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JEL Classification: L42, L50, L81

Keywords: Competing Principals, Delegates Sales, discretion, information sharing, List Prices

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Price Authority and Information Sharing with Competing Principals*

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November, 2021

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1 Introduction

Information sharing agreements are common in many prominent sectors. These agreements have been investigated by an established literature studying the effects of communication on firms' competitive conduct in static oligopolies — i.e., games where firms first decide whether to share their private information (about demand or costs) and then compete à la Cournot or Bertrand (see, e.g., Khun and Vives, 1995, and Vives, 2006, for surveys of this literature). A major benefit of information sharing in these models is that firms can better adjust prices or production plans to actual costs or demand. If the information is not available, they tend to produce too much at unexpectedly high costs (or low demand) and too little at unexpectedly low costs (or high demand). Hence, other things being equal, firms always have an incentive (at least reciprocal) to exchange information.

Yet, this literature assumes that firms are profit maximizing *black boxes* and, therefore, it is silent on the interplay between information exchanges and agency conflicts within organizations. A few exceptions are Calzolari and Pavan (2006) and Maier and Ottaviani (2009), who consider common agency models in which two principals may share the information they obtain by contracting with a common agent[1], and Piccolo and Pagnozzi (2013) and Piccolo *et al.* (2015), who consider competing vertical organizations where principals can share information about their exclusive agents.[2] These models posit that monetary transfers between principals and agents are feasible. Hence, principals partly internalize agents' incentives to misreport their private information (adverse selection) and exert low effort (moral hazard) through fixed (lump sum) fees.

In this paper, instead, we study information sharing in a framework where monetary transfers are unfeasible: principals cannot internalize agents' incentives but they can only decide what agents are entitled to do by designing permission sets from which agents must select their choices. The width of these sets determines the extent of what Aghion and Tirole (1997) define *real authority* (the effective control over decisions within organizations). The trade-off that shapes the balance between formal and real authority within hierarchical organizations has been examined in the 'so-called' delegation literature. In these models, principals face a simple dilemma: giving up control to gain flexibility, or imposing rigid rules unresponsive to changes of the environment?

Holmstrom (1977-1984) was the first to show that the solution of such a dilemma leads to the idea of constrained delegation: principals allow agents to choose their 'ideal' action in the states of nature where the conflict of interest is not too pronounced and impose a rigid rule, ceiling or flooring the agents' action depending on the direction of the conflict of interest, otherwise (see, e.g., Amador and Bagwell, 2013, Dessein, 2002, Martimort and Semenov, 2006, Melumad and Shibano, 1991). The findings of this literature are broadly coherent with recent empirical regularities showing that price delegation is a profitable business strategy in several industries. For example, by exploiting data from the auto-lending market, Phillips et al. (2021) estimate that sales forces' freedom to adjust prices to local market

[1] Calzolari and Pavan (2006) consider adverse selection while Maier and Ottaviani (2009) focus on moral hazard.

[2] Piccolo and Pagnozzi (2013) consider adverse selection while Piccolo et al. (2015) focus on moral hazard.

fluctuations generates an average profit increase of approximately 11%. Similarly, by comparing a sample of 181 companies from Germany's industrial machinery and electrical engineering industry, Frezen et al. (2010) document a positive effect of price delegation on firm performance, which amplifies under high market uncertainty and information asymmetry. Instead, Homburg et al. (2012) consider various B2B industries in Germany and find an inverted U-shaped relationship between delegation and profitability.

We innovate upon this literature in two dimensions. First, we consider partial delegation in a competing organizations framework where principals are not totally uninformed about the uncertain (payoff relevant) state of the world, but learn it with some probability. Hence, we study the determinants of partial delegation and, in particular, how principals' information accuracy affects their equilibrium delegation choices. Second, we assess the competitive effects of an information-sharing agreement between principals.

