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ABSTRACT

Selling to a cartel of retailers: a model of hub-and-spoke collusion*

This model describes the working of hub-and-spoke collusion that has been discussed recently by competition policy authorities. We develop a model of tacit collusion between a manufacturer and two retailers, competing a la Rotemberg and Saloner (1986). The best collusive equilibrium between retailers is inefficient and it is in the interest of the supplier to help retailers reach a more efficient collusive equilibrium. The hub and spoke conspiracy reduces double marginalization, but raises the ability of retailers to collude. The impact of a hub-and-spoke cartel on consumer's welfare depends on the bargaining power in the relationship. If the supplier has the bargaining power, the agreement, comparable to a vertical restraint, can be welfare improving in reducing double marginalization. When retailers have the bargaining power, the agreement is closer to an horizontal agreement in which retailers use the supplier to improve their collusive scheme, which leads to a loss of welfare. The result has important implications for competition policy and antitrust enforcement which are further developed in our companion paper Sahuguet and Walckiers (2013).

JEL Classification: D43, L41 and L42
Keywords: collusion, competition policy, horizontal relations, hub-and-spoke and vertical relations

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1 Introduction

Collusive conduct can endanger the benefits of competitive markets and be harmful to consumer's welfare. Competition authorities and economists have analyzed in depth the consequences of horizontal agreements between competitors prohibiting such practices. Much analysis has also been devoted to vertical agreements between firms and their suppliers. Some vertical restrictions are prohibited by competition law, but in general vertical agreements are viewed as less harmful to competition than horizontal agreements.

Recently, some cases of collusive conduct have been investigated that can not clearly be classified as either horizontal or vertical agreements. The so-called hub-and-spoke collusion generally involves retail competitors and their common supplier(s); sensitive information is passed between competitors not directly but through a supplier that facilitates price collusion. Also named A to B to C information exchange, these collusive practices have been discussed quite extensively by competition policy authorities.

In the latest version of its Guidelines on horizontal cooperation agreements, the European Commission dedicates a section (Section 2) to information exchanges. The Commission notes in the first paragraph of this section that

> Information exchange can take various forms. Firstly, data can be directly shared between competitors. Secondly, data can be shared indirectly through a common agency (for example, a trade association) or a third party such as a market research organization or through the companies' suppliers or retailers.

Further in the same document, the European Commission explains that "an information exchange can constitute a concerted practice if it reduces strategic uncertainty in the market thereby facilitating collusion". Competition authorities have prosecuted indirect exchanges of information through suppliers in a number of jurisdictions, including the United States, the United Kingdom and Belgium (see Odudu (2011) and Sahuguet and Walckiers (2013), for a recent review of the case law).

In many cases, the suppliers participating in the hub-and-spoke collusion have some degree of market power. However, the economic mechanism behind these indirect information exchanges is not well understood. Odudu (2011) notes for instance that:

> The additional challenge [...] in the hub-and-spoke context is to explain why [the supplier] is involved (and thus liable) in the indirect information disclosure. It has been argued that [the supplier] has no incentive to police [the retailers'] horizontal arrangement and strong incentives to do just the opposite.

At a first sight, one would indeed think that an undertaking with some degree of market power would fight any attempt of downstream retailers to cooperate in order to increase their

margins. A Chicago School-type of argument would support that there is only one monopoly profit, and that the higher retail margins reduce the profit accruing to the supplier[1].

This article builds a model of hub-and-spoke collusion in which a supplier chooses to participate in a collusive tacit agreement with retailers to help them collude more efficiently. Our benchmark is a situation in which collusion between retailers is inefficient from the point of view of the whole supply chain. Such inefficient collusion would not obtain in a simple model of repeated Bertrand competition since the inability of retailers to collude on a high price would directly benefit the supplier who would suffer less from the double-marginalization problem.

Our starting point is the model of collusion of Rotemberg and Saloner (1986)[2]. In this model, demand is stochastic and varies from period to period. To deter deviations from collusive prices, retailers need to rationally limit their collusive activity in periods of high demand, when the collusive agreement and thus a potential deviation is most profitable. Such a collusive scheme is not only inefficient for retailers but also harms the supplier. In the high demand state, when collusion on high prices is not sustainable, all parties would gain if they could better coordinate. The supplier can improve the outcome of collusion of downstream retailers by taking part in the collusive scheme (hub-and-spoke agreement).

