistent with the conjecture that pricing in many industries is based on long-term competitive dynamics. Studying the automobile industry, Sudhir (2001a) demonstrates that prices in the compact and midsize segment of the US car market during the 1980s are indicative of manufacturer collusion and cannot be explained by short-term competition.[6] Similar observations can be made in markets where the prevalent channel structure is common retailing. For example, in the soft drink industry, Saltzman et al. (1999) provide detailed evidence that bottlers colluded on the prices charged to supermarkets and general merchandisers during the 1980s and the early 1990s. Likewise, using data on food categories for two suburban retail stores, Sudhir (2001b) finds that manufacturer pricing is consistent with cooperation.

Building on these considerations, the objective of this paper is to examine how the structure of the distribution channel affects the strategic choices of manufacturers aiming to achieve cooperative outcomes. We seek to address the following questions on the channel structure in a dynamic setting. *How does the channel structure affect collusive behavior between manufactures? Are cooperation strategies under common retailing fundamentally different from those under independent retailing? How does contract observability affect tacit collusion between competing manufacturers? Which channel structure leads to a higher welfare? Are the findings robust to changes in the contractual form?*

To answer these questions, we consider a simple infinitely-repeated game with two single-product manufacturers contracting either with a common retailer or with independent (exclusive) retailers. In the baseline model, the contractual form is a two-part tariff.[7] We focus on tacit collusion between manufacturers and determine contracting decisions in the collusive agreement and the critical discount factors above which collusion can be sustained. For expositional simplicity, we suppose that the retailer (or the retailers) are short-lived. However, we demonstrate that all our results carry over to the case of long-lived retailers. Within this framework, the channel structure has several distinct effects on manufacturers' collusion.

Concerning the first research question, we show that when manufacturers sell through a common retailer, tacit collusion works in a fundamentally different way than in case they sell directly to final consumers. In particular, colluding manufacturers propose contracts with per unit wholesale prices above marginal cost, deliberately accepting *double marginalization.* Thus, the industry profits under collusion are not maximized and even *below* those of the static game. However, in doing so, manufacturers obtain a larger share of the channel profits.

[6] Bresnahan (1987) reaches an analogous conclusion when analyzing the pricing behavior in this industry during the 1950s.

[7] In an extension, we analyze linear wholesale price contracts and compare the results.

The intuition underlying this finding lies in the common retailer's opportunity to threaten a manufacturer with rejecting his offer and only selling the rival's product. This effect allows the retailer to pit manufacturers against each other and keep part of the industry profits. We show that when tacitly colluding, manufacturers face a trade-off between maximizing channel profits and mitigating the common retailer's opportunity of rejecting one contract offer. Our analysis reveals that they achieve the latter by raising the collusive wholesale price above the industry profit maximizing level. Setting the collusive wholesale price sufficiently high lowers the common retailer's profit from selling only one manufacturer's product, thereby squeezing the share of the industry profits that can be kept by the retailer. By contrast, when manufacturers compete against each other (as in the static game), each one offers a contract that maximizes the bilateral profit of the manufacturer and the retailer, which avoids double marginalization and maximizes channel profits. Thus, the manufacturers' collusive strategy is to get a larger share of a smaller 'pie'.

Instead, when manufacturers sell through independent (exclusive) retailers, tacit collusion works in a similar way as in the case in which manufacturers sell directly to final consumers. This holds independently of whether or not contracts are observable to the rival retailer. An independent retailer obtains only an offer from the own manufacturer, thereby lacking the opportunity to sell a different product. Therefore, colluding manufacturers set wholesale prices that maximize industry profits.

We then compare the channel structures with respect to their impact on the stability of manufacturer collusion. As explained above, the common retailer can keep part of the industry profits. This leads to higher collusion profits for manufacturers under independent retailing. However, for the same reason, manufacturers can also realize higher static profits and therefore higher profits along the punishment phase with independent retailers.

We demonstrate that the result is nevertheless unambiguous in favor of independent retailing due to a novel effect: defection from collusion implies that the deviant induces the common retailer to reject the offer of the non-deviating manufacturer because the low wholesale price of the deviant makes the rival manufacturer's contract unattractive for the common retailer. This leads to monopolization of the downstream market. Therefore, the ratio between deviation and collusion profits is higher under common retailing than under independent retailing, implying that the incentive to deviate is larger in the former regime. As a consequence, manufacturer collusion can be sustained for a larger range of discount factors if products are sold through independent retailers.

Despite this result, we show that welfare is larger with independent retailers. The reason is that a common retailer sets monopoly prices in the downstream market, whatever the wholesale prices manufacturers have chosen. Even if the discount factor is such that manufacturer collusion is possible under independent retailing but not under common retailing, the effect that downstream competition is eliminated under the latter dominates.

We then turn to the question if contract observability facilitates collusion under independent retailing. Previous studies on static models (e.g., Coughlan 1985, Rey and Stiglitz 1995) find that contract observability gives rise to a strategic effect: manufacturers set higher wholesale prices, resulting in a dampening of the competitive pressure in the retail market and in higher profits. Thus, in a static framework, contract observability is always profitable.

In a dynamic setting, we demonstrate that contract observability imposes two opposing effects on the sustainability of manufacturer collusion. One the one hand, retailers can immediately react to a deviation of the rival manufacturer, which makes collusion more stable. On the other hand, due to the strategic effect, the punishment following a deviation is less severe, leading to a destabilization of collusive agreements. We show that the second effect dominates if products are close substitutes. The intuition is that in this case the retailer of the non-deviating manufacturer is constrained by the high wholesale price and the possibility to react immediately loses importance. As a consequence, we obtain that observable contracts facilitate collusion if competition is low or moderate, whereas private contracts are more suitable for collusive purposes if competition is fierce. This result provides a strategic rationale for secret contracting, which is not encompassed by static models.

Finally, we show that the main insights derived with two-part tariffs carry over to the case with linear wholesale price contracts.[8] In particular, tacit collusion under common retailing leads to increased wholesale prices which lower channel profits but increase the share manufacturers can keep. Turning to independent retailing, the only difference is that contract observability unambiguously favors collusion. The intuition is that, due to the strategic effect, manufacturers need a lower wholesale price under public contracts to realize identical collusion profits as under private contracts. This makes deviation always more profitable under secrecy of contracts.

Our paper has also interesting implications for antitrust authorities. It demonstrates that a distribution channel of exclusive retailers is more prone to collusion compared to a channel with a common retailer. For example, the "Guidelines on Vertical Restraints" issued by the European Commission state that "(when) most or all of the suppliers apply exclusive distribution this may (...) facilitate collusion."[9] Our paper provides a rationale for this statement by demonstrating a clear mechanism why this effect occurs. However, this does not imply that independent retailing is anticompetitive relative to common retailing. Therefore, it does not justify to consider the former channel structure more suspiciously.

[8]Linear wholesale price contract are still prominent in many industries due to their simplicity.

[9]See p. 45, European Commission (2010), Guidelines on Vertical Restraints.

The rest of the paper is organized as follows: Section 2 presents the relation to previous literature. Section 3 sets up the model. Section 4 characterizes the equilibrium under common retailing. Section 5 provides the equilibrium analysis in case manufacturers sell through independent retailers for both secret and public contracts. Section 6 studies sustainability of cooperation under the different channel structures and provides a welfare analysis. Section 7 analyzes linear wholesale price contracts, and Section 8 concludes.

2 Relation to the Literature

This paper contributes to the literature on competition in manufacturer-retailer relationships in several aspects. First, it extends the recent and growing literature on collusion in vertical settings. This literature started with Nocke and White (2007) who analyze whether vertical integration can facilitate tacit collusion between manufacturers under two-part tariffs. They show that this is indeed the case because the downstream affiliate of the integrated firm is no longer a potential buyer for a deviating manufacturer.[10] Normann (2009) considers linear upstream contracts and shows that a similar result obtains even with double marginalization. Jullien and Rey (2007) demonstrate in a model with stochastic demand that resale price maintenance reduces profits in a static framework, but helps to facilitate collusion because it simplifies the detection of deviations. Piccolo and Reisinger (2011) analyze exclusive territories and find that they help to sustain collusion if wholesale contracts are observable because this enables retailers to react to deviations. Piccolo and Miklòs-Thal (2012) analyze collusion at the retail level and find that retailers can collude through manufacturers via above-cost wholesale prices and negative fixed fees. Finally, Gilo and Yehezkel (2016) consider collusion between retailers and a common supplier. They show that the presence of a common supplier helps retailers to sustain collusion (that is, vertical collusion is easier to maintain than horizontal collusion) and demonstrate how collusion profits are distributed between the firms as the discount factor varies.[11]

To the best of our knowledge, our paper is the first one analyzing the effects of different channel structures on manufacturer collusion in a dynamic framework and how changes in the contractual form affect the respective outcomes.[12]

[10] Nocke and White (2010) conclude that the ability to collude is stronger, the larger the size of the integrated downstream buyer.

[11] Schinkel et al. (2008) consider a model in which retailers can sue manufacturers when wholesale prices exceed those of a competitive environment. They demonstrate that allowing only direct retailers to claim damages facilitates collusion because manufacturers can pay them in exchange for not suing.

[12] Gabrielsen (1997) also studies common and independent retailing in an infinitely repeated game. However, in contrast to our analysis, he does not consider the collusive effects of the channel structure.

Our paper also relates to the work analyzing strategic effects of the channel structure in static environments. One strand of this work focuses on a framework with multiple manufacturers and a common retailer. For example, Choi (1991) analyzes wholesale price contracts and distinguishes between the scenarios in which either manufacturers or retailers are the Stackelberg price leader. O'Brien and Shaffer (1997) analyze the effects of non-linear contracts and exclusive dealing on foreclosure incentives. They show that exclusive dealing leads to lower equilibrium profits for manufacturers than contracts allowing the retailer to carry both brands.[13] Finally, Cachon and Kök (2010) examine the impact of different contractual forms and find that two-part tariffs and quantity-discount contracts may be disadvantageous for manufacturers compared to wholesale price contracts if products are close substitutes.

A second strand of research focuses on competition between multiple manufacturers selling through independent (exclusive) retailers. McGuire and Staelin (1983) demonstrate that independent retailing leads to a dampening of retail competition and can therefore be preferred by manufacturers to vertical integration.[14] Bonanno and Vickers (1988) demonstrate that this is also the case if manufacturers employ two-part tariffs. In a similar vein, Rey and Stiglitz (1995) emphasize the strategic effect of exclusive distribution and show that two-part tariffs dominate wholesale price contracts.

Lin (1990) provides a comparison between independent and common retailing. He demonstrates that the competition-dampening strategic effect makes independent retailing more profitable for manufacturers. O'Brien and Shaffer (1993) point out that this is not the only reason why manufacturers prefer independent retailing: they show that a common retailer can keep part of the profits due to the threat of rejecting one contract offer. In contrast to all of these papers, our work considers a dynamic framework.

The comparison between distinct channel structures also motivates the literature on common agency. In their seminal paper, Bernheim and Whinston (1985) analyze an industry structure in which manufacturers delegate marketing activities to merchandise agents and offer different contracts for common and exclusive agents. They show that a common agent leads to collusive pricing and is therefore preferred by manufacturers. However, in contrast to Lin (1990) and O'Brien and Shaffer (1993), manufacturers have the outside option to hire another agent if their offer is rejected by a common agent.

Since then, several papers in the common agency literature offered explanations for why manufacturers may benefit from exclusive agents. Gal-Or (1991) assumes that agents have

[13] A detailed analysis of the implications of exclusive dealing is provided by Bernheim and Whinston (1998).

[14] Moorthy (1988) analyzes a generalization of the model and shows under which conditions this effect occurs.

private information about their costs that is correlated. She shows that a common agent can secure higher information rents due to the ability to provide manipulated information to both manufacturers and not just one. Besanko and Perry (1993) analyze the case in which manufacturers can make demand enhancing investments. In case of common agency, such investments entail positive spillovers on the rival. They show that this can induce manufacturers to choose exclusive dealing. Martimort (1996) considers a related model to Gal-Or (1991) in a more general setting. He confirms the finding that exclusive agency occurs if the information asymmetry between manufacturers and agents is strong (because the information rent kept by an exclusive agent is lower). Our paper provides another explanation for why manufacturers prefer exclusive distribution based on collusive considerations.

Finally, the paper also contributes to the literature on the observability of wholesale contracts. Coughlan and Wernerfelt (1989) and Caillaud and Rey (1995) show that the strategic effect, which dampens retail competition, is only present if wholesale contracts are observable.[15] Manufacturers therefore prefer contracts that can be observed by the rival retailer.[16] Our analysis demonstrates that this is no longer necessarily true in an infinitely repeated game given that the contractual form is a two-part tariff.

3 The Model

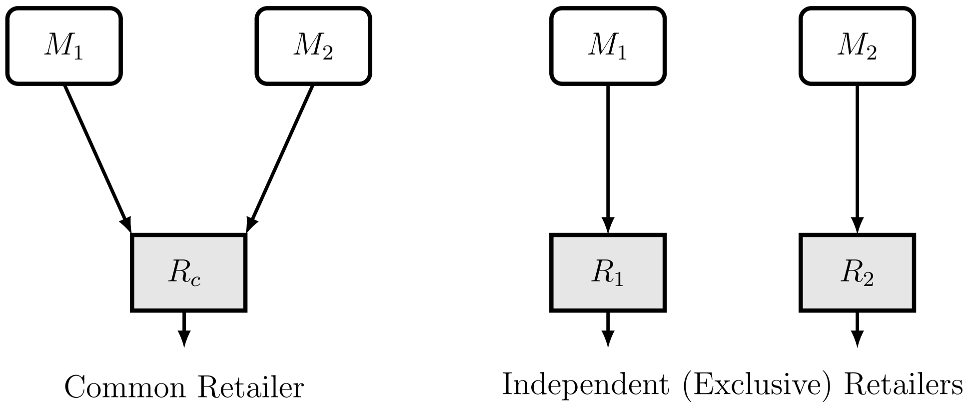
3.1 Players & Environment

Consider competition between two manufacturers, M_1 and M_2, which sell imperfect substitute products. We distinguish between two channel structures: *i*) the goods are sold through a common retailer and *ii*) the goods are sold through independent retailers. The two structures are displayed in Figure 1. The retailing technology is one-to-one, and the final demand for manufacturer M_i's product is $D^i(p_i, p_j)$, where p_i and p_j are the retail prices, with $i, j = 1, 2$ and $i \neq j$. The cost functions of manufacturers and retailers are linear with marginal cost normalized to zero.

[15] For a detailed analysis why secret wholesale contracts can nevertheless matter for market outcomes, see Katz (1991).

[16] Pagnozzi and Piccolo (2011) show that this result also hinges on the assumption on retailers' conjectures about their rivals' contracts. For example, the result can be reverted if retailers hold symmetric conjectures instead of the commonly used passive conjectures.

Figure 1: Distribution Channel Structure: Common vs. Independent Retailing



3.2 Contracts

Each manufacturer M_i offers a two-part tariff contract $C_i(w_i, T_i)$ either to his independent retailer R_i or to the common retailer R_c.[17] This contract specifies the wholesale price w_i and the franchise fee T_i a retailer must pay to M_i when accepting the contract. A common retailer observes the offered contracts of both manufacturers before deciding about acceptance or rejection. If there are two independent retailers R_i and R_j, we consider both the scenario that a retailer can and cannot observe the contract offered to its rival.

3.3 Timing

We consider an infinitely repeated game with discrete time $t = 0, ..., \infty$. As in many papers in the literature on tacit collusion in vertically related markets (e.g., Jullien and Rey 2007, Nocke and White 2007, or Normann 2009), our focus is on manufacturer collusion. Manufacturers have a common discount factor $\delta \in [0, 1]$. In the main analysis, the retailer (or the retailers) maximizes spot profits.[18] After the equilibrium analysis of both channel structures, we demonstrate that our insights remain valid if retailers are far-sighted as well.