Specifically, we consider a competitive environment in which two upstream principals (e.g., manufacturers) compete by producing differentiated products and choose how much price authority to grant their downstream agents (dealers, sales managers, retailers, etc.) who are privately informed about an aggregate demand shock — i.e., being closer to the final market, these agents are better informed than principals about consumer preferences.

To introduce a wedge between upstream and downstream objectives, we assume that agents incur an observable but unverifiable distribution cost to finalize a sale — e.g., the opportunity cost of the time required to convince a buyer to purchase the product, the cost of effort that an agent must invest in this negotiation process (which may depend, among other things, on the buyers' unverifiable propensity to acquire the product), the cost of targeting perspective customers with informative and/or promotional activities, etc. Hence, as in earlier delegation models, we posit that principals cannot internalize this cost through monetary incentives, which would not be enforceable in Court. This misalignment of preferences creates a natural conflict of interest. Agents have an incentive to pass on their distribution costs to consumers: a friction echoing the standard double marginalization problem arising in vertical contracting models where upstream firms are bound to offer linear contracts to their retailers (see, e.g., Motta, 2004, for an account of the double marginalization phenomenon). Hence, agents charge too high prices compared to what upstream profit maximization would mandate. Yet, unlike in other delegation models, principals are not totally uninformed in our framework: with some probability, they observe the state of demand and can therefore condition the degree of price authority granted to agents on this information. In addition, we allow them to share such information and study their incentive to enter these agreements and their competitive effects. Within this setting we show the following results.

Characterization and existence. We first characterize equilibria with partial delegation in both information-sharing regimes. We find that these equilibria feature a price cap (or equivalently a list price) binding when demand is high, while agents are entitled to choose prices when demand is low. This result is broadly consistent with *customized pricing with discretion* (see, e.g., Phillips et al., 2021). This practice is widespread in many B2B and B2C markets where prices are inherently customized due to the additional costs needed to satisfy buyers (e.g., quality customization, delivery requirements, service provision such as loan and insurance application, etc.). Yet, salespeople are allowed further discretion to negotiate rebates with customers off the list price set in advance by their headquarters.

We then investigate the conditions under which these equilibria exist. As intuition suggests, partial delegation equilibria exist when distribution costs are not too high, meaning that the conflict of interest between principals and agents is not too pronounced. The region of parameters in which partial delegation occurs in equilibrium shrinks when products become closer substitutes because agents have a greater incentive to pass on their distribution costs to consumers to shield against competition. On the contrary, this region of parameters expands as principals' information accuracy and demand uncertainty increase. The higher the probability that principals are informed, the easier it is for them to sustain an equilibrium with partial delegation: a principal that expects its rival to be informed with higher probability will be keener to delegate because it expects the rival's price to be more aligned to what competition would mandate. Moreover, the more uncertain demand, the higher the cost for the principals to give up flexibility and implement a rigid pricing rule (pooling) that makes prices unresponsive to demand shocks.

Competitive Effects. Turning to the competitive effects of the exchange of information, we show that expected prices are lower with information sharing than without. Essentially, by aligning incentives within organizations, information sharing reduces the pass-through rate according to which distribution costs are passed on to consumers. Hence, the exchange of information exerts a downward pressure on prices, thereby benefitting consumers. Yet, principals have a reciprocal incentive to enter an information-sharing agreement only when products are sufficiently differentiated, when their information accuracy is high, and distribution costs are neither too high nor too low. The following effects determine this result. When principals share information, each learns the demand shock with greater probability than without information sharing (because an uninformed principal learns the state of demand when the rival is informed). Other things being equal, this effect benefits principals because it mitigates the conflict of interest with their agents. However, when principals do not share information, expected prices increase because agents are more likely to pass on their distribution costs to final consumers when they can choose prices. This price-increasing effect has an ambiguous impact on principals' expected profits. On the one hand, the fact that agents charge higher prices than what their informed principals would do in a non-cooperative equilibrium increases profits since it moves the solution of the game towards the monopoly benchmark. On the other hand, when distribution costs are excessively high, the pass-through is too strong, which reduces sales and thus profits: an effect echoing the standard double marginalization phenomenon. On the net, information sharing benefits principals if agents' distribution costs are not too small and products are sufficiently differentiated: in this case, solving internal agency conflicts is relatively more important than softening competition.