The hub-and-spoke collusive equilibrium works through an exchange of information between supplier and retailers. Retailers inform the supplier about the state of demand, allowing the supplier to increase its wholesale price when demand is high, thereby relaxing retailers' deviation constraint, because there is less to gain from deviation with a higher wholesale price. Collusion in the high demand state becomes more efficient and leads to increased profits for the vertical chain. Indeed, the supplier reduces the effect of double marginalization by varying the wholesale price across the demand cycle. For the retailers to agree, this scheme needs to provide them with profits as high as those they would get if they did not inform the supplier about the state of demand. An important feature of the analysis is that hub-and-spoke collusion increases the profits of the vertical chain through a better coordination and not at the expense of others actors in the market (another supplier or other retailers). The logic of the hub-and-spoke collusion in the model is not based on the exclusion of competitors (downstream or upstream).

The economic effects of the hub-and-spoke collusion are ambiguous. To understand whether such agreements should be forbidden, the distribution of bargaining power in the vertical chain is crucial. We show that when the supplier has most of the bargaining power, hub-and-spoke collusion displays the features of vertical agreements, solving some of the prob-

[1] This argument has been put forward by practitioners in their informal economic analysis of the effects of hub and spoke conspiracies. See for instance
http://www.crai.be/ecp/assets/Effects_Analysis_in_Hub_and_Spoke_Cartels.pdf

[2] The main reason we use the Rotemberg and Saloner's model is that it delivers inefficient collusion while remaining tractable. We believe that the logic of hub and spoke collusion would extend to many other models in which collusion between retailers is inefficient.

lems associated with double marginalization. As is well-known in the literature on vertical relations, such agreements can be welfare improving. However, when retailers have the bargaining power, hub-and-spoke agreements lead to improved collusion between retailers. As most horizontal agreements, consumers are hurt by retailer driven hub-and-spoke collusion.

In terms of competition policy recommendations, our analysis thus does not find that hub-and-spoke agreements are necessarily undesirable. However, in the presence of buyer power, the welfare effects of hub-and-spoke conspiracy appear to be adverse since it mostly helps the retailers to improve their collusive conduct.

Related literature

The economic literature on hub-and-spoke collusion is rather scant. Odudu (2011) discusses relevant legal cases and gives some informal economic arguments about the logic of this type of agreement. Kuhn (2001) discusses the consequences of information exchanges for competition policy but does not explicitly deal with hub-and-spoke agreements. Gerlach (2009) studies information exchange in a model of collusion with varying demand. He shows that communication between horizontal firms can in some circumstances improve collusion and consumers welfare by facilitating coordination. Athey and Bagwell (2001) and Athey et al. (2004) also analyze the exchange of private information about costs in a model of collusion.

The papers that are closest to our can be grouped into two categories. A first group of papers studies how vertical restraints and more specifically contractual agreements between suppliers and retailers (such as resale price maintenance) can help implementing horizontal collusion. They usually study bilateral duopolies and focus on incentives of upstream suppliers to design contractual agreements with downstream retailers (such as RPM) to facilitate upstream collusion. Shaffer (1991) shows that downstream firms' competition can be softened if upstream firms introduce slotting allowances. Jullien and Rey (2007) explain that resale price maintenance yields more uniform prices downstream, which facilitates tacit collusion upstream, by making deviations easier to detect. Rey and Vergé (2010) study "interlocking relationships": resale price maintenance, associated with two-part tariffs, serves to dampen interbrand competition (upstream) and intrabrand competition (downstream) and restore monopoly prices and profits. Dobson and Waterson (2007) assume that manufacturers use (inefficient) linear wholesale prices and show that resale price maintenance contractual agreements can be socially desirable when retailers are in a weak bargaining position, to reduce the effect of double-marginalization problems. In all those papers, competition is present in both upstream and downstream markets. But contractual agreements allow to soften competition and thus to create more profit industry-wide[3]. Our model studies an hub-and-spoke conspiracy without vertical contractual agreement.