The timing of events in the stage game is as follows. First, manufacturers simultaneously offer wholesale contracts $C_i(w_i, T_i)$ to either the common retailer R_c or the respective independent retailer R_i. Second, retailers accept or reject the contract offer(s). In case R_i rejects the contract offer, or R_c rejects both offers, the retailer obtains an outside option normalized to zero. Afterwards, retailers set downstream prices and the consumer market clears, that is, final demand materializes and input orders are placed.

[17]In what follows, we refer to a retailer by 'she' and to a manufacturer by 'he'.

[18]In fact, the competition policy guidelines on vertical market relationships both in the US and the EU focus exclusively on manufacturer collusion.

3.4 Tacit Collusion

If manufacturers collude, they maximize their discounted joint profits. We assume that collusion is sustained by Nash-reversion trigger strategies. That is, deviation by one manufacturer from collusion is punished by playing the Nash equilibrium of the stage game forever. We note that although manufacturers cannot observe contracts, a manufacturer can infer a deviation by the rival because he observes the input order of the retailer in each period.

We determine the value of the critical discount factor above which collusion is sustainable for each channel structure. We say that a structure facilitates collusion relative to the other if the critical discount factor is lower.

3.5 Assumptions & Equilibrium Concept

We develop our analysis under the following simplifying assumptions:

A1. The inverse demand function for product i is $P^i(q_i, q_j) = \alpha - \beta q_i - \gamma q_j$, for $i = 1, 2$, where q_i is product i's total quantity.[19] We assume that $\alpha > 0$ and $\beta > \gamma \geq 0$. The parameter γ measures the substitutability between products. The products are perfect substitutes if $\gamma = 1$, whereas each manufacturer is a monopolist if $\gamma = 0$. As there is price competition in the retail market, the system of inverse demand functions is inverted to get

$$D^i(p_i, p_j) = \frac{\alpha(\beta - \gamma) - \beta p_i + \gamma p_j}{\beta^2 - \gamma^2} \quad \text{for} \quad i = 1, 2.$$

If only one product (i.e., product i) is sold, then $q_j = 0$ or $p_j \to \infty$, leading to an inverse demand function of $P^i(q_i, 0) = \alpha - \beta q_i$. Hence, the direct demand function is then $D^i(p_i, \infty) = (\alpha - p_i)/\beta$. This linear demand specification allows us to derive our results in the simplest possible way.

A2. A retailer will accept a contract offer when being indifferent between accepting and rejecting it. This assumption allows to restrict attention to equilibria with positive sales. Our solution concept is perfect Bayesian equilibrium because our model involves unobservable actions.

[19] This inverse demand results from a representative consumer with utility function

$$U(q_i, q_j) = \sum_{i=1}^{2} \left(\alpha q_i - \frac{1}{2} \beta q_i^2 \right) - \gamma q_1 q_2 - \sum_{i=1}^{2} p_i q_i + m,$$

where m denotes income. Maximizing the utility function with respect to q_i, $i = 1, 2$, yields the inverse demand function above.

4 Common Retailer

Downstream Stage

We start with the case in which manufacturers distribute their products through a single retailer. When accepting the contract offers of both manufacturers, the common retailer's maximization program is given by

$$\pi_c(p_i, p_j) = D^i(p_i, p_j)(p_i - w_i) + D^j(p_j, p_i)(p_j - w_j) - T_i - T_j. \tag{1}$$

The first-order conditions providing a solution to (1) are given by the following system:[20]

$$(p_i - w_i)\frac{\partial D^i(p_i, p_j)}{\partial p_i} + D^i(p_i, p_j) + (p_j - w_j)\frac{\partial D^j(p_j, p_i)}{\partial p_i} = 0, \quad i = 1, 2. \tag{2}$$

The optimal retail prices are not affected by the fixed fees.

The common retailer is not obliged to sell both products. She can reject one offer and distribute only the other product. Suppose R_c rejects the offer of M_i and sells only product j. Her profit function is then

$$\pi_c^j(w_j) = \max_{p_j} D^j(p_j, \infty)(p_j - w_j) - T_j. \tag{3}$$

This implies that R_c optimally sets the monopoly price for product j given the wholesale price w_j. Let us denote this monopoly price by $p_j^M(w_j)$. R_c's profit is then the monopoly profit minus the fixed fee T_j. Hence, although R_c does not have the power to offer contracts, threatening to reject a contract offer provides her with the opportunity to pit one manufacturer against the other, thereby allowing her to obtain a positive profit.

Upstream Stage and Collusion

In what follows, we first analyze the stage game equilibrium that arises along the punishment phase if manufacturer collusion breaks down. We then determine the collusive outcome.

In either case, R_c's option to reject one offer implies that a representative manufacturer M_i can maximally extract his product's marginal contribution to R_c's profit. This marginal contribution is the profit of R_c in case she accepts both offers, which is given by the optimized value of $\pi_c(p_i, p_j)$, minus the profit she obtains when only accepting M_j's contract, which is given by (3). Denoting by $\mathbf{w} = (w_1, w_2)$ the vector of wholesale prices, M_i maximizes his

[20] Second-order conditions are globally satisfied as long as D^i and D^j are concave or not strongly convex. Hence, they are satisfied with linear demand.

stage game profit

$$\Pi_i = D^i(p_i(\mathbf{w}), p_j(\mathbf{w}))w_i + T_i,$$

subject to the common retailer's participation constraint

$$D^i(p_i(\mathbf{w}), p_j(\mathbf{w}))(p_i(\mathbf{w}) - w_i) + D^j(p_j(\mathbf{w}), p_i(\mathbf{w}))(p_j(\mathbf{w}) - w_j) - T_i - T_j \geq \pi_c^j(w_j). \quad (4)$$

Evidently, the participation constraint must be binding in equilibrium. The optimization problem can then be written as

$$\max_{w_i} \; \Pi_i(\mathbf{w}) = D^i(p_i(\mathbf{w}), p_j(\mathbf{w}))p_i(\mathbf{w}) + D^j(p_j(\mathbf{w}), p_i(\mathbf{w}))(p_j(\mathbf{w}) - w_j) - T_j - \pi_c^j(w_j),$$

where the right-hand side of the equation is equivalent to

$$D^i(p_i(\mathbf{w}), p_j(\mathbf{w}))p_i(\mathbf{w}) + D^j(p_j(\mathbf{w}), p_i(\mathbf{w}))(p_j(\mathbf{w}) - w_j) - D^j(p_j^M(w_j), \infty)(p_j^M(w_j) - w_j). \quad (5)$$

Given that both products are sold, the wholesale price w_c^N chosen by both manufacturers in the symmetric Nash equilibrium is derived from the following system of first-order conditions:

$$\left(\frac{\partial D^i(\cdot)}{\partial p_i}\, p_i(\mathbf{w}) + D^i(\cdot) + \frac{\partial D^j(\cdot)}{\partial p_i}\,(p_j(\mathbf{w}) - w_j)\right)\frac{\partial p_i}{\partial w_i} \quad (6)$$

$$+\left(\frac{\partial D^i(\cdot)}{\partial p_j}\, p_i(\mathbf{w}) + D^j(\cdot) + \frac{\partial D^j(\cdot)}{\partial p_j}\,(p_j(\mathbf{w}) - w_j)\right)\frac{\partial p_j}{\partial w_i} = 0, \quad i = 1, 2,$$

where the arguments of $D^i(\cdot)$ and $D^j(\cdot)$ are those of the optimization program. Invoking the Envelope Theorem by using (2), we can rewrite (6) as

$$w_i\left(\frac{\partial D^i(\cdot)}{\partial p_i}\frac{\partial p_i}{\partial w_i} + \frac{\partial D^i(\cdot)}{\partial p_j}\frac{\partial p_j}{\partial w_i}\right) = 0, \quad i = 1, 2.$$

Since the bracket on the left-hand side of the last equation is negative, the equation can only be satisfied if manufacturers charge a wholesale price equal to marginal cost. Hence, the wholesale price in the symmetric Nash equilibrium is $w_c^N = 0$.

Each manufacturer sets a wholesale price as if he was integrated with the common retailer, maximizing the bilateral joint profit subject to the contract offered by the rival manufacturer (see O'Brien and Shaffer 1993). Because both manufacturers offer a wholesale price equal to marginal cost, there is no double marginalization. The common retailer therefore sets the same retail prices as a two-product monopolist. This implies that industry profits are maximized in the Nash equilibrium. The manufacturers and the common retailer share these profits.[21] With linear demand, each manufacturer realizes an equilibrium profit of

$$\Pi_c^N = \frac{\alpha^2(\beta-\gamma)}{4\beta(\beta+\gamma)}. \tag{7}$$

It is evident that, if brands are perfect substitutes (i.e., $\gamma \to \beta$), manufacturers obtain zero profits. In the infinitely repeated game, the profit given by (7) is the profit along the punishment phase.

Consider now collusion between manufacturers. The retail prices for both products are always chosen by the common retailer according to (2) for given wholesale prices w_i and w_j. Even if manufacturers collude, they need to take into account R_c's option to reject a contract. Therefore, the joint profit is $D^i(p_i(\mathbf{w}), p_j(\mathbf{w}))w_i + D^j(p_j(\mathbf{w}), p_i(\mathbf{w}))w_j + T_i + T_j$, where T_i and T_j are determined by the respective participation constraints. To determine the collusion profit, we can sum up the individual profits, given in (5), to get[22]

$$\begin{aligned} \max_{(w_1,w_2)} \quad & D^i(p_i(\mathbf{w}), p_j(\mathbf{w}))p_i(\mathbf{w}) + D^j(p_j(\mathbf{w}), p_i(\mathbf{w}))p_j(\mathbf{w}) \\ & - \left[D^1(p_1^M(w_1), \infty)(p_1^M(w_1) - w_1) - D^1(p_1(\mathbf{w}), p_2(\mathbf{w}))(p_1(\mathbf{w}) - w_1)\right] \\ & - \left[D^2(p_2^M(w_2), \infty)(p_2^M(w_2) - w_2) - D^2(p_2(\mathbf{w}), p_1(\mathbf{w}))(p_2(\mathbf{w}) - w_2)\right]. \end{aligned}$$

The first term is the industry profit, whereas the rent that must be left to the retailer is equal to the sum of the second and the third term. Using the Envelope Theorem, we obtain the system of first-order conditions that determines the solution to the above program:

$$\begin{aligned} & \left(\frac{\partial D^i(\cdot)}{\partial p_i} p_i(\mathbf{w}) + D^i(\cdot) + \frac{\partial D^j(\cdot)}{\partial p_i} p_j(\mathbf{w})\right)\frac{\partial p_i}{\partial w_i} + \left(\frac{\partial D^i(\cdot)}{\partial p_j} p_i(\mathbf{w}) + D^j(\cdot) + \frac{\partial D^j(\cdot)}{\partial p_j} p_j(\mathbf{w})\right)\frac{\partial p_j}{\partial w_i} \\ & \quad + D^i(p_i^M(w_i), \infty) - D^i(p_i(\mathbf{w}), p_j(\mathbf{w})) = 0, \quad i = 1, 2. \end{aligned} \tag{8}$$

In the case of linear demand, the solution to (8) is

$$w_c^C = \frac{\alpha\gamma}{\beta+\gamma}.$$

Because manufacturers are symmetric, they receive the same share of the aggregate collusion

[21] We provide a more detailed explanation how these shares change with the degree of competition below; see Lemma 1.

[22] As is standard in the analysis of collusion (see, e.g., Tirole 1988, or Nocke and White 2007), both manufacturers maximize joint profits by independently offering contracts to the retailer, and there is no contracting agency which proposes a single (bundled) contract to the retailer.

profit, which is

$$\Pi_c^C = \frac{\alpha^2\beta}{4(\beta+\gamma)^2}. \tag{9}$$

In contrast to the Nash equilibrium, manufacturers set a wholesale price above marginal cost. This implies that manufacturers willingly accept double marginalization. Thus, industry profits are not maximized under collusion because the common retailer sets retail prices above the monopoly level.

To grasp the intuition behind the result, it is helpful to compare industry profits under collusion and in the stage game equilibrium and the respective shares obtained by manufacturers when varying the degree of competition:[23]

Lemma 1. *With a common retailer, the fiercer competition, the lower the industry profits under manufacturer collusion relative to those in the Nash equilibrium. However, as competition intensifies, the share of the industry profits obtained by manufacturers under collusion decreases to a smaller degree than in the Nash equilibrium.*

The industry profits in the Nash equilibrium correspond to the maximized industry profits. This is independent of the level of competition because manufacturers set wholesale prices equal to zero and the common retailer acts as two-product monopolist. If competition gets fiercer (i.e., γ increases), it follows from (7) that the manufacturers' portion of the profits decreases and vanishes if products are perfect substitutes. The reason is that, at wholesale prices equal to marginal cost, an increase in competition makes the option of the common retailer to reject one manufacturer's contract and selling only its rival's product more valuable.

If the manufacturers collude, they aim to mitigate this effect, i.e., to lower the retailer's profit from pitting one manufacturer against another. They do so by raising the collusive wholesale price above marginal cost. This increase is larger the higher the degree of substitutability between the products. This strategy induces the retailer to increase downstream prices which causes industry profits to decrease. As a consequence, the industry profits under collusion are lower than those in the Nash equilibrium.

The lemma also shows that industry profits under collusion decrease to a larger extent than in the Nash equilibrium if competition becomes more intense. However, the share that manufacturers obtain is always higher under the former regime. This can be seen from (7) and (9), where, as competition intensifies, the decrease in the manufacturers' portion of the profits is larger in the Nash equilibrium than under collusion. For example, if products

[23] The proof of this Lemma and Lemma 2 in Section 7 is relegated to the Appendix.

become perfect substitutes (i.e., $\gamma \to 1$), this portion reaches a minimum of 2/3 under collusion but equals 0 in the stage game.

These results demonstrate that collusion with a common retailer works in a markedly different way as compared to a scenario in which firms sell directly to consumers. In the latter case, firms always seek to maximize industry profits.

The following proposition summarizes the preceding discussion.

Proposition 1. *With a common retailer, each manufacturer realizes a profit from collusion that is given by (9). The industry profits under manufacturer collusion are lower than those under competition. However, manufacturers obtain a larger share.*

Deviation and Sustainability of Collusion

To examine stability of the cooperative agreement between manufacturers, consider that one of them, say M_i, deviates from collusion. Suppose M_i offers a wholesale contract that departs from the collusive one, while M_j continues to offer the collusive contract. Assume first that deviation from the collusive agreement implies that the common retailer chooses to distribute only the deviant's product. The maximization program of the deviant is then given by

$$\max_{w_i} \ \Pi_i(w_i, w_c^C) = D^i(p_i^M(w_i), \infty)p_i^M(w_i) - \pi_c^j(w_c^C), \tag{10}$$

which yields the first-order condition

$$\frac{\partial p_i(\cdot)}{\partial w_i}\left(\frac{\partial D^i(\cdot)}{\partial p_i}p_i(\cdot) + D^i(\cdot)\right) = 0, \tag{11}$$

where the arguments of $D^i(\cdot)$ and $p_i(\cdot)$ are those given by (10). By the same arguments as above, the deviating manufacturer sets the wholesale price to maximize the joint bilateral profit. Therefore, the wholesale price solving (11) is given by $w_c^D = 0$, and the deviant obtains profits only through the franchise fee. The resulting deviation profit is

$$\Pi_c^D = \frac{\alpha^2\left(\beta^2(\beta+\gamma) + \gamma^2(3\beta+\gamma)\right)}{4\beta(\beta+\gamma)^3}. \tag{12}$$

In Appendix A, we demonstrate that the optimal deviation in fact implies that only the deviant's product will be distributed in the retail market. This is intuitive: under the collusive regime, the retailer was indifferent between accepting or rejecting each contract. When deviating, a manufacturer offers a strictly lower wholesale price (i.e., $w_c^D < w_c^C$), which makes the non-deviating manufacturer's offer strictly less profitable for the common retailer.