A second group of papers focuses on non-binding vertical agreements within the value chain.

[3]See also Miklos-Thal, Rey and Vergé (2011).

Buehler and Gärtner (2012) model retail-price recommendations that are non-binding, that is, in contrast to resale price maintenance agreements, the manufacturer does not control the retail price directly and does not require means of pressuring retailers into adherence. They show that retail-price recommendations are irrelevant in a static set-up, but when suppliers and retailers interact repeatedly, retail-price recommendations can become part of a self-enforcing relational contract (Levin, 2003) that serves to maximize joint surplus. In their model, non-binding price recommendations act as a communication device within the value chain that conveys private supplier information on production costs and consumer demand to its retailer. The information exchange is at the core of the vertical agreement and no contract is needed to enforce the collusive mechanism. However, they do not consider the case of multiple retailers and how this type of agreement would work in the presence of competition or collusion between retailers.

Our paper also shares similarities with Piccolo and Miklos-Thal (2012), who show that retailers can collude more easily in the downstream market if they can also collude on the wholesale tariffs they offer to suppliers. By agreeing on a wholesale price as high as the retail price (in a two-part tariff), retailers can completely eliminate their own incentives to undercut the retail price. The main difference is that they consider competition between competing hierarchies where each supplier only interacts with a single retailer. Their set-up is thus not one of hub-and-spoke collusion.

The idea that a third party can help organize collusion[4] and can benefit from it has been studied in other contexts. Greif, Milgrom and Weingast (1994) analyze the relations between a city with merchants. They model the interaction as a repeated game of trust. They show that in order to credibly promise protection to the merchant, the city may have an interest to help the merchants get organized in a guild that can effectively punish the city when it breaks its protection promises. See also Dessi and Piccolo (2012) for an extension to a set-up closer to the present paper.

Our model finally contributes to the literature on information exchanges in oligopolies. In static models, the issue of information exchange has been analyzed extensively (see for instance Vives (1984)). The incentives to exchange information and the impact on consumer welfare depend on the details of the modelling (whether goods are substitutes or complements and whether firms choose prices or quantities). The analysis has been extended to include vertical information exchanges (see Li (2002) and Zhang (2002)). These papers take an operation management perspective and analyze the best ways to coordinate efficiently a supply-chain and do not discuss the consequences of such information exchanges for competition policy analysis.

[4]See also Bernheim and Whinston (1987) on the role of marketing common agency to improve collusion.

2 Model

We consider a vertically related industry with one supplier and two retailers. The supplier produces a consumption good at constant marginal cost, which we normalize to 0 for simplicity. The good is sold to consumers by two retailers with zero costs. Consumers view the products sold by retailers as homogeneous and buy from the retailer which proposes the lowest price.

We consider this industry in an infinite-horizon setting with discrete time $t = 1, 2...$ and a discount factor δ common to all players of this infinitely-repeated game.

As in Rotemberg and Saloner (1986), demand is stochastic and varies from period to period. We assume that ε_t, the random variable denoting the demand shock in period t, can take two values 0 and 1 with probability λ and $1 - \lambda$. The random variables representing the demand shocks ε_t are assumed to be independently and identically distributed. We also assume that the state of demand is commonly observed at the beginning of period t by the retailers but not by the supplier. The demand function takes the form:

$$Q_t = (1 + \varepsilon_t)(1 - p_t) \tag{1}$$

Retailers compete in price. The retailer with the lowest price sells to all consumers at its quoted price.

Each period the timing of the game is as follows:

1. The state of demand is revealed to retailers.
2. Retailers can decide to truthfully[5] reveal the state of demand to the supplier.
3. The supplier sets the wholesale price w, potentially as a function of information revealed.
4. Retailers set final prices.

The first-best outcome from the perspective of the industry chain (supplier and retailers) would be for the supplier to set a wholesale price equal to its marginal cost of production, and for retailers to collude on the monopoly price that depends on the realization of the market demand. This arrangement leads to monopoly price, quantities and profits in every period. Note that an alternative way to reach the first best would be for the supplier to set

[5]The assumption that communication is truthful corresponds to the case of hard, verifiable information. When retailers possess soft information, the analysis becomes more complex since incentives to lie about the state of the world should be accounted for. See Athey and Bagwell (2001) and Gerlach (2009) for models of collusion with strategic communication.

the wholesale price equal to the first-best price and that retailers compete in every period so that the retail price equals the wholesale price.

Proposition 1 *First best profits for the supply chain*

The retail price that maximizes the vertical chain profits is $p = 1/2$ *in both states of demand. The optimal quantities are* $q_L = 1/2$ *when demand is low, and* $q_H = 1$ *when demand is high. The profits to be shared by the vertical chain are* $\Pi_L^{FB} = 1/2$ *when demand is low, and* $\Pi_H^{FB} = 1$ *when demand is high.*

To reach the first best, not only do the parties need to be able to communicate, but side-payments must be used to share the surplus. Since competition policy forbids explicit colluding practices, we limit the type of contractual arrangements available within the supply chain. The supply chain needs to overcome at least two types of issues. First, retailers' tacit collusion must be sustainable: retailers need to have an incentive to maintain prices in all states of demand. Second, retailers need to be willing to communicate the state of demand to the supplier. The supplier also needs to keep in mind the double-marginalization problem; in particular, when the supplier helps retailers' collusion he may exacerbate the double marginalization problem.

2.1 Collusion between retailers

Consider retailers in isolation and suppose that they face a wholesale price w. The best collusive scheme would be to share the market between them by setting the (same) price that maximizes their joint profit (the double marginalization retail price given the wholesale price imposed by the supplier). Denote $\Pi_L(w)$, $\Pi_H(w)$ the maximum joint profit in each state of demand.

There exists an equilibrium in which both retailers set $p = w$ in every period. Both retailers make zero-profit. This price-war equilibrium will be used as a threat to sustain collusion. In what follows we focus on the best equilibrium that retailers can sustain through tacit collusion. If retailers could sustain a perfect collusive agreement, they would share the market in every period setting the optimal retail price $(1 + w)/2$.

The value of perfect collusion is thus: $\frac{1}{1-\delta}\left(\lambda\frac{\Pi_L(w)}{2} + (1-\lambda)\frac{\Pi_H(w)}{2}\right)$.

Collusion is sustainable if retailers do not want to cut their price to capture the whole market, knowing that this leads to a break-down of collusion in the future and a reversion to the zero-profit equilibrium. The gain from a deviation is larger in the high state of demand. The relevant incentive constraint is:

$$\Pi_H \leq \frac{\delta}{1-\delta}\left(\lambda\Pi_L + (1-\lambda)\Pi_H\right).$$

Rewriting the constraint as

$$\Pi_H \leq \frac{\frac{\delta}{1-\delta}\lambda}{\left(1-\frac{\delta}{1-\delta}(1-\lambda)\right)}\Pi_L = k\Pi_L,$$

we see that for $k < 2$, a perfect collusive agreement is not sustainable. As in Rotemberg and Saloner (1986), the best collusive scheme that retailers can sustain is described as follows: in the low state of demand, retailers collude perfectly, and in the high state of demand, they set a price that leads to a profit $\Pi_H^{\max} = k\Pi_L$. In this way, a deviation in the high state of demand is not profitable.

That price $p_H^{\max}$ is computed as follows:

$$2\left(1-p_H^{\max}\right)\left(p_H^{\max}-w\right) = k\Pi_L = k(1-w)^2/4.$$

The price $p_H^{\max}$ is the smallest number that solves this equation. We get:

$$\begin{aligned} p_{\max}^H &= \frac{1}{2}(1+w) - \frac{1}{2}(1-w)\sqrt{1-k/2}, \\ q_{\max}^H &= (1-w)\left(1+\sqrt{1-k/2}\right). \end{aligned}$$