Equipped with this characterization, we can determine the critical discount factor above which manufacturers can sustain tacit collusion. The condition to determine this discount factor is standard, i.e., a manufacturer's profit stream from collusion must exceed the sum of profits realized in the deviation and the punishment phase. Formally,

$$\frac{\Pi_c^C}{1-\delta} \geq \Pi_c^D + \frac{\delta \Pi_c^N}{1-\delta}.$$

Using (7), (9) and (12) yields the following result:

Proposition 2. *With a common retailer, manufacturers can sustain tacit collusion for all discount factors above*

$$\delta_c = \frac{3\beta + \gamma}{2(2\beta + \gamma)}. \tag{13}$$

It is easy to show that the critical discount factor decreases in γ, i.e., collusion is easier to sustain when products are closer substitutes. The reason is (as is stated by Lemma 1) that the Nash profit falls to a larger degree than the collusion profit as competition becomes more intense, implying that the punishment becomes more severe. Conversely, δ_c increases in β, that is, cooperation is harder to sustain with a demand function that is less sensitive to own price changes.

We note that with a common retailer we do not need to distinguish between public or private contracts because the retailer observes the terms of both contracts and there is no competing retailer. By contrast, when turning to the case of independent retailers, the distinction between public and private contracts becomes important.

Far-Sighted Retailer

In our analysis, we assumed that the common retailer is short-lived, that is, her discount factor equals zero. We now demonstrate that our analysis carries over to the situation with a long-lived retailer (i.e., a retailer with discount factor $\delta \in (0, 1]$). The retailer can then also follow a grim-trigger strategy to obtain a higher share (or all) of the downstream profit. Such a grim-trigger strategy involves a punishment that the retailer inflicts upon manufacturers, after the manufacturers demanded too large a share of the profit. A punishment can either be carried out by rejecting one or both contract offers or by setting high retail prices, which lead to small quantities.[24]

[24] This setting follows the analysis of Gilo and Yehezkel (2016) who consider long-lived firms at both layers. In their model, retailers make offers and the grim-trigger strategy of the single manufacturer also consists of rejecting one or both contract offers.

However, the only scenario constituting a subgame perfect equilibrium at the retail level is the one in which the retailer sets prices according to (2) and accepts contracts adhering to the participation constraint (4). Since the collusion contracts meet this participation constraint and the retailer sets prices at the monopoly level, there is no opportunity for the retailer to punish manufacturers with a continuation play constituting a Nash equilibrium. As a consequence, even when being far-sighted, the retailer cannot do better but accepting the manufacturers' collusion contracts. Hence, the retailer has no credible grim-trigger strategy that leads to a breakdown of manufacturer collusion, implying that our results remains valid with a forward-looking retailer.

5 Independent Retailers

5.1 Private Contracts

Downstream Stage

Suppose now that manufacturers distribute their products through independent (exclusive) retailers. The retailers R_i and R_j independently set prices in the downstream market. We start with the case in which both retailers receive the contract offer from their respective manufacturer without observing the contract that is proposed to the rival. This implies that each retailer forms an expectation about the rival's retail price. To distinguish the notation with private contracts from the one with public contracts, we denote by p_j^e the expectation of R_i about the retail price of R_j. By contrast, in case of public offers we will just write p_j, as R_i observes w_j. The objective function of R_i with secret contracts is

$$\max_{p_i} D^i\left(p_i, p_j^e\right)(p_i - w_i) - T_i.$$

Differentiating R_i's objective function gives

$$(p_i - w_i)\frac{\partial D^i(p_i, p_j^e)}{\partial p_i} + D^i(p_i, p_j^e) = 0, \quad i = 1, 2. \tag{14}$$

The system (14) implicitly determines the optimal retail prices denoted by $p_i(w_i, p_j^e)$.

Upstream Stage and Collusion

Using backward induction, we can now solve the upstream game. As in the previous section, we start with the analysis of the stage game that yields the manufacturers' profits along the punishment phase. Manufacturer M_i offers a contract to R_i that maximizes his profit, subject to R_i's participation constraint. The participation constraint is given by

$$D^i\left(p_i(w_i,p_j^e),p_j^e\right)\left(p_i(w_i,p_j^e)-w_i\right)-T_i\geq 0.$$

In contrast to the common retailer, R_i does not have the option to reject M_i's offer and sell a different product. Therefore, M_i can extract R_i's entire profit via the franchise fee. The maximization program of M_i is

$$\max_{w_i}\ \Pi_i(w_i)=D^i\left(p_i(w_i,p_j^e),p_j^e\right)p_i(w_i,p_j^e).$$

Differentiating M_i's objective function gives

$$\frac{\partial p_i(w_i,p_j^e)}{\partial w_i}\left(\frac{\partial D^i\left(p_i(w_i,p_j^e),p_j^e\right)}{\partial p_i}p_i(w_i,p_j^e)+D^i\left(p_i(w_i,p_j^e),p_j^e\right)\right)=0.$$

In a symmetric equilibrium, both manufacturers offer the same contract and expectations are fulfilled. Denoting the equilibrium wholesale price by w_I^N, this implies $p_j^e=p_j(w_I^N)$. Inserting this into the last equation, we obtain that w_I^N satisfies

$$\frac{\partial p_i(w_I^N)}{\partial w_i}\left(\frac{\partial D^i\left(p_i(w_I^N),p_j(w_I^N)\right)}{\partial p_i}p_i(w_I^N)+D^i\left(p_i(w_I^N),p_j(w_I^N)\right)\right)=0.$$

Using (14), it is straightforward to show that the optimal wholesale price is equal to marginal cost, that is, $w_I^N=0$. Since a retailer cannot observe the contract proposed by the rival manufacturer, each manufacturer acts as if integrated with his retailer. With linear demand, the profit along the punishment phase realized by each manufacturer is given by

$$\Pi_I^N=\frac{\alpha^2\beta(\beta-\gamma)}{(\beta+\gamma)(2\beta-\gamma)^2}. \tag{15}$$

In contrast to the common retailer, a wholesale price of zero does not maximize industry profits with independent retailers. Independent retailers are competitors at the downstream level. Consequently, they are not able to set monopoly retail prices if manufacturers charge them a wholesale price equal to marginal cost.

Consider now collusion. Retailers set prices according to (14) for given wholesale prices. Manufacturers anticipate the retailers' reactions and their objective function is

$$\max_{(w_1,w_2)}\ D^i\left(p_i(w_i),p_j(w_j)\right)p_i(w_i)+D^j\left(p_j(w_j),p_i(w_i)\right)p_j(w_j).$$

The wholesale prices solving the manufacturers' maximization problem are determined by the following first-order conditions:

$$\frac{\partial p_i(w_i)}{\partial w_i}\left(\frac{\partial D^i\left(p_i(w_i),p_j(w_j)\right)}{\partial p_i}p_i(w_i)+D^i\left(p_i(w_i),p_j(w_j)\right)+\frac{\partial D^j\left(p_j(w_j),p_i(w_i)\right)}{\partial p_i}p_j(w_j)\right)=0.$$

With linear demand, the symmetric collusive wholesale price is

$$w_I^C=\frac{\alpha\gamma}{2\beta}. \tag{16}$$

Colluding manufacturers choose the wholesale price to induce retailers to set the final price at the monopoly level ($p_I^M=\alpha/2$) independent of the degree of differentiation. Each manufacturer's profit from collusion is

$$\Pi_I^C=\frac{\alpha^2}{4(\beta+\gamma)}. \tag{17}$$

When they tacitly collude with independent retailers, manufacturers, in fact, choose a strategy that aims at maximizing industry profits. Since the retailers have no outside option, the only strategic purpose of colluding manufacturers is to induce retailers to set the monopoly retail prices. Manufacturers can do so by raising their wholesale prices above marginal cost. Thus, the competing retailers face higher per-unit costs and optimally increase the retail price. Manufacturers obtain the entire industry profits via the fixed fee and the wholesale margin. Therefore, tacit collusion between manufacturers distributing through independent retailers works in similar way as tacit collusion between firms that directly sell to consumers: industry profits are maximized under collusion. The results are highlighted in the following proposition.

Proposition 3. *With independent (exclusive) retailers, each manufacturer realizes a profit from collusion that is given by (17). The collusion profits correspond to the maximized industry profits, which exceed those under competition.*

Deviation and Sustainability of Collusion

Applying the same logic developed above, we can determine the deviation wholesale price and profit. The objective function of the deviant is

$$\max_{w_i}\ \Pi_i(w_i,w_I^C)=D^i\left(p_i(w_i),p_j(w_I^C)\right)p_i(w_i),$$

leading to a first-order condition of

$$\frac{\partial p_i(w_i)}{\partial w_i}\left(\frac{\partial D^i\left(p_i(w_i), p_j(w_I^C)\right)}{\partial p_i}p_i(w_i) + D^i\left(p_i(w_i), p_j(w_I^C)\right)\right) = 0.$$

Again, using (14), it is easy to see that the deviant's optimal wholesale price is $w_I^D = 0$. Because contracts are unobservable, M_i's contract choice has no impact on the price of retailer j. This implies that M_i sets the wholesale price to maximize channel profits. A wholesale price of zero avoids double marginalization and, therefore, aligns the incentives of the manufacturer and the retailer. The resulting profit realized by the deviant is given by

$$\Pi_I^D = \frac{\alpha^2(2\beta-\gamma)^2}{16\beta(\beta-\gamma)(\beta+\gamma)}. \tag{18}$$

Before we can determine the critical discount factor above which collusion is sustainable, we need to check whether a deviation leads to zero demand for the product of the non-deviating manufacturer. If M_i deviates, he offers w_I^D to R_i, while M_j sticks to w_I^C. The resulting demand for product j in the retail market is

$$D^j(w_I^C, w_I^D) = \frac{\alpha\left(2\beta(\beta-\gamma)-\gamma^2\right)}{4\beta(\beta+\gamma)(\beta-\gamma)}.$$

Setting $D^j(w_I^C, w_I^D)$ equal to zero shows that the demand for product j is positive if and only if $\gamma \leq \widehat{\gamma} \equiv (\sqrt{3}-1)\beta \approx (0.732)\beta$.[25] Thus, the analysis of independent retailers conducted so far only applies if the products are sufficiently differentiated.

For $\gamma > \widehat{\gamma}$, the retailer of the deviating manufacturer M_i optimally sets her retail price such that the demand for product j equals zero. With $p_j = p_I^M = \alpha/2$, this is achieved with a retail price of $p_i = \widehat{p}_I^D = (\alpha(2\gamma-\beta))/(2\gamma)$. The corresponding deviation profit realized by M_i is[26]

$$\widehat{\Pi}_I^D = \frac{\alpha^2(2\gamma-\beta)}{4\gamma^2}. \tag{19}$$

We can now determine the critical discount factor by inserting (15), (17), (18) and (19) into the condition $\Pi_I^C/(1-\delta) \geq \Pi_I^D + \delta\Pi_I^N/(1-\delta)$.

[25] Here and in what follows, we round the thresholds to three decimal places to simplify the exposition.

[26] It can be easily verified that $\Pi_I^D = \widehat{\Pi}_I^D$ for $\gamma = (\sqrt{3}-1)\beta$.

Proposition 4. *With independent (exclusive) retailers and unobservable contracts, manufacturers can sustain tacit collusion for all discount factors above*

$$\delta_I = \begin{cases} \frac{(2\beta-\gamma)^2}{8\beta(\beta-\gamma)+\gamma^2} & \text{for} \quad \gamma \in [0, \widehat{\gamma}] \\ \frac{(2\beta-\gamma)^2\left(\beta(\beta-\gamma)-\gamma^2\right)}{4\beta^3(\beta-2\gamma)+\gamma^2(\beta(\beta+3\gamma)-2\gamma^2)} & \text{for} \quad \gamma \in (\widehat{\gamma}, \beta). \end{cases} \tag{20}$$

In contrast to the critical discount factor with a common retailer, (20) is an increasing function in γ if $\gamma \leq \widehat{\gamma}$, that is, collusion becomes more difficult to sustain when products are closer substitutes. Conversely, it is a decreasing function in β, that is, collusion is facilitated if the impact of own price variations on the demand is low. If $\gamma > \widehat{\gamma}$, the critical discount factor changes non-monotonically with γ and β. It increases in γ if $\gamma \leq (0.745)\beta$ and decreases if $\gamma > (0.745)\beta$, whereas the opposite slope occurs for β. Therefore, if products are close substitutes, δ_I is affected by γ and β in the same way as δ_c, whereas the opposite holds true for moderate or low degrees of competition.

Far-Sighted Retailers

As in the previous section, we derived our results under the assumption that retailers maximize only spot profits. Consider now that retailers are far-sighted and discount future profits with a common discount factor. In case they collude, they *jointly* set retail prices and decide on accepting or rejecting contracts. In particular, under the assumption that retailers can make side-payments, they will coordinate their acceptance decisions so that joint profits are maximized and that the split of profits minimizes deviation incentives.[27] In case that the discount factor is sufficiently large, the collusive strategy of the retailers is therefore identical to the one of the common retailer. This implies that each manufacturer, when dealing with his retailer, needs to take participation constraint (4) into account. In contrast, if the critical discount factor is small, the retail cartel will break down since retailers are not patient enough to sustain collusion. Thus, depending on the discount factor with which retailers discount future profits, either our analysis of the common retailer or of short-lived independent retailers applies.[28]

[27]Side payments between colluding firms are well established in the literature (see Tirole 1988 or Athey and Bagwell 2001, among many others).

[28]Note that for intermediate values of the retailers' discount factor, manufacturers may set wholesale prices to just destroy the retail cartel. Even if this implies wholesale prices slightly different from those derived above, the qualitative results remain valid.

5.2 Public Contracts

Downstream Stage

Consider now that retailers observe both contract offers before entering competition. This may be the case, for instance, if disclosure standards are mandatory or if manufacturers can easily form information-sharing agreements. In addition, supplier trade associations may facilitate transmission of information among competing distribution channels. For example, information-intensive channels, where channel members invested in information technologies such as telecommunication and satellite linkages or bar coding, became more important in recent years (see e.g., Palmatier et al. 2016).

Under public contracts, retailer R_i chooses her retail price to maximize $D^i(p_i, p_j)(p_i - w_i) - T_i$. The second-stage equilibrium is determined by the first-order conditions

$$\frac{\partial D^i(p_i, p_j)}{\partial p_i}(p_i - w_i) + D^i(p_i, p_j) = 0, \quad i = 1, 2. \tag{21}$$

This system can be solved for the retailers' best response functions, i.e., $p_i(w_i, w_j)$, $i = 1, 2$, which are increasing in both w_i and w_j. In contrast to private contracts, a retailer's optimal retail price depends on both wholesale prices because each retailer observes the contract proposed to the rival retailer.

Upstream Stage and Collusion

In the upstream game, each manufacturer chooses the franchise fee such that the participation constraint of his retailer is met. Hence, M_i sets his wholesale price to maximize

$$\max_{w_i} \ \Pi_i(w_i, w_j) = D^i\left(p_i(w_i, w_j), p_j(w_j, w_i)\right) p_i(w_i, w_j). \tag{22}$$

The wholesale price in the symmetric Nash-equilibrium of the upstream game is therefore implicitly defined by the following first-order conditions:

$$\left(\frac{\partial D^i(\cdot)}{\partial p_i} \, p_i(\cdot) + D^i(\cdot)\right) \frac{\partial p_i(\cdot)}{\partial w_i} + \frac{\partial D^i(\cdot)}{\partial p_j} \frac{\partial p_j(\cdot)}{\partial w_i} \, p_i(\cdot) = 0, \quad i = 1, 2, \tag{23}$$

where the arguments of $D^i(\cdot)$, $p_i(\cdot)$, and $p_j(\cdot)$ are those of (22). In contrast to private contracts, M_i now takes R_j's reaction into account when setting the wholesale price. This strategic effect is represented by the second term of (23), which is positive because prices are strategic complements. Hence, raising w_i leads to an increase in p_j which positively affects M_i's profit. Consequently, the wholesale prices chosen by manufacturers in the stage game along the punishment phase are above marginal cost. With linear demand, the equilibrium wholesale price with independent retailing and observable contracts is given by

$$w_{IO}^{N} = \frac{\alpha\gamma^2(\beta-\gamma)}{\beta\left(4\beta^2-\gamma^2-2\beta\gamma\right)}.$$

The resulting manufacturer profit is given by

$$\Pi_{IO}^{N} = \frac{2\alpha^2\beta(\beta-\gamma)\left(2\beta^2-\gamma^2\right)}{(\beta+\gamma)\left(4\beta^2-\gamma^2-2\beta\gamma\right)^2}.$$

If $\gamma \to \beta$, both manufacturers price at marginal cost and realize zero profits.