Proposition 2 *Retailers' collusion*

Given the wholesale price w, if $k = \frac{\frac{\delta}{1-\delta}\lambda}{\left(1-\frac{\delta}{1-\delta}(1-\lambda)\right)} < 2$, retailers cannot tacitly collude and set double marginalization retail prices in both states of demand. The profit maximizing equilibrium for retailers consists in setting the double marginalization retail price in the low state of demand and the highest price $p_{\max}^H$ that leads to sustainable collusion in the high state of demand.

$$\begin{aligned} p_L &= (1+w)/2,\ q_L = (1-w)/2, \\ p_{\max}^H &= \frac{1}{2}(1+w) - \frac{1}{2}(1-w)\sqrt{1-k/2}, \\ q_{\max}^H &= (1-w)\left(1+\sqrt{1-k/2}\right), \\ \Pi_L &= (1-w)^2/4,\ \Pi_H^{\max} = k(1-w)^2/4. \end{aligned}$$

Thus k parametrizes the friction in retailers' ability to collude. When k is larger than 2, optimal collusion is possible. When k decreases the cartel's profits sustainable with tacit collusion decrease too. Since k is an increasing function of both δ and λ, it becomes easier to sustain perfect collusion when retailers become more patient and the state of low demand becomes more likely,

Collusion is not only inefficient for retailers, but also for the entire supply chain. The reason behind this inefficiency is that the double-marginalization problem is not constant across

demand states. When demand is low, retailers perfectly collude and the supplier would be willing to decrease its wholesale price to mitigate double marginalization. When demand is high, retailers set a relatively low price and double marginalization is less problematic for the supplier who would like to set a higher wholesale price. This inefficient collusion leaves room for improvement in the vertical chain through exchanges of information.

2.2 Choice of wholesale price when the supplier does not know the state of demand

We now solve for the optimal choice of wholesale price w by the supplier, when retailers do not communicate the state of demand and retailers use the best possible collusive equilibrium, as derived above.

The profit of the supplier is thus:

$$\begin{aligned} \Pi^S(w) &= w\left(\lambda q^L + (1-\lambda) q^H_{\max}\right) \\ &= w(1-w)\left(\lambda/2 + (1-\lambda)\left(1+\sqrt{1-k/2}\right)\right). \end{aligned}$$

The optimal wholesale price for the supplier is $w^* = 1/2$. This choice of wholesale price implicitly assumes that the supplier has all the bargaining power. If retailers had most of the bargaining power, the supplier would set a wholesale price close to the marginal cost of production of 0. We can parametrize the relative bargaining power of the supplier by $\alpha \in [0,1]$ and the corresponding wholesale price $w(\alpha) = \alpha/2$. We show in the appendix how this can be microfounded using a Nash bargaining model.

Proposition 3 *Wholesale price without communication*

When the supplier does not know the state of demand, the wholesale price depends on the relative bargaining power α of the supplier. The optimal wholesale price for the supplier is $w = 1/2$. The optimal wholesale price for the retailers is $w = 0$. The result of the bargaining leads to a wholesale price $w(\alpha) = \alpha/2$.

The retailers use the best collusive strategy given the wholesale price $\alpha/2$.

2.3 Hub-and-spoke collusive equilibrium

We now analyze a hub-and-spoke collusive scheme in which retailers communicate the state of demand to the supplier. In turn, the supplier sets the wholesale prices w_L and w_H as a function of the state of demand. Retailers subsequently coordinate on the best collusive equilibrium, given these wholesale prices.

We first consider the situation in which the supplier has all the bargaining power and sets the wholesale prices without taking into account the incentives of retailers to communicate the state of demand. We then consider the incentives of retailers to reveal the state of demand to the supplier. This forces the supplier to set wholesale prices that insure that retailers' profits are the same as when they do not reveal the state of demand. Finally, we consider the case in which the supplier and the retailers bargain on the details of the hub-and-spoke agreement.