Consider now that manufacturers collude. The retailers' optimal responses to the wholesale prices that maximize the manufacturers' joint profits are still determined by (21). As under private contracts, it can be easily shown that manufacturers offer contracts to their retailers that induce them to set the monopoly retail price. Hence, with linear demand, the optimal collusive wholesale price w_{IO}^{C} is identical to (16), and the resulting profit Π_{IO}^{C} that each manufacturer receives in equilibrium is likewise given by (17). Collusion under observable contracts works in a similar way as under private contracts: manufacturers seek to maximize industry profits which they fully extract from their retailers. However, strategies to punish a deviation differ. Due to the strategic effect, manufacturers realize higher stage game profits if contract offers are observable to the rival retailer.

Deviation and Sustainability of Collusion

When deviating from the collusive agreement, M_i faces a maximization program given by

$$\max_{w_i} \ \Pi_i(w_i, w_{IO}^{C}) = D^i\left(p_i(w_i, w_{IO}^{C}), p_j(w_{IO}^{C}, w_i)\right) p_i(w_i, w_{IO}^{C}). \tag{24}$$

The first-order condition is determined by (23) where the arguments of $D^i(\cdot)$, $p_i(\cdot)$ and $p_j(\cdot)$ are replaced by those of (24). With linear demand, the optimal deviation wholesale price is

$$w_{IO}^{D} = \frac{\alpha\gamma^2\left(4\beta^2-2\beta\gamma-\gamma^2\right)}{8\beta^2\left(2\beta^2-\gamma^2\right)}.$$

In contrast to the case with private contracts, R_j now immediately responds to M_i's deviation by lowering the retail price. This induces M_i to undercut the collusive wholesale price to a smaller extent than in case of private contracts. Under observable contracts, the deviation wholesale price exceeds marginal cost and the resulting deviation profit is given by

$$\Pi_{IO}^{D} = \frac{\alpha^2\left(4\beta^2-2\beta\gamma-\gamma^2\right)^2}{32\beta\left(\beta+\gamma\right)\left(\beta-\gamma\right)\left(2\beta^2-\gamma^2\right)}.$$

Proceeding in the same way as above, we check if deviation of M_i implies that M_j's demand becomes zero when competition gets fierce. We obtain that this occurs for $\gamma > (0.841)\beta \equiv \widetilde{\gamma}$. For $\gamma > \widetilde{\gamma}$, M_i optimally sets a deviation wholesale price given by

$$\widetilde{w}_{IO}^{D} = \frac{\alpha \left(2\beta \left(2\beta(\gamma - \beta) + \gamma^2\right) - \gamma^3\right)}{2\beta^2\gamma},$$

which results in a deviation profit of

$$\widetilde{\Pi}_{IO}^{D} = \frac{\alpha^2 \left(4\beta \left(2\gamma - \beta\right) - 3\gamma^2\right)}{4\beta\gamma^4}.$$

Now we have all relevant information to determine the critical discount factor above which collusion is sustainable if contracts are observable. The solution to the standard indifference condition is provided in the next proposition.

Proposition 5. *With independent (exclusive) retailers and under observable contracts, manufacturers can sustain tacit collusion for all discount factors above*

$$\delta_{IO} = \begin{cases} \frac{\left(2\beta(2\beta-\gamma)-\gamma^2\right)^2}{4\beta(\beta-\gamma)(8\beta^2-3\gamma^2)+\gamma^4} & \text{for} \quad \gamma \in [0, \widetilde{\gamma}] \\ \frac{\left(2\beta(2\beta-\gamma)-\gamma^2\right)^2\left(3\gamma^3+4\beta\left(\beta(\beta-\gamma)-\gamma^2\right)\right)}{3\gamma^7+\beta(7\gamma^6+4\beta(4\beta(\beta(9\gamma^3+\beta(4\beta^2-8\beta\gamma-\gamma^2))-3\gamma^4)-7\gamma^5))} & \text{for} \quad \gamma \in (\widetilde{\gamma}, \beta). \end{cases} \tag{25}$$

6 Stability of Tacit Collusion and Welfare Implications

6.1 Stability

Following the analysis of Sections 4 and 5, the natural question arises which channel structure is most suitable for manufacturers to sustain tacit collusion. Using the critical discount factors obtained in *Proposition 2*, *Proposition 4* and *Proposition 5*, we start with the comparison between common retailing and independent retailing under both observable and private contracts.[29]

Proposition 6. *With linear demand, each manufacturer realizes a higher collusion profit with independent retailers than with a common retailer. In addition, the critical discount factor above which collusion can be sustained is lower when distributing through*

[29]The proofs of all subsequent propositions are relegated to the Appendix.

independent retailers as compared to selling through a common retailer. This result holds regardless of whether contracts are private or observable with independent retailers. Formally, $\delta_I < \delta_c$ *and* $\delta_{IO} < \delta_c$.

Distribution through independent retailers allows manufacturers to sustain collusion for a larger range of discount factors irrespective of whether contracts are observable or not. To develop the intuition behind this result, we proceed by analyzing the difference between the discount factors with general demand functions for the case in which brands are close substitutes.

We start with independent retailers and focus on private contracts.[30] Since manufacturers set their wholesale prices equal to marginal cost in the Nash equilibrium, the profit along the punishment phase is given by $\Pi_I^N = D^i(p_i(0), p_j(0))p_i(0)$. By contrast, in the collusion phase, each manufacturer obtains the monopoly profit, which is $\Pi_I^C = D^i(p_i^M, p_j^M)p_i^M$. Finally, the deviation profit of M_i is $\Pi_I^D = D^i(p_i(0), p_j^M)p_i(0)$. If products become close substitutes, $\Pi_I^N \to 0$ as $p_i(0) \to 0$. When colluding, each manufacturer obtains half of the maximized industry profits, while, under high product substitutability, Π_I^D approaches the total maximized industry profits, as the deviant marginally undercuts the collusive downstream price so that the rival product is driven out of the market. Inserting this in the formula for the critical discount factor yields the well-known result that $\delta_I \to 1/2$ due to the fact that $(\Pi_I^D - \Pi_I^C)/(\Pi_I^D - \Pi_I^N) \to 1/2$.

We now turn to the common retailer. Along the punishment phase, each manufacturer sets $w_c^N = 0$. Using (5) and symmetry of manufacturers, the Nash profit of a representative manufacturer M_i can be written as $\Pi_c^N = 2D^i(p_i(0,0), p_j(0,0))p_i(0,0) - D^j(p_j^M(0), \infty)p_j^M(0)$. Under collusion, M_i gets $D^i\left(p_i(w_c^C, w_c^C), p_j(w_c^C, w_c^C)\right) w_c^C + T_i^C$, where T_i^C equals

$$2D^i\left(p_i(w_c^C, w_c^C), p_j(w_c^C, w_c^C)\right)\left(p_i(w_c^C, w_c^C) - w_c^C\right) - D^j\left(p_j^M(w_c^C), \infty\right)\left(p_j^M(w_c^C) - w_c^C\right).$$

When M_i deviates from this collusive agreement, he sets $w_c^D = 0$ and the common retailer only accepts the deviant's offer. The deviant's profit is therefore equal to the maximized industry profit minus the profit that the common retailer obtains in case she accepts only the offer of the manufacturer who sticks to collusion. The latter is $D^j\left(p_j^M(w_c^C), \infty\right)\left(p_j^M(w_c^C) - w_c^C\right)$ $-T_j^C$. Thus, Π_c^D is

$$D^i(p_i(0), \infty)p_i(0) + 2D^i\left(p_i(\cdot), p_i(\cdot)\right)\left(p_j(\cdot) - w_c^C\right) - 2D^j\left(p_j^M(w_c^C)\right)\left(p_j^M(w_c^C) - w_c^C\right),$$

where $(\cdot) = (w_c^C, w_c^C)$.

[30] The analysis with public contracts follows very similar lines.

If brands become close substitutes, $D^i(p_i(0,0), p_j(0,0))p_i(0,0)$ converges to $D^j(p_j^M(0), \infty)$ $p_j^M(0)/2$ (i.e., half of the monopoly profit), as the common retailer sets the monopoly price for each product. This implies that $\Pi_c^N \to 0$. Therefore, the critical discount factor under common retailing approaches $\delta_c = 1 - \Pi_c^C/\Pi_c^D$.

We can now determine whether δ_c is larger than 1/2, which is equivalent to $\Pi_c^C/\Pi_c^D < 1/2$. Inserting the respective expressions for the profits and rearranging yields that this holds if

$$D^i(p_i(0), \infty)p_i(0) > 2D^i\left(p_i(w_c^C, w_c^C), p_j(w_c^C, w_c^C)\right)p_i(w_c^C, w_c^C). \tag{26}$$

At high product substitutability, the left-hand side is equal to the maximized industry profits as the wholesale price approaches marginal cost, thereby avoiding double marginalization. By contrast, the term on the right-hand side involves industry profits with wholesale prices above marginal cost (i.e., at $w_c^C > 0$). Given that product are close substitutes, the right-hand side is therefore close to $D^i\left(p_i^M(w_c^C), \infty\right)p_i^M(w_c^C)$, which must consequently be lower than $D^i(p_i(0), \infty)p_i(0)$.

The above discussion demonstrates that the ratio between deviation and collusion profits is larger under common retailing than under independent retailing. The intuition behind this result lies in the common retailer's option to reject M_i's contract and accept only the contract of the rival manufacturer. The value of this option is the same under collusion and under deviation because the competing manufacturer sticks to collusion and offers the same contract independent of M_i's action. When deviating, M_i obtains the approximately maximized industry profits minus the retailer's outside option because the retailer optimally accepts only the deviant's offer. In contrast, when sticking to collusion, M_i obtains *less* than half of the maximized industry profits minus the retailer's outside option. This is due to the fact that manufacturers collude by raising their wholesale prices to reduce the retailer's threat of pitting them against each other.[31] Instead, with independent retailers, each manufacturer obtains approximately maximized industry profits when deviating and half of them when colluding. As a consequence, deviation incentives are higher with a common retailer than with independent retailers.

We derived the intuition for the case in which brands are close substitutes. With strictly differentiated products, the punishment profit is no longer approximately zero, which makes the comparison between the two channel structures with general demand complex. However, the main intuition for our result carries over to this case. As we have shown with linear demand, the collusion profit with common retailing is also below the maximum in this case whereas deviation leads to monopolization of the downstream market. Although the

[31] This is reflected by the right-hand side of (26), which involves wholesale prices of w_c^C, whereas the wholesale price on the left-hand side equals 0.

punishment is then less severe under independent retailing than under common retailing, the effect of the stronger deviation incentives with a common retailer dominates, implying that independent retailing facilitates collusion.

We now examine whether observability of contracts facilitates collusion for manufacturers in case of independent retailing. The following proposition shows that this is not necessarily true.

Proposition 7. *If manufacturers distribute through independent retailers, public contracts make manufacturers' collusion harder to sustain compared to private contracts if and only if competition is fierce, i.e., if and only if* $\gamma > 0.825\beta$.

With independent retailers, contract observability facilitates collusion if competition is not particularly strong and impedes it otherwise. The intuition for this result arises from the strategic effect and its implications for the deviation and punishment profit. If a manufacturer deviates from the collusive agreement and contracts are observable, the rival retailer detects the deviation in the very same period and can therefore react immediately. Because downstream prices are strategic complements, the rival retailer's optimal reaction is to lower the downstream price, which renders deviation less profitable. In contrast, under private contracts, the deviation cannot be observed in the same period and the rival retailer continues to set the collusive downstream price. Consequently, the deviation profit is higher under private contracts. This effect makes the cartel more stable under public contracts.

However, the opposite applies to the punishment phase where the strategic effect dampens competition in the Nash equilibrium. Under observable contracts, a manufacturer can induce the competing retailer to increase the downstream price by proposing a higher wholesale price to his own retailer. That is, a higher w_i results in a higher downstream price of R_i and, due to the strategic complementary of the downstream prices, R_j reacts by increasing her downstream price as well. Consequently, Nash profits are higher under public contracts and punishment is less severe. This effect works in favor of collusion under private contracts.

As competition gets fiercer (i.e., γ increases), the first effect loses significance relative to the second effect. The retailer of the non-deviating manufacturer is constrained in her reaction by the relatively high collusive wholesale price. Although being able to react in the period of deviation, the retailer is a weak competitor, and if products are close enough substitutes, she can no longer obtain positive sales. Consequently, the effect of the immediate reaction to deviation becomes less important relative to the difference in punishment profits. Hence, private contracts facilitate collusion if competition is fierce. By contrast, for low or intermediate levels of competition, contract observability is more suitable for collusive purposes because the ability to detect and to react to a deviation dominates.

Table 1 summarizes the manufacturers' equilibrium profits for each channel structure, and the resulting critical discount factors above which they can sustain collusion. To facilitate the comparison, β is set equal to 1.

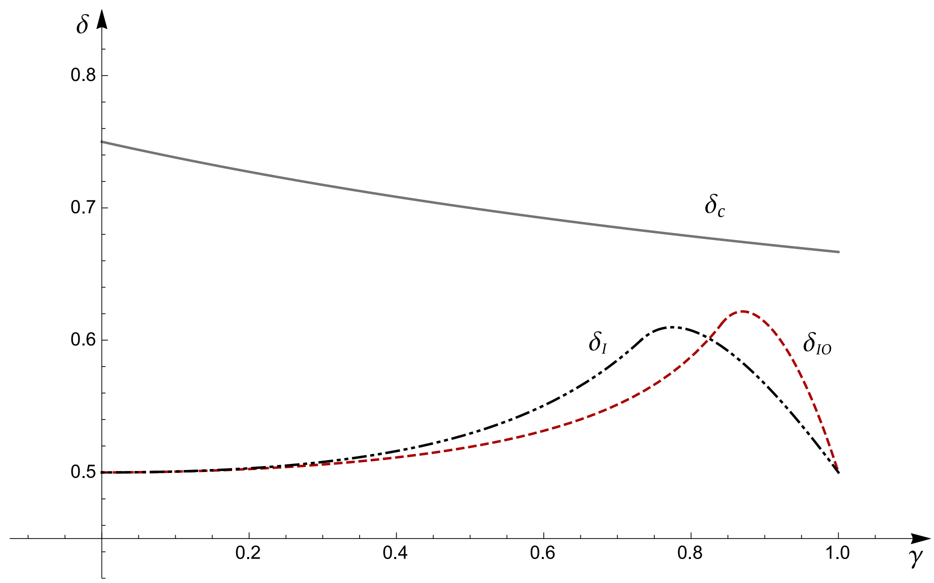
Table 1: Equilibrium profits and critical discount factors for different levels of competition ($\beta = 1$)

	Punishment profit $\left(\Pi^N\right)$	Collusion profit $\left(\Pi^C\right)$	Deviation profit $\left(\Pi^D\right)$	Critical discount factor
Common retailer	$\frac{\alpha^2(1-\gamma)}{4(1+\gamma)}$	$\frac{\alpha^2}{4(1+\gamma)^2}$	$\frac{\alpha^2(1+\gamma+\gamma^2(3+\gamma))}{4(1+\gamma)^3}$	0.7 $(\gamma = 0.5)$ 0.672 $(\gamma = 0.9)$
Independent retailers – secret offers	$\frac{\alpha^2(1-\gamma)}{(1+\gamma)(2-\gamma)^2}$	$\frac{\alpha^2}{4(1+\gamma)}$	$\frac{\alpha^2(2-\gamma)^2}{16(1-\gamma^2)}$ $(\gamma \leq 0.732)$ $\frac{\alpha^2(2\gamma-1)}{4\gamma^2}$ $(\gamma > 0.732)$	0.529 $(\gamma = 0.5)$ 0.567 $(\gamma = 0.9)$
Independent retailers – public offers	$\frac{2\alpha^2(1-\gamma)\left(2-\gamma^2\right)}{(1+\gamma)(4-\gamma^2-2\gamma)^2}$	$\frac{\alpha^2}{4(1+\gamma)}$	$\frac{\alpha^2(4-2\gamma-\gamma^2)^2}{32(2-\gamma^2(3-\gamma^2))}$ $(\gamma \leq 0.841)$ $\frac{\alpha^2(4(2\gamma-1)-3\gamma^2)}{4\gamma^4}$ $(\gamma > 0.841)$	0.519 $(\gamma = 0.5)$ 0.614 $(\gamma = 0.9)$

Interestingly, our results reveal that, whereas public contracts are always preferred from the perspective of static (or one-shot) competition, this is no longer true when dynamic considerations come into play. In this respect, our model provides a strategic explanation for why manufacturers want to keep their contracts secret. There may be several reasons for not disclosing wholesale contracts voluntarily, e.g., privacy concerns on input costs or production flows. However, from a strategic perspective, such secrecy is hard to justify. Our model shows that disclosing wholesale contracts can lead to a breakdown of collusion (due to reduced punishment threats) if products are close enough substitutes. Figure 2 plots the discount factors above which manufacturers can form a stable tacit cartel for the respective channel structures.