The supplier chooses wholesale prices w_L, w_H to maximize its expected profit:

$$\begin{aligned} & Max_{w_L,w_H} \left\{ \lambda w_L q_L + (1-\lambda) w_H q_H \right\} \\ \Longleftrightarrow \quad & Max_{w_L,w_H} \left\{ \lambda w_L \left(\frac{1-w_L}{2} \right) + (1-\lambda) w_H \left(1 - w_H + \sqrt{w_H^2 - 2w_H - 2k\Pi_L + 1} \right) \right\}. \end{aligned}$$

Note that, for a given w_L, the supplier chooses w_H to maximize its profit in the high state of demand under the constraint that the profit of the retailers are k times the profit in the low state of demand. This means that the choice of w_L influences the profit in the state of high demand, but that the choice of w_H does not influence the profit in the state of low demand. The choice of w_L and w_H can be made independently.

The optimal choice of w_H solves:

$$\begin{aligned} & Max_{w_H} \left\{ q_H w_H \right\} \\ st \quad : \quad & \Pi_H = q_H \left(1 - q_H/2 - w_H \right) = k\Pi_L. \end{aligned}$$

We can rewrite the constraint as $q_H \left(1 - q_H/2\right) = k\Pi_L + q w_H$. We see that the supplier in fact chooses q_H to maximize the total profit of the chain $q_H \left(1 - q_H/2\right)$. The optimal quantity is the monopoly quantity $q_H = 1$. The wholesale price w_H is then adjusted so that retailers' profits Π_H equal $k\Pi_L$ and collusion is sustainable. The corresponding wholesale price is $w_H^* = 1/2 - k\Pi_L$.

The supplier always chooses w_H such that retailers collude on the monopoly quantity in the high-demand state and sets the wholesale price in such a way that the profit of the retailers in the high state of demand satisfies the incentive constraint for collusion.

We now turn to the choice of wholesale price in the low state of demand. Since retailers profits Π_L equal $\left(\left(1 - w_L\right)/2\right)^2$, the problem of the supplier can be rewritten as :

$$Max_{w_L} \left\{ \lambda \left(\frac{1-w_L}{2} \right) w_L + (1-\lambda) \left(1/2 - k \left(\left(1 - w_L\right)/2 \right)^2 \right) \right\}.$$

Taking first order conditions, we get that the supplier sets w_L^* equal $\frac{\lambda + (1-\lambda)k}{2\lambda + (1-\lambda)k}$.

Acting in its best interest, the supplier increases the wholesale price in the low demand state in order to decrease the profits of the retailers and extract more in the high demand state. However, it must be in the interest of retailers to reveal the state of demand to the supplier. Assuming that only truthful information can be revealed and that retailers can conceal information if it is in their interest to do so, the supplier needs to choose wholesale prices in such a way that retailers' profit is at least as high as in the scenario with a single wholesale price and without communication.

Retailers' profit in the low state of demand directly impacts their profit in the high state of demand, and retailers' expected profit. The supplier can therefore insure retailers' willingness to communicate by setting the wholesale price in the low state of demand equal to the one they use in both states of demand when they have no information. This guarantees that retailers make the same profits and accept to reveal information about the state of demand.

Proposition 4 *Hub-and-spoke collusive equilibrium.*

In the optimal hub-and-spoke equilibrium, retailers transmit the state of demand to the supplier. The supplier adjusts the wholesale price to the state of demand, with a higher wholesale price when the state of demand is high. For a given wholesale price, in the low state of demand retailers collude on the optimal price and quantities, while in the high state of demand, they produce the vertical chain monopoly quantity - the retail price is computed so that no retailer has an incentive to deviate from the scheme and cut its price. The profit of the supplier is higher in the hub-and-spoke equilibrium, while retailers' profits do not decrease.

The interpretation of the scheme is fairly simple. The supplier uses wholesale prices to improve upon the supply chain's inefficiency which comes from the inability of retailers to collude in the high state of demand. The collusive scheme is proposed by the supplier to the retailers as a take-it-or-leave-it offer, with the supplier taking all the surplus created by the conspiracy, just making sure that retailers agree to reveal the state of demand. Retailers' profit is the same under hub-and-spoke collusion and under the scheme derived in the previous subsection.

In practice, the surplus generated by the agreement is likely to be bargained upon and the division of surplus will depend on the retailer's bargaining power. When retailers have more bargaining power, the profits of retailers will be adjusted by decreasing the wholesale price in the low state of demand.

3 Welfare analysis and recommendations for competition policy

As we have seen, hub-and-spoke collusion between supplier and retailers can be sustained as a tacit agreement. Retailers communicate the state of demand to the supplier and the

supplier adjusts its wholesale price to the state of demand, while retailers collude in the best possible way, taking wholesale prices as given.

To assess the consequences of the hub-and-spoke equilibrium on consumer welfare, two scenarios should be compared:

1. there is no hub-and-spoke agreement, the supplier does not know about the state of demand, sets a unique wholesale price and retailers tacitly collude in the best possible way,
2. supplier and retailers play the hub-and-spoke collusive equilibrium described in the previous section.

From a consumer welfare's perspective, the quantities consumed are the same in the low state of demand. Therefore, comparing the scenarios boils down to comparing quantities produced in the high state of demand. We show in the appendix that if $w < \frac{1}{k}\left(k + \sqrt{2}\sqrt{2-k} - 2\right)$ then $q_H^{\max} > 1$ and the hub-and-spoke agreement leads to lower welfare. Thus the impact of hub-and-spoke collusion depends on the distribution of the bargaining power. Since we assumed that $1 \leq k \leq 2$, (so that perfect collusion between retailers is not possible), we get a condition on the maximum value for which the hub-and-spoke agreement proposed by the supplier is welfare improving.

When $k = 1$, the condition boils down to $w < \sqrt{2} - 1$; when $k = 2$ the condition boils down to $w < 0$. The higher k, the more the bargaining power needs to be in the hands of retailers for the hub-and-spoke agreement to be welfare improving.

Proposition 5 *The hub-and-spoke agreement decreases consumers' welfare if the wholesale price in the no communication equilibrium is low, $\alpha < \frac{2}{k}\left(k + \sqrt{2}\sqrt{2-k} - 2\right)$, and the supplier makes a take-it-or leave-it offer to the cartel of retailers, .*

Retailers and the supplier bargain about the wholesale price in the low state of demand. The hub-and-spoke agreement is then fully characterized: the wholesale price in the high state of demand is determined so that the profit of the cartel when retailers collude is sustainable. The disagreement points $\underline{\Pi}_S$ and $\underline{\Pi}_R$ are the profits made by the supplier and retailers in the equilibrium in which there is no communication.

We have that $\Pi_S(w) = w\left(\lambda(1-w)/2 + (1-\lambda)\right)$ and $\Pi_R(w) = \left(\lambda + (1-\lambda)k\right)\left(\frac{1-w}{2}\right)^2$.

The disagreement points are:

$$\begin{aligned}
\underline{\Pi}_R &= \left(\lambda + (1-\lambda)k\right)\left(\frac{1-\alpha/2}{2}\right)^2, \\
\underline{\Pi}_S &= \alpha/2\,(1-\alpha/2)\left(\lambda/2 + (1-\lambda)\left(1 + \sqrt{1-k/2}\right)\right).
\end{aligned}$$

The wholesale price w_{HS}^* in the low state of demand solves:

$$Max_w \left\{ \left(\Pi_S (w) - \underline{\Pi}_S \right)^{\alpha} \left(\Pi_R (w) - \underline{\Pi}_R \right)^{1-\alpha} \right\}.$$

Given that retailers prefer a low wholesale price (in fact they prefer $w = 0$), and the supplier prefers a high wholesale price (they would choose $w = 1/2$), the result of the bargaining will lie in the interval $[\underline{w}, \alpha/2]$; the end points of the interval are determined by the wholesale prices corresponding to the disagreement point of the bargaining parties. The result of the bargaining will be closer to $\alpha/2$, when the supplier has substantial bargaining power, and closer to $\underline{w}$ when retailers enjoy the bargaining power.

To evaluate the economic effects of the hub-and-spoke agreement, we now need to trade-off the impact of the agreement in both states of demand. In the high state of demand, the quantity sold under the hub-and-spoke agreement is $q_H = 1$. In the low state of demand, the quantity produced is $(1 - w_{HS}^*/2)/2$ which is higher than $(1 - \alpha/2)/2$ which is produced in the no communication equilibrium.

When $q_H^{\max} \leq 1$, the hub-and-spoke agreement is welfare improving.