We also note that if retailers were to make contract offers and collusion takes place only at the retail level, observable contracts would still be unambiguously preferred over secret ones by retailers. This result is obtained in Piccolo and Miklòs-Thal (2012). The intuition is twofold: first, with secrecy each retailer acts as if vertically integrated with its manufacturer since no strategic effect is present. This implies that manufacturers do not serve as a collusion-facilitating device for retailers. Second, similar to our paper, observable contracts allow for an reaction to a deviation in the very same period, whereas this is not possible with secret contracts. However, in contrast to our paper, the punishment profit is the same with observability and secrecy because retailers always offer a contract involving marginal-cost pricing in the Nash equilibrium. Instead, we show that in case manufacturers make contract offers, punishment is less severe with public contracting, which can facilitate collusion under secret contracting.

Figure 2: Critical Discount Factors ($\beta = 1$).



6.2 Welfare

This section discusses the welfare implications of the findings. From the result of *Proposition 6*, one may suggest that independent retailing has a larger detrimental effect on social welfare than common retailing and should therefore be subject to scrutiny by the antitrust authorities. However, this neglects that the common retailer operates as a downstream monopolist.

Consider first the case in which collusion is not sustainable in any regime, that is, $\delta < \delta_I < \delta_c$. In this scenario, the common retailer gets the inputs at marginal cost and acts as two-product monopolist in the consumer market. This is not the case with independent retailers. Although they also buy the input from their manufacturer at marginal cost, they face competition from their rival, which drives retail prices below the monopoly level. In fact, $p_c^N = \alpha/2 > \alpha(\beta - \gamma)/(2\beta - \gamma) = p_I^N$. Second, if $\delta_I < \delta_c \leq \delta$ collusion is sustainable under either regime. It is straightforward that common retailing is again more harmful than independent retailing in this scenario. The reason is that colluding manufacturers optimally raise the wholesale price to diminish the retailer's opportunity to reject one contract. This collusive strategy involves double marginalization and induces the common retailer to increase prices above the monopoly level. We obtain $p_c^C = \alpha(\beta + 2\gamma)/(\beta + \gamma) > \alpha/2 = p_I^C$. Finally, in case that $\delta_I \leq \delta < \delta_c$, i.e., collusion is sustainable with independent retailers but not with a common retailer, final good prices are the same under both regimes, that is, $p_c^N = \alpha/2 = p_I^C$. Under common retailing, wholesale prices are equal to marginal cost and the retailer sets monopoly prices for the two brands. Similarly, under independent retailing, colluding manufacturers set wholesale prices in such a way that their retailers charge monopoly prices.

The latter result is due to the fact that we focused on full collusion. Allowing for partial collusion again yields the result that common retailing is more detrimental to welfare. To see this, note that for $\delta_I \leq \delta < \delta_c$, manufacturers achieve full collusion with independent retailing; hence, considering partial collusion does not change the result. By contrast, under common retailing partial collusion allows manufacturers to raise wholesale prices above marginal cost, which again leads to retail prices above the monopoly level.

As a consequence, welfare is always higher under independent retailing, and this result holds although collusion with independent retailers can be sustained for a larger range of discount factors. The effect that a common retailer monopolizes the downstream market is dominant.

6.3 Outside Option for Retailers

In our analysis, we assumed that retailers do not have an outside option, that is, a retailer can only distribute product i when accepting the offer of manufacturer i but there is no other firm offering the product. In this subsection, we briefly demonstrate that our main results are robust to the introduction of an outside option.

To this end, suppose that for each product there is a competitive fringe of firms producing the product at marginal cost of $\hat{c} > 0$. Therefore, a retailer can always obtain a product at cost $\hat{c}$. The fringe is less efficient than either manufacturer, so that in equilibrium manufacturers will supply the retailer(s). However, the fringe constrains the bargaining power of manufacturers. For example, in case of independent retailers, manufacturers cannot extract the full retail profits via the fixed fee. In what follows, we assume that $\hat{c} < w_I^C$,[32] which implies that the fringe is not only constraining the fixed fee but also provides a ceiling on the collusive wholesale prices.

[32]Since $w_I^C < w_c^C$, this assumption also implies $\hat{c} < w_c^C$.

We demonstrate the robustness of our results by following the analysis with close substitutes provided in Section 6.1. Manufacturers cannot set collusive wholesale prices above $\hat{c}$ if retailers can buy the products from the fringe firms. With independent retailers, colluding manufacturers will therefore optimally set a wholesale price of $\hat{c}$ and a fixed fee of zero. A deviating manufacturer then sets $w_I^D = 0$, thereby inducing his retailer to set a downstream price equal to $\hat{c} - \epsilon$, with $\epsilon \to 0$, and extracting the resulting profit from the retailer.[33] It is easy to see that, as above, Π_I^D is twice as large as Π_I^C, leading to critical discount factor of 1/2.

With a common retailer, manufacturers also optimally collude by setting a wholesale price equal to $\hat{c}$. The common retailer's outside option of buying from the fringe is then equivalent to the option of rejecting one contract, and manufacturers cannot demand a positive fixed fee. The collusion profit of each manufacturer is then $D^i\left(p_i(\hat{c},\hat{c}), p_j(\hat{c},\hat{c})\right)\hat{c}$. Proceeding in the same way as in Section 6.1 to determine whether $\Pi_c^C/\Pi_c^D < 1/2$, we obtain that the equivalent to (26) is

$$D^i\left(p_i(0),\infty)\right)p_i(0) > 2D^i\left(p_i(\hat{c},\hat{c}), p_j(\hat{c},\hat{c})\right)p_i(\hat{c},\hat{c}). \tag{27}$$

This implies that the analysis is unchanged except for w_c^C replaced by $\hat{c}$. Since the right-hand side of (27) is equal to $D^i\left(p_i(\hat{c}),\infty)\right)p_i(\hat{c})$, which is lower than $D^i\left(p_i(0),\infty)\right)p_i(0)$, the inequality is fulfilled. As a consequence, the critical discount factor with a common retailer is above the one with independent retailers. Therefore, the intuition driving our result carries over to the case in which retailers have an outside option.

We finally note that the effect becomes weaker the lower $\hat{c}$. In particular, $D^i\left(p_i(w),\infty)\right)p_i(w)$ is falling in w for all $w > 0$. Since the collusive wholesale price under both channel structures equals $\hat{c}$, a lower $\hat{c}$ implies an increase in the right-hand side of (27). Therefore, as fringe firms become more efficient, the critical discount factors are getting closer to each other. But, as long as $\hat{c} > 0$, independent retailing facilitates collusion. This result also holds with differentiated products and linear demand.

7 Linear Wholesale Price Contracts

In this section, we study the case in which manufacturers' contract offers consist of a single per-unit wholesale price. That is, franchise fees are not available and the contract proposed by M_i reduces to $C_i(w_i)$. Linear wholesale price contracts are appealing due to their simplic-

[33] In fact, any wholesale price between 0 and $\hat{c} - \epsilon$ will lead to the same profit because the deviant can adjust the fixed fee accordingly.

ity and are commonly used as a mechanism governing transactions within the distribution channel in several industries.

7.1 Common Retailer

Downstream Stage

We proceed as in the previous analysis and start with a single downstream firm. Without franchise fees, the common retailer's objective function, when accepting both contracts, is $\pi_c(p_i, p_j) = D^i(p_i, p_j)(p_i - w_i) + D^j(p_j, p_i)(p_j - w_j)$. The first-order conditions for p_i and p_j are identical to those with two-part tariffs specified by (2).[34]

Upstream Stage and Collusion

In contrast to the equilibrium with two-part tariffs, manufacturers now propose only a wholesale price to the common retailer. Hence, M_i's maximization program is $\max_{w_i} \Pi_i = D^i(p_i(\mathbf{w}), p_j(\mathbf{w}))w_i$, yielding the system of first-order conditions

$$w_i \left(\frac{\partial D^i(\cdot)}{\partial p_i} \frac{\partial p_i(\mathbf{w})}{\partial w_i} + \frac{\partial D^i(\cdot)}{\partial p_j} \frac{\partial p_j(\mathbf{w})}{\partial w_i} \right) + D^i(\cdot) = 0, \quad i = 1, 2. \tag{28}$$

The equilibrium wholesale price is above marginal cost since manufacturers can now obtain only profits per unit sold and therefore set a positive margin. With linear demand, the symmetric wholesale price solving the system above is $w_c^N = (\alpha(\beta - \gamma))/(2\beta - \gamma)$. The resulting profit a manufacturer realizes in the punishment phase is

$$\Pi_c^N = \frac{\alpha^2 \beta(\beta - \gamma)}{2(\beta + \gamma)(2\beta - \gamma)^2}. \tag{29}$$

Now consider collusion. When maximizing joint profits, the manufacturers' optimization program is $\max_{(w_1, w_2)} D^i(p_i(\mathbf{w}), p_j(\mathbf{w}))w_i + D^j(p_j(\mathbf{w}), p_i(\mathbf{w}))w_j$. Maximizing with respect to the wholesale prices gives the following system of first-order conditions:

$$w_i \left(\frac{\partial D^i(\cdot)}{\partial p_i} \frac{\partial p_i(\mathbf{w})}{\partial w_i} + \frac{\partial D^i(\cdot)}{\partial p_j} \frac{\partial p_j(\mathbf{w})}{\partial w_i} \right) + D^i(\cdot) + w_j \left(\frac{\partial D^j(\cdot)}{\partial p_j} \frac{\partial p_j(\mathbf{w})}{\partial w_i} + \frac{\partial D^j(\cdot)}{\partial p_i} \frac{\partial p_i(\mathbf{w})}{\partial w_i} \right) = 0, \; i = 1, 2.$$

With linear demand, the solution to this system is $w_c^C = \alpha/2$. Each manufacturer obtains

[34] With two-part tariffs, the franchise fees cancel out in the first-order conditions of the common retailer's profit maximization with respect to the retail prices.

an equilibrium profit from collusion given by

$$\Pi_c^C = \frac{\alpha^2}{8(\beta+\gamma)}. \tag{30}$$

Linear wholesale price contracts impair the ability to coordinate the distribution channel as compared to two-part tariffs: double marginalization occurs in the Nash and the collusion equilibrium. However, in analogy to two-part tariffs, manufacturers set wholesale prices particularly high under collusion, implying that industry profits are relatively low.

Lemma 2. *With a common retailer and linear wholesale price contracts, an increase in competition reduces industry profits under manufacturer collusion to a larger extent compared to the stage game equilibrium. However, as competition intensifies, the share of the profits kept by manufacturers remains constant at* $2/3$*, while it decreases in the Nash equilibrium.*

With linear wholesale price contracts, neither the collusive regime nor the stage game implies a maximization of the industry profits. It follows from (29) that, analogously to two-part tariffs, the share of the Nash industry profits obtained by manufacturers decreases with the level of competition and vanishes if products become perfect substitutes. This is not the case under collusion. The collusive wholesale prices, and therefore the prices set by the retailer, are independent of the level of competition (i.e., they do not depend on γ). It follows that industry profits decrease as products become closer substitutes. However, similar to the intuition obtained under two-part tariffs, keeping prices constant allows manufacturers to keep up the share of the profits they appropriate from the common retailer.

The above discussion exemplifies that linear contracts do not only fail on channel coordination but also limit the rents that colluding manufacturers can extract from a common retailer. The manufacturers' portion of the industry profits is considerably larger with a two-part tariff.

The next proposition summarizes the results:

Proposition 8. *Using linear wholesale price contracts, each manufacturer realizes a collusion profit that is given by (30) if products are distributed through a common retailer. As with two-part tariffs, industry profits under collusion are lower than those under competition, but manufacturers appropriate a larger share.*

Deviation and Sustainability of Collusion

Under linear wholesale price contracts, M_i's maximization program when deviating is $\max_{w_i} D^i(p_i(w_i, w_c^C), p_j(w_c^C, w_i))w_i$. The first-order condition that solves this program is identical to (28) with arguments of p_i and p_j being (w_i, w_c^C) and (w_c^C, w_i) instead of $\mathbf{w}$, respectively. With linear demand, the solution is $w_c^D = \alpha(2\beta - \gamma)/(4\beta)$, yielding a deviation profit of

$$\Pi_c^D = \frac{\alpha^2(2\beta - \gamma)^2}{32\beta(\beta + \gamma)(\beta - \gamma)}. \tag{31}$$

It can be easily verified that the common retailer is better off selling both products if they are sufficiently differentiated. Under wholesale price contracts, the common retailer does not pay a franchise fee to M_j, which renders distribution of product j profitable. However, if products are close substitutes, the demand for M_j's product becomes zero after a deviation of M_i. Setting $D^j\left(p_j(w_c^C, w_c^D), p_i(w_c^D, w_c^C)\right)$ equal to zero, we obtain that this occurs whenever γ exceeds $(\sqrt{3} - 1)\beta \approx (0.732)\beta$, which is identical to the threshold value $\widehat{\gamma}$ derived in Subsection 5.1. If $\gamma > \widehat{\gamma}$, the deviant optimally sets a wholesale price of $\widehat{w}_c^D = \alpha(2\gamma - \beta)/(2\gamma)$, which drives the rival out of the market.[35] The corresponding deviation profit is

$$\widehat{\Pi}_c^D = \frac{\alpha^2(2\gamma - \beta)}{8\gamma^2}. \tag{32}$$

Using (29), (30), (31) and (32), we can determine the critical discount factor δ_c above which manufacturers can sustain collusion under wholesale price contracts if products are sold through a common retailer. We obtain

$$\delta_c = \frac{(2\beta - \gamma)^2}{8\beta\,(\beta - \gamma) + \gamma^2} \quad \text{for} \quad \gamma \in [0, \widehat{\gamma}],$$

and

$$\delta_c = \frac{(2\beta - \gamma)^2\,(\beta^2 - \beta\gamma - \gamma^2)}{\beta(2\beta - 3\gamma)(\beta - \gamma)(2\beta + \gamma) - 2\gamma^4} \quad \text{for} \quad \gamma \in (\widehat{\gamma}, \beta). \tag{33}$$

7.2 Independent Retailers

Consider now that manufacturers distribute through independent retailers and that contracts cannot be observed by the rival retailer. Because the franchise fee does not affect a retailer's maximization program, the retail prices are still determined by (14).

Upstream Stage and Collusion

[35] As above, $\widehat{w}_c^D$ equals w_c^D at $\gamma = (0.732)\beta$.