When $q_H^{\max} > 1$, the hub-and-spoke agreement is not always welfare decreasing. However, there exists α^* such that for $\alpha < \alpha^*$ the hub-and-spoke agreement hurts consumers welfare.

The fact that welfare consequences of an agreement between suppliers and retailers depend on the relative bargaining position of the supplier and the retailers is reminiscent of Dobson and Watson (1997). They showed in a different context that the welfare effects of resale price maintenance depends on whether retailer power is strong or not.

4 Conclusion

We have developed a model of repeated interaction between a supplier and two retailers. We show that a hub-and-spoke collusive equilibrium can be sustained with retailers providing information to the supplier about market demand and the supplier adjusting its wholesale price taking into consideration the fact that the retailers are colluding over prices.

In a static interaction, retailers would not communicate their information to the supplier who would take advantage of it. This leads to bad coordination of the industry chain with inefficiently low production in the low state of demand (due to high wholesale prices). This lack of coordination has also negative consequences in terms of consumer welfare. The hub-and-spoke scheme leads to a Pareto-improvement in the chain. Coordination improves profits of retailers and of the supplier. Under imperfect collusion, the profits in the high demand state does not really matter since retailers cannot collude efficiently in that state of demand. Transmitting information increases coordination at a lower cost for the retailers. The supplier

is clearly better off since it can adjust its wholesale price to the state of demand. The effect on consumer welfare is ambiguous. On the one hand, the hub-and-spoke conspiracy reduces double marginalization, which can improve welfare. On the other hand, it fosters horizontal coordination, which reduces welfare. When the retailers have the bargaining power, the supplier essentially acts a go between in order to achieve horizontal agreement, which is detrimental for consumer welfare.

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6 Appendix

6.1 The wholesale price is determined by bargaining

We model bargaining game between the supplier and the cartel of retailers using the Nash bargaining solution (Nash 1950). The Nash bargaining solution over the wholesale price w corresponds to the maximand of the Nash product:

$$\left(\Pi^S\right)^{\alpha}\left(\Pi^R\right)^{1-\alpha}$$

As shown in section 2.2, the expected profit of the supplier is:

$$\begin{aligned}\Pi^S &= w\left(\lambda q^L + (1-\lambda)\, q^H_{\max}\right) \\ &= w\,(1-w)\left(\lambda/2 + (1-\lambda)\left(1+\sqrt{1-k/2}\right)\right).\end{aligned}$$

The expected profit of the cartel is:

$$\begin{aligned}\Pi^R &= \lambda\left(\frac{1-w}{2}\right)^2 + (1-\lambda)\,k\left(\frac{1-w}{2}\right)^2 \\ &= (\lambda + (1-\lambda)\,k)\left(\frac{1-w}{2}\right)^2.\end{aligned}$$

The parameter α represents the relative bargaining power of the supplier. It captures factors that influence the outcome of the negotiation.

The solution is $w^* = \alpha/2$. It is a weighted average of the wholesale price preferred by the supplier which is $1/2$ and the wholesale price preferred by the cartel, which is 0.

6.2 Derivation of the condition for welfare improving hub-and-spoke agreement

We need to compare the quantities consumed in the high state of demand. In the hub-and-spoke agreement, the supplier sets the wholesale price so that the quantity is equal to 1. In the original equilibrium without communication, we have that $q_H^{\max} = (1-w)\left(1+\sqrt{1-k/2}\right)$.

The condition is just

$$\begin{aligned} q_H^{\max} &> 1 \\ &\Leftrightarrow \quad w < \frac{k + 2\sqrt{1 - k/2} - 2}{k}. \end{aligned}$$

Since we assumed that $1 \leq k \leq 2$, (so that perfect collusion between retailers is not possible), we get a condition on the maximum value for which the hub-and-spoke agreement proposed by the supplier is welfare improving. When $k = 1$, the condition boils down to $w < \sqrt{2} - 1$; when $k = 2$ the condition boils down to $w < 0$. The higher k, the bargaining power needs to be in the hands of the retailers for the hub-and-spoke agreement to be welfare improving.