In the wholesale stage, the optimization problem of manufacturer M_i is $\max_{w_i} \Pi_i = D^i\left(p_i(w_i, w_j^e), p_j^e\right) w_i$. Differentiating gives

$$w_i \frac{\partial D^i(\cdot)}{\partial p_i} \frac{\partial p_i(w_i, w_j^e)}{\partial w_i} + D^i(\cdot) = 0, \quad i = 1, 2. \tag{34}$$

With linear demand, the wholesale price that solves the system of first-order conditions, such that retailers' expectations are fulfilled, is $w_I^N = 2\alpha(\beta - \gamma)/(4\beta - 3\gamma)$, which results in a punishment profit of

$$\Pi_I^N = \frac{2\alpha^2\beta(\beta - \gamma)}{(\beta + \gamma)(4\beta - 3\gamma)^2}. \tag{35}$$

In case manufacturers collude, their maximization problem is $\max_{w_1, w_2} \sum_{i=1}^{2} D^i\big(p_i(w_i, w_j^e), p_j(w_j, w_i^e)\big) w_i$, whose solution is determined by the following system of first-order conditions:

$$\left(\frac{\partial D^i(\cdot)}{\partial p_i} w_i + \frac{\partial D^j(\cdot)}{\partial p_i} w_j\right) \frac{\partial p_i(w_i, w_j^e)}{\partial w_i} + D^i(\cdot) = 0, \quad i = 1, 2.$$

With linear demand, the equilibrium collusive wholesale price is $w_I^C = 2\alpha\beta/(4\beta - \gamma)$, leading to a collusion profit of

$$\Pi_I^C = \frac{2\alpha^2\beta^2}{(\beta + \gamma)(4\beta - \gamma)^2}. \tag{36}$$

In contrast to the case with two-part tariffs, manufacturers do no longer maximize industry profits. This is because wholesale price contracts prevent them from channel coordination. Under collusion, manufacturers optimally increase the wholesale price, which softens competition at the retail level. Because their only instrument to extract rents is the per unit margin, they set the collusive wholesale price so that retailers optimally raise the downstream price above the monopoly level. The next proposition summarizes the analysis:

Proposition 9. *With independent (exclusive) retailers, each manufacturer realizes a profit from collusion that is given by (36). In contrast to two-part tariffs, collusion profits are below the maximized industry profits.*

Deviation and Sustainability of Collusion

If M_i deviates from the collusive agreement, his maximization program is $\max_{w_i} \Pi_i = D^i\left(p_i(w_i, w_I^C), p_j(w_I^C, w_I^C)\right) w_i$. The corresponding first-order condition is identical to (34) except for the arguments of p_i and p_j, which are (w_i, w_I^C) and (w_I^C, w_I^C), respectively. Solving for the deviation wholesale price yields $w_I^D = \alpha(2\beta-\gamma)/(4\beta-\gamma)$. The deviant's profit is

$$\Pi_I^D = \frac{\alpha^2\beta\left(2\beta-\gamma\right)^2}{2(4\beta-\gamma)^2\left(\beta^2-\gamma^2\right)}.$$

As above, the demand for the non-deviant's product becomes zero for γ large enough. Inserting w_I^D and w_I^C into M_j's demand shows that this occurs again if γ is larger than $\widehat{\gamma}$. If $\gamma > \widehat{\gamma}$, M_i sets a wholesale price equal to $\widehat{w}_I^D = 2\alpha\beta(2\gamma-\beta)/(\gamma(4\beta-\gamma))$ to drive M_j's demand to zero. The resulting deviation profit is

$$\widehat{\Pi}_I^D = \frac{2\alpha^2\beta^2(2\gamma-\beta)}{\gamma^2(4\beta-\gamma)^2}.$$

Determining the critical discount factor δ_I yields

$$\delta_I = \frac{(4\beta-3\gamma)^2}{4\beta(4\beta-5\gamma)+5\gamma^2} \quad \text{for} \quad \gamma \in [0,\widehat{\gamma}]$$

and

$$\delta_I = \frac{\beta(4\beta-3\gamma)^2\left(\beta^2-\beta\gamma-\gamma^2\right)}{\beta\left(4\beta-3\gamma\right)^2\left(\beta^2-\beta\gamma-\gamma^2\right)-\gamma^5} \quad \text{for} \quad \gamma \in (\widehat{\gamma},\beta). \tag{37}$$

7.3 Public Contracts, Stability of Tacit Collusion, and Welfare

Public Contracts

This subsection studies how tacit collusion between manufacturers works if they propose wholesale price contracts to their independent retailers that can be observed by the rival retailer. We delegate all calculations to Appendix B and confine ourselves to a verbal explanation since the formal presentation follows the same lines as the one under private contracts. From subsection 5.2, we know that contract observability involves a strategic effect. In the stage game, manufacturers choose wholesale prices above marginal cost to relax downstream competition. This result extends to the scenario under wholesale price contracts: in the Nash equilibrium, the wholesale price set by manufacturers and their respective stage game profits are higher under public than under private contracts. Turning to collusion, with two-part tariffs the profit is the same under contract observability and secrecy. This is no longer true under wholesale price contracts. The following proposition states how the manufacturers' collusive strategy changes when contracts become observable.

Proposition 10. *With independent (exclusive) retailers, each manufacturer sets a lower collusive wholesale price and earns a higher collusion profit under contract observabil-*

ity as compared to the scenario under contract secrecy.

Proposition 10 demonstrates that observable contracts lead to higher collusion profits than secret contracts. Interestingly, manufacturers set a collusive wholesale price that is lower under public contracts than under private contracts. The reason for this is rooted in the strategic effect. However, in contrast to the well-known consequence that an increase in wholesale prices dampens downstream competition, the strategic effect induces manufacturers to *lower* their wholesale prices if they collude under wholesale price contracts. The intuition is as follows: colluding manufacturers maximize joint profits at the upstream level. Due to the strategic effect, a decrease in the wholesale price for product i induces retailer j to decrease her retail price because prices are strategic complements. Under wholesale price contracts, a decrease in downstream prices has a beneficial effect on the upstream collusion profit: it reduces double marginalization and leads to an increase in the quantities sold. This is in contrast to the competitive scenario where manufacturers strategically increase wholesale prices to induce the rival retailer to price less aggressively. As a consequence, collusive wholesale prices are higher under secret contracts, which leads to lower quantities, and thus to lower collusion profits.

Stability of Collusion

Following the analysis of Section 6, the natural question is which channel structure is most suitable for manufacturer collusion under wholesale price contracts. Comparing the collusion profit and the critical discount factor under common retailing with those under independent retailing and secret contracts, we obtain that not only the collusion profit but also the critical discount factor is higher under the latter channel structure. However, this does not imply that collusion is more difficult to sustain with independent retailers because manufacturers can also collude only partially in this regime resulting in a collusion profit below the maximum, but making collusion sustainable for a larger range of discount factors. A similar problem arises in the comparison between public and private contracts with independent retailers where, in contrast to two-part tariffs, the collusion profit under observable contracts exceeds the one under private contracts but the critical discount factor is also higher.

In order to provide a meaningful comparison, we need to proceed in a different way than above by focusing on partial collusion. In particular, we equate the collusion profits of the two channel structures that we aim to compare. If we find that one structure yields a strictly lower critical discount factor, this implies, by continuity of the model, that it is possible to find a collusion profit which is slightly higher than under the other structure, and this collusion profit can be sustained for a strictly lower discount factor. The results of this analysis are summarized in the next proposition and illustrated in Figure 3.

Proposition 11. *With linear demand, under wholesale price contracts, distributing through a common retailer makes collusion most difficult to sustain. In addition, with independent (exclusive) retailers, public contracts facilitate collusion compared to private contracts. Formally, $\delta_c \geq \delta_I \geq \delta_{IO}$.*

Comparing common with independent retailing yields the same qualitative result as with two-part tariffs. In particular, the collusion profit realized under common retailing can be sustained under independent retailing for a strictly larger range of discount factors, no matter if contracts are observable or not. The intuition behind the result slightly differs from to the one with two-part tariffs but follows similar lines. With two-part tariffs, the deviant always induces the common retailer to reject the rival's contract. Under wholesale price contracts, this monopolization is not possible (as long as competition is not too fierce). However, the deviant affects the quantity that the common retailer procures from the rival. When deviating and setting the wholesale price below the collusive level, the deviant induces the common retailer to order less from the rival, which is not possible with independent retailers. As a consequence, the ratio between the deviation and the collusion profit is higher with common retailing compared to independent retailing.

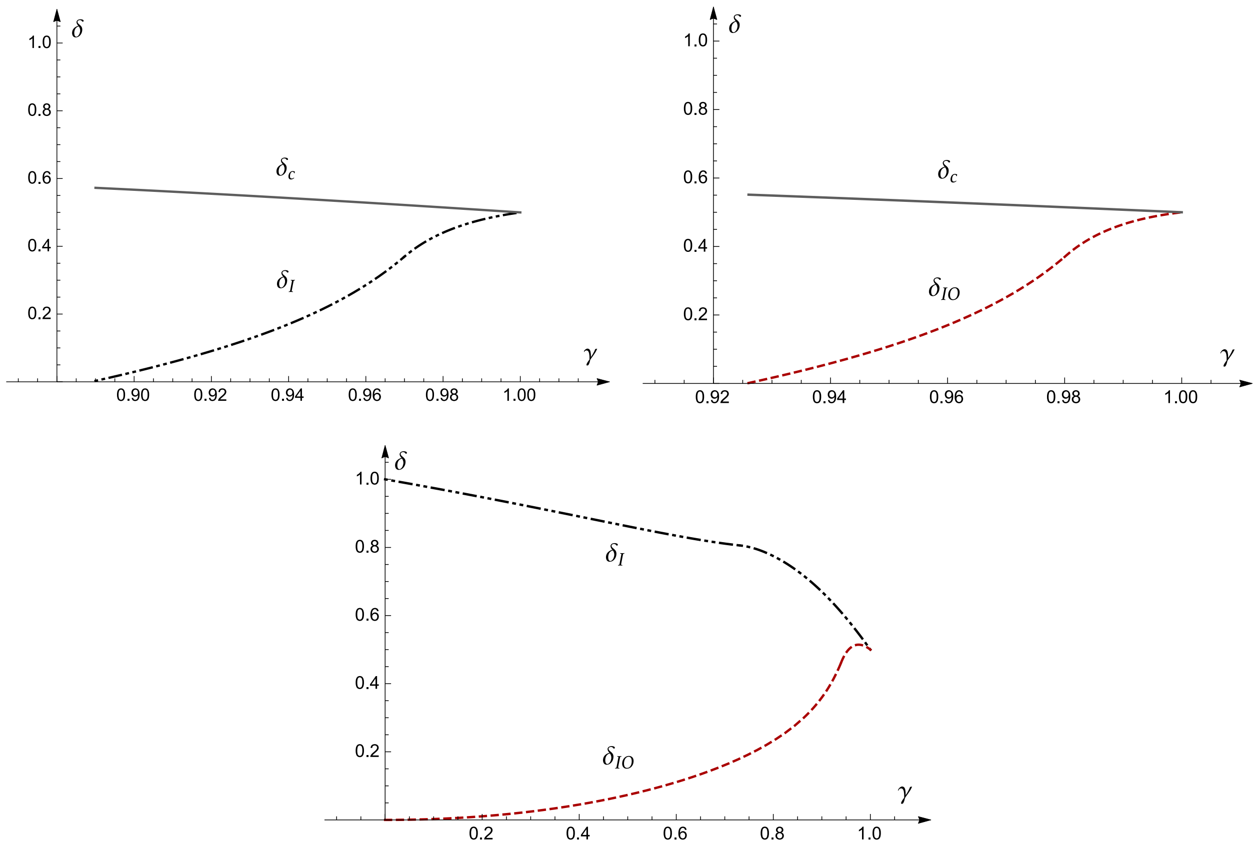
Turning to the comparison between contract observability and secret contracts with independent retailers, we find that the former facilitates collusion for all degrees of product substitutability. This result differs from the one obtained with two-part tariffs where private contracts facilitate collusion if products are close substitutes. The intuition is as follows: the strategic effect allows colluding manufacturers to influence the downstream price of the rival retailer under observable contracts. As explained above, this allows manufacturers to obtain the same collusion profit under public contracts with a lower wholesale price than under private contracts. The reason is that the quantity increase following the reduction in the wholesale prices is larger under public than under private contracts, leading to higher deviation incentives under the latter. As a consequence, observable contracts make tacit collusion more stable than secret contracts if manufacturers distribute through independent retailers.

Welfare

As with two-part tariffs, social welfare is always lower in case that the manufacturers distribute through a common retailer, irrespective of whether contracts are observable or not with independent retailers. This holds for all ranges of the critical discount factor.

In what follows, we focus on private contracts. First, consider that $\delta < \delta_I < \delta_c$, i.e.,

Figure 3: Critical Discount Factors under Partial Collusion ($\beta = 1$)



collusion is not sustainable under both channel structures. We have that $p_c^N = \alpha(3\beta - 2\gamma)/(4\beta - 2\gamma)$ and $p_I^N = 3\alpha(\beta - \gamma)/(4\beta - 3\gamma)$. It is easily checked that $p_c^N > p_I^N$. Second, consider $\delta_I \leq \delta < \delta_c$, i.e., collusion is sustainable with independent retailers but not with a common retailer. The respective downstream price under partial collusion is $p_I^C = \alpha\left(6\beta - \sqrt{2}\sqrt{\beta}\sqrt{\gamma} - 4\gamma\right)/4(2\beta - \gamma)$. A comparison yields $p_c^N - p_I^C = \alpha\sqrt{\beta}\sqrt{\gamma}/\sqrt{2}(4\beta - 2\gamma)$, which is strictly positive. Finally, for $\delta_I < \delta_c \leq \delta$, it directly follows that $p_c^C > p_I^C$ because the collusive downstream price exceeds the Nash downstream price under common retailing. Thus, common retailing always leads to higher consumer prices than independent retailing with private contracts. Conducting the same analysis for independent retailing with public contracts leads to the same qualitative results that for every δ, retail prices are higher under common retailing than under independent retailing.

8 Conclusion

We analyzed the effects of different channel structures on the ability of manufacturers to tacitly collude. We demonstrated that tacit collusion between manufacturers under common retailing works in a fundamentally different way than in case they sell directly to final consumers. In the latter case, manufacturers maximize industry profits under collusion. By contrast, with a common retailer, manufacturers willingly accept industry profits below the static ones. They set higher wholesale prices to increase their profit share at the expense of the retailer, thereby obtaining a larger piece of a smaller pie.

When comparing common with independent retailing, our paper demonstrates that the latter genuinely facilitates collusion. The result holds both for public and private contracts and is robust if manufacturers offer wholesale price contracts instead of a two-part tariff. Deviation under common retailing is shown to be particularly attractive relative to sticking to collusion: a deviating manufacturer monopolizes the downstream market in the period of deviation—an effect not present with independent retailers. However, although independent retailing facilitates collusion, it leads to higher welfare because a common retailer always acts as monopolist in the downstream market.

In case manufacturers sell through independent retailers and coordinate the channel with a two-part tariff, our analysis reveals that secret contracts facilitate collusion if products are close substitutes. This result provides a rationale for why manufacturers want to keep contracts secret. Therefore, it contrasts with the findings obtained in static models, which conclude that manufacturers always prefer public contracts due to their competition-dampening effect at the retail level.

In our analysis we restricted attention to punishments involving infinite reversion of the stage game outcome. A natural question is therefore if our main results still hold with optimal punishment. Characterizing optimal penal codes is difficult in models with differentiated products because manufacturers' profits are positive even during the punishment phase (see e.g., Wernerfelt 1989 or Häckner 1996). Determining the punishment profit then involves the calculation of the optimal punishment length, which cannot be done in closed form. However, with homogeneous goods, optimal penal codes are equivalent to infinite reversion of the stage game because the latter already implies that manufacturers obtain zero profits. Therefore, optimal punishment cannot inflict lower profits on the deviant manufacturer (see e.g., Belleflamme and Peitz 2010). It follows that for homogeneous products, our results hold even under consideration of optimal penal codes. In addition, the intuition of our main result rested on the finding that colluding manufacturers do not maximize industry profits when distributing through a common retailer. This effect is independent of the form of the punishment because it does not affect the punishment phase. This hints to the fact that a similar effect as the one identified in our analysis drives the critical discount factor when considering optimal punishments. However, we leave an analysis of this case for future research.

Finally, our analysis focuses on common versus independent (exclusive) retailing. However, other channel structures are also common. For example, in markets exhibiting shopping costs on the consumer side, competing manufacturers often sell their brands through multiple common retailers. This implies that there is not only competition between the manufacturers (inter-brand competition) but also between retailers (intra-brand competition). A natural extension of our paper for future research would be to analyze whether intra-brand competition leads to new effects on the sustainability of cooperative agreements between suppliers.

Appendix

Appendix A

First, we check whether the common retailer prefers to accept both the offer of the deviant M_i and the one of M_j who sticks to collusion. The demand for product j at the retail level given wholesale prices $w_i = w_c^D$ and $w_j = w_c^C$ is

$$D^j(p_j(w_c^C, w_c^D), p_i(w_c^D, w_c^C)) = \frac{\alpha\,(\beta^2 - \beta\gamma - \gamma^2)}{2(\beta-\gamma)(\beta+\gamma)^2}.$$

Solving $D^j(p_j(w_c^C, w_c^D), p_i(w_c^D, w_c^C)) = 0$ yields that the demand for M_j's product is only positive if $\gamma \leq (\sqrt{5}-1)\beta/2 \approx (0.618)\beta$.[36] It follows that for $\gamma > (0.618)\beta$, the retailer can never optimally accept both offers. Let us now look at $\gamma \leq (0.618)\beta$. Inserting the wholesale prices $w_i = w_c^D$ and $w_j = w_c^C$ and the franchise fees $T_i = T_c^D$ and $T_j = T_c^C$ into (1) gives

$$\pi_c^D(w_c^D, w_c^C, T_c^D, T_c^C) = \frac{\alpha^2\gamma\,(2\beta^2(\beta-2\gamma) + \gamma^2(2\beta+\gamma))}{4\beta(\beta-\gamma)(\beta+\gamma)^2}.$$

The profit of the common retailer when accepting only the deviant's offer is given by[37]

$$\pi_c^D(w_c^D, \infty, T_c^D, \infty) = \frac{\alpha^2\beta\gamma}{2(\beta+\gamma)^3}.$$

Subtracting $\pi_c^D(w_c^C, w_c^D, T_c^C, T_c^D)$ from $\pi_c^D(w_c^D, \infty, T_c^D, \infty)$ yields

$$\pi_c^D(w_c^D, \infty, T_c^D, \infty) - \pi_c^D(w_c^D, w_c^C, T_c^D, T_c^C) = \frac{\alpha^2\gamma^2\,(2\beta^2 - 2\beta\gamma - \gamma^2)}{4\beta(\beta-\gamma)(\beta+\gamma)^3}, \tag{38}$$

which is positive for $\gamma \leq (\sqrt{3}-1)\beta \approx (0.732)\beta$. Thus, the common retailer prefers to accept only the deviant's offer for all parameter constellations at which the demands for both products can be positive.

Second, let us check whether M_i deviates so that the common retailer only accepts his offer. From the main text, we know that M_i's profit in this case is given by (12). If M_i deviates so that R_c accepts both offers, his deviation profit maximizes $D^i(w_i, w_c^C)w_i + T_i$ with respect to w_i and T_i. The highest fixed fee that M_i can demand is given by the

[36] Here and in the following, numbers are rounded to three decimal places.

[37] As explained in Assumption A.1, the demand function of product i if $q_j = 0$ is $D^i(p_i) = (\alpha - p_i)/\beta$. Inserting the optimal retail price for $w_i = w_c^D$ then yields $\pi_c^D(w_c^D, \infty, T_c^D, \infty)$.

expression

$$D^i(p_i(w_i, w_c^C), p_j(w_c^C, w_i))(p_i(w_i, w_c^C) - w_i) + D^j(p_j(w_c^C, w_i), p_i(w_i, w_c^C))(p_j(w_c^C, w_i) - w_c^C) - T_i$$

$$= D^j(p_j^M(w_c^C), \infty)(p_j^M(w_c^C) - w_c^C).$$

Solving for T_i and inserting into $D^i(p_i(w_i, w_c^C), p_j(w_c^C, w_i))w_i + T_i$, we obtain that M_i deviates by maximizing $D^i(p_i(w_i, w_c^C), p_j(w_c^C, w_i))p_i(w_i, w_c^C) + D^j(p_j(w_c^C, w_i), p_i(w_i, w_c^C))(p_j(w_c^C, w_i) - w_c^C)$ with respect to w_i. With linear demand, the maximization program is

$$\frac{\beta\left(\alpha\beta + w_i(\beta+\gamma)\right)\left(\alpha\beta - w_i(\beta+\gamma)\right)}{4(\beta-\gamma)(\beta+\gamma)^3}.$$

Maximizing with respect to w_i yields $w_c^D = 0$, that is, the deviation wholesale price is identical to the one in case R_c accepts only M_i's offer. Inserting $w_c^D = 0$ yields a deviation profit of

$$\frac{\alpha^2\beta^3}{4(\beta-\gamma)(\beta+\gamma)^3}.$$

Subtracting this expression from Π_c^D given by (12) yields

$$\frac{\alpha^2\gamma^2\left(2\beta^2 - 2\beta\gamma - \gamma^2\right)}{4\beta(\beta-\gamma)(\beta+\gamma)^3},$$

which is identical to (38). It follows that there does not exist a parameter range where M_i profitably deviates so that both products are distributed. Therefore, the optimal deviation implies that M_i induces R_c to reject M_j's offer.

Proof of Lemma 1

In the Nash equilibrium, each manufacturer sets $w_c^N = 0$ and R_c sets $p_c^N = \alpha/2$ for either brand. Industry profits are maximized and given by $IP_c^N = \alpha^2/(2(\beta+\gamma))$. In the collusive regime, M_i and M_j set w_c^C above marginal cost (i.e., $w_c^C = \alpha\gamma/(\beta+\gamma)$) and R_c raises the downstream prices to $p_c^C = \alpha(\beta+2\gamma)/2(\beta+\gamma)$, which is above the monopoly level. Thus, industry profits are below their maximum value and given by $IP_c^C = \alpha^2\beta(\beta+2\gamma)/2(\beta+\gamma)^3$. The ratio between the industry profits under collusion and those in the Nash equilibrium is $IP_c^C/IP_c^N = \beta(\beta+2\gamma)/(\beta+\gamma)^2$. Taking the derivative of IP_c^C/IP_c^N with respect to γ yields $\partial\left(IP_c^C/IP_c^N\right)/\partial\gamma = -2\beta\gamma/(\beta+\gamma)^3$, which is strictly negative. Therefore, an increase in competition implies a larger decrease in IP_c^C relative to IP_c^N. Using (7) and (9) yields the respective shares of the industry profits obtained by manufacturers, which are

$\Pi_c^N/IP_c^N = (\beta-\gamma)/\beta$ in the stage game equilibrium and $\Pi_c^C/IP_c^C = (\beta+\gamma)/(\beta+2\gamma)$ under collusion. Straightforward calculations show that $\Pi_c^C/IP_c^C > \Pi_c^N/IP_c^N$ and

$$\frac{\partial \frac{\Pi_c^C/IP_c^C}{\Pi_c^N/IP_c^N}}{\partial \gamma} = \frac{2\beta\gamma(2\beta+\gamma)}{(\beta+2\gamma)^2(\beta-\gamma)^2} > 0.$$

■

Proof of Proposition 6.

First, using (9) and (17), we can compare the equilibrium collusion profits. This yields $\Pi_c^C - \Pi_I^C = -\gamma\alpha^2/\left(4(\beta+\gamma)^2\right) < 0$. Because $\Pi_{IO}^C = \Pi_I^C$, it follows that $\Pi_{IO}^C > \Pi_c^C$. Thus, collusion profits are strictly larger under independent than under common retailing.

Second, using (13) and (20), we can compare the critical discount factor above which manufacturers can sustain collusion under common retailing with the one under independent retailing and private contracts. Doing so yields

$$\delta_c - \delta_I = \frac{8\beta^2(\beta-\gamma) - \gamma^2(\beta+\gamma)}{2(2\beta+\gamma)\left(8\beta(\beta-\gamma)+\gamma^2\right)} \quad \text{for } \gamma \in [0, \widehat{\gamma}]$$

and

$$\delta_c - \delta_I = \frac{\beta\left(4\beta^3(\beta-\gamma) + \gamma^2\left(\gamma(4\beta+5\gamma) - 7\beta^2\right)\right)}{2(2\beta+\gamma)\left(4\beta^3(2\gamma-\beta) - \gamma^2\left(\beta^2+3\gamma\beta-2\gamma^2\right)\right)} \quad \text{for} \quad \gamma \in (\widehat{\gamma}, \beta).$$

It can be immediately verified that the first expression is positive if and only if $\gamma \leq (0.838)\beta$. Since the expression is valid for $\gamma \leq \widehat{\gamma} \equiv (0.732)\beta$, it is positive for $\gamma \in [0, \widehat{\gamma}]$. The numerator of the second expression is positive for $\gamma \in [0, \beta)$ and the denominator is positive for $\gamma \in ((0.591)\beta, \beta]$. Since the second expression is valid for $\gamma > (0.732)\beta$, it is strictly positive for $\gamma \in (\widehat{\gamma}, \beta)$. Finally, comparing the critical discount factor under common retailing with the one under independent retailing and observable contracts yields that $\delta_c - \delta_{IO}$ is given by

$$\frac{32\beta^4(\beta-\gamma) - 4\beta^2\gamma^2(5\beta-4\gamma) + \gamma^4(3\beta-\gamma)}{2(2\beta+\gamma)\left(32\beta^3(\beta-\gamma) - 12\beta\gamma^2(\beta-\gamma) + \gamma^4\right)} \text{ for } \gamma \in [0, \widetilde{\gamma}],$$

$$\frac{64\beta^7(\beta-\gamma) - 16\beta^5\gamma^2(9\beta-8\gamma) + 28\beta^3\gamma^4(4\beta-3\gamma) - 25\gamma^6\beta^2 + 3\gamma^7(4\beta+\gamma)}{2(2\beta+\gamma)\left(64\beta^7(2\gamma-\beta) + 16\beta^4\gamma^2(\beta-9\gamma) + 4\beta^2\gamma^4(12\beta+7\gamma) - 7\beta\gamma^6 - 3\gamma^7\right)} \text{ for } \gamma \in (\widetilde{\gamma}, \beta).$$

Both expressions are positive in the relevant range, implying that $\delta_c > \delta_{IO}$. Consequently, collusion is easier to sustain with independent retailers, regardless of whether contracts are observable or not. ■

Proof of Proposition 7.

We use (20) and (25) to compare the critical discount factor under private contracts with the one under public contracts: the difference $\delta_I - \delta_{IO}$ is given by

$$\frac{4\beta\gamma^3(4\beta-3\gamma)(\beta-\gamma)}{[8\beta^2-8\beta\gamma+\gamma^2]\,[\gamma^4+4\beta(\beta-\gamma)(8\beta^2-3\gamma^2)]} \text{ for } \gamma\in[0,\widehat{\gamma}],$$

$$\frac{\gamma^8+4\beta(\beta-\gamma)(2\beta-\gamma)\,(8\beta^5-12\beta^4\gamma-8\beta^3\gamma^2+10\beta^2\gamma^3+4\beta\gamma^4-\gamma^5)}{\kappa\,(4\beta^3(\beta-2\gamma)+\beta\gamma^2(\beta+3\gamma)-2\gamma^4)\,(4\beta(8\beta^2-3\gamma^2)(\beta-\gamma)+\gamma^4)} \text{ for } \gamma\in(\widehat{\gamma},\widetilde{\gamma}],$$

$$\frac{\gamma^4\,(\beta-\gamma)\,(4\beta^2-4\beta\gamma-\gamma^2)\,(12\beta^4+4\beta^3\gamma-15\beta^2\gamma^2+3\gamma^4)}{\kappa\,(64\beta^7(2\gamma-\beta)+16\beta^4\gamma^2(\beta-9\gamma)+4\beta^2\gamma^4(12\beta+7\gamma)-\gamma^6(7\beta+3\gamma))} \text{ for } \gamma\in(\widetilde{\gamma},\beta).$$

with $\kappa \equiv (4\beta^3(\beta-2\gamma)+\beta\gamma^2(\beta+3\gamma)-2\gamma^4)$. It is readily checked that the first term is positive for $\gamma\in[0,\beta)$. The second expression is valid between $\widehat{\gamma}=(0.732)\beta$ and $\widetilde{\gamma}=(0.841)\beta$. Setting it equal to zero and solving for γ, we obtain that it is positive for $\gamma\leq(0.825)\beta$ and negative for $\gamma>(0.825)\beta$. Finally, it is easy to verify that the third expression is strictly negative for all γ between $\widetilde{\gamma}$ and β. Therefore, collusion is easier to sustain under public than under private contracts if $\gamma\leq(0.825)\beta$ and vice versa. ■

Proof of Lemma 2

In the Nash equilibrium, manufacturers set $w_c^N=\alpha(\beta-\gamma)\,(2\beta-\gamma)$ and R_c sets $p_c^N=\alpha(3\beta-2\gamma)/2(2\beta-\gamma)$. Industry profits are given by

$$IP_c^N=\frac{\alpha^2\beta(3\beta-2\gamma)}{2(2\beta-\gamma)^2(\beta+\gamma)}.$$

Under collusion, M_i and M_j raise the wholesale price to $w_c^C=\alpha/2$, resulting in a downstream price of $p_c^C=3\alpha/4$. Industry profits are given by $IP_c^C=3\alpha^2/8(\beta+\gamma)$.
Following the proof of *Lemma 1*, the ratio between industry profits under collusion and in the Nash equilibrium is $IP_c^C/IP_c^N=3(2\beta-\gamma)^2/4\beta(3\beta-2\gamma)$. Taking the derivative with respect to γ yields $\partial\left(IP_c^C/IP_c^N\right)/\partial\gamma=-3\left(2\beta^2-3\beta\gamma+\gamma^2\right)/2\beta(3\beta-2\gamma)^2$, which is strictly negative. The portion of the industry profits obtained by manufacturers are derived from (29) and (30) and given by $\Pi_c^N/IP_c^N=2(\beta-\gamma)/\left(3\beta-2\gamma\right)$ in the stage game equilibrium and by $\Pi_c^C/IP_c^C=2/3$ under collusion. As with two-part tariffs, $\Pi_c^C/IP_c^C>\Pi_c^N/IP_c^N$ and

$$\frac{\partial\frac{\Pi_c^C/IP_c^C}{\Pi_c^N/IP_c^N}}{\partial\gamma}=\frac{\beta}{3(\beta-\gamma)^2}>0.$$

$\blacksquare$

Appendix B

Under wholesale price contracts and contract observability, the stage game wholesale price that manufacturers set with linear demand is $w_{IO}^N = \alpha(\beta-\gamma)(2\beta+\gamma)/(4\beta^2-\beta\gamma-2\gamma^2)$. This wholesale price exceeds the one under private contracts, that is,

$$w_{IO}^N - w_I^N = \frac{\alpha\gamma^2(\beta-\gamma)}{(4\beta-3\gamma)\left(\beta(4\beta-\gamma)-2\gamma^2\right)} > 0.$$

The resulting profit in the punishment phase is

$$\Pi_{IO}^N = \frac{\alpha^2\beta(\beta-\gamma)(2\beta+\gamma)\left(2\beta^2-\gamma^2\right)}{\left(4\beta^2-\beta\gamma-2\gamma^2\right)^2\left(2\beta^2+\beta\gamma-\gamma^2\right)}.$$

As with two-part tariffs, the stage game profit under observable contracts is larger than the one under private contracts given by (35). We have that

$$\Pi_{IO}^N - \Pi_I^N = \frac{\alpha^2\beta\gamma^3(\beta-\gamma)\left(2\beta(2\beta-\gamma)-\gamma^2\right)}{(4\beta-3\gamma)^2(2\beta-\gamma)(\beta+\gamma)\left(\beta(4\beta-\gamma)-2\gamma^2\right)^2},$$

which is strictly positive. The equilibrium wholesale price chosen by manufacturers under collusion is $w_{IO}^C = \alpha/2$. This collusive wholesale price is below the one under private contracts, i.e., $w_{IO}^C - w_I^C = -\alpha\gamma/(8\beta-2\gamma) < 0$. The respective collusion profit is given by

$$\Pi_{IO}^C = \frac{\alpha^2\beta}{2(\beta+\gamma)(2\beta-\gamma)}.$$

Subtracting the collusion profit under private contracts (36) gives

$$\Pi_{IO}^C - \Pi_I^C = \frac{\alpha^2\beta\left(4\beta(2\beta-\gamma)+\gamma^2\right)}{2(2\beta-\gamma)(\gamma-4\beta)^2(\beta+\gamma)},$$

which is positive. Thus, when colluding, manufacturers generate higher profits under observable contracts than under secret contracts. If M_i deviates from the collusive agreement, M_i optimally sets $w_{IO}^D = \alpha\left(4\beta^2-\beta\gamma-2\gamma^2\right)/4\left(2\beta^2-\gamma^2\right)$. The deviation profit is given by

$$\Pi_{IO}^D = \frac{\alpha^2\beta\left(-4\beta^2+\beta\gamma+2\gamma^2\right)^2}{16(\beta-\gamma)(2\beta-\gamma)(\beta+\gamma)(2\beta+\gamma)\left(2\beta^2-\gamma^2\right)}.$$

As above, the demand for the product of the non-deviant becomes zero for γ large enough. Inserting w_{IO}^D and w_{IO}^C into M_j's demand function shows that this occurs if $\gamma > (0.887)\beta$. If $\gamma > (0.887)\beta$, M_i sets a wholesale price equal to $\widehat{w}_{IO}^D = \alpha\left(\gamma(2\beta+\gamma) - 2\beta^2\right)/2\beta\gamma$, which drives M_j's demand to zero. The resulting deviation profit is

$$\widehat{\Pi}_{IO}^D = \frac{\alpha^2\left(\gamma(2\beta+\gamma) - 2\beta^2\right)}{4\beta\gamma^2}.$$

Determining the critical discount factor δ_{IO} yields

$$\delta_{IO} = \frac{\left(4\beta^2 - \beta\gamma - 2\gamma^2\right)^2}{16\beta^3(2\beta-\gamma) - 31\beta^2\gamma^2 + 8\gamma^3(\beta+\gamma)}$$

for $\gamma \leq (0.887)\beta$ and

$$\delta_{IO} = \frac{\left(4\beta^2 - \beta\gamma - 2\gamma^2\right)^2\left(2\beta^3(2\beta-\gamma) - \beta\gamma^2(5\beta-\gamma) + \gamma^4\right)}{64\beta^7(\beta-\gamma) - 31\beta^2\gamma^6 - 2\beta^4\gamma^2\left(62\beta^2 - 45\gamma^2\right) + 51\beta^3\gamma^3\left(2\beta^2-\gamma^2\right) + 4\gamma^7(2\beta+\gamma)}$$

for $\gamma \in ((0.887)\beta, \beta)$.

Appendix C

Sustainability of Collusion: Common vs. Independent Retailing under Private Contracts

To derive comparable results we need to consider partial collusion so that the collusion profit with independent retailers and private contracts is the same as the one with a common retailer given by (30). Determining the symmetric wholesale price that gives manufacturers the same collusion profit as under common retailing, we obtain

$$w_I^C = \frac{\alpha\left(2\beta - \sqrt{2}\sqrt{\beta}\sqrt{\gamma}\right)}{4\beta}.$$

If M_i deviates from this partially collusive agreement, his maximization program is $\max\limits_{w_i} \Pi_i = D^i\left(p_i(w_i, w_I^C), p_j(w_I^C, w_I^C)\right) w_i$. The corresponding first-order condition is identical to (34) except for the arguments of p_i and p_j, which are (w_i, w_I^C) and (w_I^C, w_I^C), respectively. With linear demand, M_i sets a deviation wholesale price which is given by

$$w_I^D = \frac{\alpha\left(2\beta(4\beta-3\gamma) - \gamma\sqrt{2}\sqrt{\beta}\sqrt{\gamma}\right)}{8\beta(2\beta-\gamma)},$$

yielding a profit from deviation equal to

$$\Pi_I^D = \frac{\alpha^2 \left(8\beta\sqrt{\beta} - 6\gamma\sqrt{\beta} - \gamma\sqrt{2}\sqrt{\gamma}\right)^2}{128\left(\beta^2-\gamma^2\right)(2\beta-\gamma)^2}.$$

Proceeding in the familiar way shows that this deviation implies that the demand of M_j is positive if $\gamma \leq (0.970)\beta$. If $\gamma > (0.970)\beta$, M_i chooses a deviation wholesale price so that the demand for M_j's product is zero. The respective deviation profit is

$$\widehat{\Pi}_I^D = \frac{\alpha^2\left(2\sqrt{\beta}+\sqrt{2}\sqrt{\gamma}\right)\left(4\beta\sqrt{\beta}(2\gamma-\beta)+\sqrt{2}\sqrt{\gamma}\left(\gamma^2-2\beta^2\right)-2\gamma^2\sqrt{\beta}\right)}{16\gamma^2(2\beta-\gamma)^2}.$$

Before determining the critical discount factor, we compare the difference between the Nash profit with independent retailers (35) and the collusion profit with a common retailer (30). It can be easily shown that the former exceeds the latter if $\gamma \leq (0.889)\beta$. This implies that the the collusion profit with a common retailer can be sustained for all $\delta \geq 0$ under independent retailing.

Turning to the range $\gamma > (0.889)\beta$, the critical discount factor δ_I above which manufacturers can sustain collusion under independent retailing is

$$\delta_I = \frac{(4\beta-3\gamma)^2\left(3\sqrt{2}\sqrt{\gamma}-4\sqrt{\beta}\right)}{\sqrt{\gamma}\left(32\beta\left(\sqrt{2}(\beta-\gamma)-\sqrt{\beta}\right)+\gamma^2\left(28\sqrt{\beta}\sqrt{\gamma}+3\sqrt{2}\right)\right)},$$

for $\gamma \in [(0.889)\beta, (0.970)\beta]$, and

$$\delta_I = \frac{\beta(4\beta-3\gamma)^2\left(2\sqrt{\beta}\left(\beta\sqrt{\beta}\left(2\left(\beta+\sqrt{2}\sqrt{\beta}\sqrt{\gamma}\right)-\gamma\right)-2\gamma^2\sqrt{2}\sqrt{\gamma}\right)\right)}{\beta\left(2\sqrt{\beta}\left(2\sqrt{2}\sqrt{\gamma}(\beta-\gamma)(\beta+\gamma)(4\beta-3\gamma)^2+\sqrt{\beta}\,\Phi\right)+17\gamma^5\right)-9\gamma^6},$$

for $\gamma \in ((0.970)\beta, \beta)$, with $\Phi = 32\beta^3(\beta-2\gamma)+2\gamma^2\left(21\beta^2+\gamma^2\right)-17\beta\gamma^3$.

We know that for $\gamma \leq (0.889)\beta$, Π_I^N is higher than Π_c^C. Thus, to provide a meaningful comparison between δ_I and δ_c we focus the range $\gamma > (0.889)\beta$. We must distinguish between two cases. We start with the case $(0.889)\beta < \gamma \leq (0.970)\beta$. Subtracting the critical discount factor with independent retailers and private contracts from the one with a common retailer given by (33), we obtain that $\delta_c - \delta_I$ is given by

$$\frac{1}{2}+\frac{\sqrt{2}\sqrt{\beta}}{\sqrt{\gamma}}+\frac{\gamma^4}{\psi}+\frac{8\sqrt{\beta}\sqrt{\gamma}\left(7\sqrt{2}\sqrt{\beta}\sqrt{\gamma}-12\beta+11\gamma\right)-51\sqrt{2}\gamma^2}{8\sqrt{\beta}\left(8\sqrt{\beta}\left(\sqrt{2}\beta-\sqrt{\beta}\sqrt{\gamma}-\sqrt{2}\gamma\right)+7\gamma\sqrt{\gamma}\right)+6\sqrt{2}\gamma^2},$$

with $\psi = \beta(2\beta-3\gamma)(\beta-\gamma)(2\beta+\gamma)-2\gamma^4$. Setting this expression equal to zero and solving for γ reveals that there is no solution for $\gamma \in [(0.889)\beta, (0.970)\beta]$. The two solutions closest to this range are $\gamma = (0.607)\beta$ and $\gamma = (0.982)\beta$, and for all γ in between, the expression is positive.

In the second case, i.e., for $(0.970)\beta < \gamma < \beta$, $\delta_c - \delta_I$ yields

$$\frac{\beta(4\beta-3\gamma)^2\left(3\gamma^3-2\sqrt{\beta}\left(\beta\sqrt{\beta}\left(2\sqrt{\beta}\left(\sqrt{\beta}+\sqrt{2}\sqrt{\gamma}\right)-\gamma\right)+2\gamma^2\sqrt{2}\sqrt{\gamma}\right)\right)}{\beta\left(2\sqrt{\beta}\left(2\sqrt{2}\sqrt{\gamma}(\beta-\gamma)(\beta+\gamma)(4\beta-3\gamma)^2+\sqrt{\beta}\Phi\right)+17\gamma^5\right)-9\gamma^6}$$

$$+\frac{\left(\beta^2-\beta\gamma-\gamma^2\right)(2\beta-\gamma)^2}{\psi}.$$

Proceeding as before shows that this expression is positive for $\gamma \in [(0.970)\beta, \beta)$.

Sustainability of Collusion under Independent Retailing: Private vs. Public Contracts

To compare sustainability of collusion between private and public contracts, we proceed as above and consider partial collusion. When manufacturers collude so that the collusion profit with public contracts is identical to Π_I^C, given by (36), each of them sets a wholesale price of $w_{IO}^C = \alpha(2\beta-\gamma)/(4\beta-\gamma)$.

When deviating from the partially collusive agreement, the deviant M_i optimally sets $w_{IO}^D = \alpha\left(4\beta\left(2\beta^2-\beta\gamma-\gamma^2\right)+\gamma^3\right)/\left(2(4\beta-\gamma)(2\beta^2-\gamma^2)\right)$, realizing a deviation profit given by

$$\Pi_{IO}^D = \frac{\alpha^2\beta\left(4\beta\gamma^3(\beta-\gamma)(2\beta+\gamma)\right)^2}{4(4\beta-\gamma)^2\left(8\beta^6-7\beta^2\gamma^2\left(2\beta^2-\gamma^2\right)-\gamma^6\right)}.$$

M_i's deviation implies that M_j's demand becomes zero if $\gamma > (0.940)\beta$. It is then optimal for M_i to deviate by setting $\widehat{w}_{IO}^D = \alpha\left(4\beta(\gamma-\beta)+\gamma^2\right)/\left(\gamma(4\beta-\gamma)\right)$, which keeps M_j out of the market. M_i's resulting profit is given by

$$\widehat{\Pi}_{IO}^D = \frac{2\alpha^2\beta\left(4\beta(\gamma-\beta)+\gamma^2\right)}{\gamma^2(4\beta-\gamma)^2}.$$

Determining the critical discount factor δ_{IO} in the standard way gives

$$\frac{\gamma^2\left(4\beta^2-\beta\gamma-2\gamma^2\right)^2}{\beta\left(8\beta^2(2\beta-\gamma)\left(4\beta^2-\beta\gamma-4\gamma^2\right)+\gamma^4(13\beta-4\gamma)\right)}$$

for $0 < \gamma \leq (0.940)\beta$ and

$$\frac{2\left(\beta(4\beta-\gamma)-2\gamma^2\right)^2\left(2\beta\left(2\beta\left(\beta(2\beta-\gamma)-2\gamma^2\right)+\gamma^3\right)+\gamma^4\right)}{2\beta^2\gamma^3\left(2\beta\left(94\beta^2-43\gamma^2\right)-41\gamma^3\right)+16\beta^4\left(16\beta^3(\beta-\gamma)-\gamma^2\left(27\beta^2-17\gamma^2\right)\right)+\gamma^7(25\beta+9\gamma)}$$

for $\gamma \in ((0.940)\beta, \beta)$.[38]

Subtracting this critical discount factor from the one under private contracts given by (37) yields that $\delta_I - \delta_{IO}$ equals

$$\frac{4(\beta-\gamma)\left(2\beta(2\beta-\gamma)-\gamma^2\right)\left(4\beta^3\left(4\beta(4\beta-3\gamma)-13\gamma^2\right)+5\gamma^3\left(7\beta^2-\gamma^2\right)+11\beta\gamma^4\right)}{\beta\left(4\beta(4\beta-5\gamma)+5\gamma^2\right)\left(8\beta^2(2\beta-\gamma)\left(4\beta^2-\beta\gamma-4\gamma^2\right)+\gamma^4(13\beta-4\gamma)\right)}$$

for $\gamma \in [0, \widehat{\gamma}]$,

$$\frac{17}{4}+\frac{\gamma}{\beta}+\frac{\Xi}{\Xi-\gamma^5}+\frac{\beta\left(8\beta(4\beta-\gamma)\left(9\gamma(\beta+4\gamma)-34\beta^2\right)-289\gamma^4\right)}{4\left(\gamma^4(13\beta-4\gamma)+8\beta^2\left(4\beta^2-\beta\gamma-4\gamma^2\right)(2\beta-\gamma)\right)}$$

for $\gamma \in (\widehat{\gamma}, (0.940)\beta]$, and

$$\frac{\gamma^5(\beta-\gamma)\left(64\beta^5(\beta+\gamma)(4\beta-5\gamma)-4\gamma^3\left(9\beta^4+2\gamma^4\right)+\beta\gamma^4\left(153\beta^2+49\beta\gamma-23\gamma^2\right)\right)}{\left(256\beta^7(\beta-\gamma)-2\beta^2\gamma^5(86\beta+41\gamma)-8\beta^4\gamma^2\left(54\beta^2-47\beta\gamma-34\gamma^2\right)+25\beta\gamma^7+9\gamma^8\right)\left(\Xi-\gamma^5\right)}$$

for $\gamma \in ((0.940)\beta, \beta]$, with $\Xi = \beta\left(\beta^2-\beta\gamma-\gamma^2\right)(4\beta-3\gamma)^2$. It can be shown that all three expressions are positive for the relevant parameter ranges. This implies that $\delta_I > \delta_{IO}$.

Sustainability of Collusion: Common vs. Independent Retailing under Public Contracts

The proof proceeds along the same lines as those above. First, it is easily shown that $\Pi_{IO}^N > \Pi_c^C$ if $\gamma \leq (0.926)\beta$. We then determine the partially collusive wholesale price (so that $\Pi_{IO}^C = \Pi_c^C$) and the corresponding optimal deviation profit for $\gamma > (0.926)\beta$. We can then determine the critical discount factor under independent retailing and observable contracts. We have that δ_{IO} is given by

$$\frac{\left(4\beta-\beta\gamma-2\gamma^2\right)^2(2\beta+\gamma)\left(8\beta^3-7\beta^2\gamma-4\beta\gamma^2+4\gamma^3\right)-\Upsilon}{\beta\left(\beta\gamma(2\beta+\gamma)(8\beta^3(4\beta-3\gamma)-23\beta^2\gamma^2+4\gamma^3(3\beta+\gamma)-\Upsilon\right)},$$

with $\Upsilon = 2\sqrt{2}\sqrt{\beta\gamma}\left(4\beta-\beta\gamma-2\gamma^2\right)^3$, if $(0.926)\beta < \gamma \leq (0.980)\beta$, and

$$\frac{\left(4\beta-\beta\gamma-2\gamma^2\right)^2(2\beta+\gamma)\left(4\beta^4+2\beta^3\gamma-3\beta^2\gamma^2-3\beta\gamma^3-\gamma^4\right)+\upsilon}{64\beta^6(2\beta^3-\beta^2\gamma+\gamma^3)-2\beta^4\gamma^2(124\beta^3-3\gamma^3-91\beta\gamma^2)-63\beta^3\gamma^6-19\beta^2\gamma^7+4\gamma^8(2\beta+\gamma)+\upsilon},$$

with $\upsilon = \Upsilon(\beta+\gamma)(\beta-\gamma)(2\beta+\gamma)(2\beta-\gamma)$, for $\gamma \in ((0.980)\beta, \beta)$. We obtain that $\delta_c > \delta_{IO}$ for all $\gamma \in ((0.926)\beta, \beta)$.

[38]Note that the Nash profit under public contracts is smaller than the collusion profit under private contracts.

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