Implementation. Notably, we also show how the information-sharing agreement examined in our model can be implemented by a communication protocol according to which firms agree to disclose their price intentions (including list price intentions). The implicit assumption that most of the existing models impose to guarantee that an information sharing agreement is effective in disseminating information among its members is that these agreements are organized by certification intermediaries — e.g., auditors, trade associations, etc. — who can verify the private information of all participants to the agreement and disseminate this knowledge among them. In reality, however, firms do not communicate through a vague 'word of mouth' process, but signal their private information to rivals via their market choices — i.e., prices, investment decisions, output, etc. When this is the case, these variables de facto form the language through which firms communicate. We show that once price intentions have been disclosed, such an intermediary will just need to approve or disprove the agreement instead of redistributing information among the agreement participants. This may contribute to understanding how firms communicate in practice and shed some light on the competitive and welfare effects of agreements where firms share information about (future) list prices (see, e.g., Harrington and Ye, 2017, for a survey of recent cases where this practice is under investigation). In particular, in line with the findings of Rey and Tirole (2019), our results suggest that agreements according to which rivals share information about their price intentions are not necessarily a symptom of consumer harm.

Pooling (no delegation at all) equilibria. To complete the equilibrium characterization, we also examine (pooling) equilibria in which, when uninformed, principals retain full price authority. In this case results are in line with the existing literature (see, e.g., Khun and Vives, 1995 and Vives, 2006) since principals de facto behave as uninformed, vertically integrated oligopolists. In fact, when both information-sharing regimes feature a pooling equilibrium, information sharing has a neutral impact on consumer surplus but it still increases principals' expected profits. By contrast, when the equilibrium under information sharing features partial delegation and pooling without information sharing, we find that consumers are hurt by information sharing. Yet, in this hybrid scenario, principals will not share information when products are sufficiently differentiated, and demand is not too volatile.

The rest of the paper is organized as follows. Section 2 reviews the related literature and explains the novel results of our analysis compared to existing models. Section 3 lays down the baseline model. In Section 4 we develop two useful benchmarks and show the impossibility result demonstrating that full delegation cannot occur in equilibrium irrespective of the information sharing regime. In Section 5 we characterize and show the existence of partial delegation equilibria with and without information sharing, then we study the effect of information sharing on equilibrium prices and profits. In Section 6 we extend the model to check robustness. Section 7 concludes. Proofs are in the Appendix.

2 Related literature

Our analysis borrows from and contributes to several strands of the IO literature dealing with competition in oligopolies, delegation, information sharing and incentives within firms.

Several papers have investigated the strategic value of delegation in oligopoly games (see, e.g., Bonanno and Vickers, 1988, Fershtman and Judd, 1987, and Sklivas, 1987, and more recently, Prat and Rustichini, 2003). In these models, delegating price and output decisions to agents can be a credible mechanism to soften competition. The crucial feature is the ability of principals to disclose contracts to rivals and therefore influence their conduct. The model developed in this paper differs in two fundamental ways from this literature. First, it considers a framework where agency conflicts cannot be solved by monetary incentives. Second, in our model, delegation is not explained by its strategic commitment value since, as in the literature on secret contracting, principals' permission sets are unobservable.

A few papers have extended the idea of strategic delegation to environments with secret contracts and different forms of information asymmetries. Pagnozzi and Piccolo (2011), for example, show that vertical delegation may occur at equilibrium even when contracts are secret provided that agents do not hold passive beliefs off-equilibrium. Bhardwaj (2001), instead, shows that with competition in prices and effort the strategic nature of delegation depends on the relative intensity of competition. In contrast to us, with unobservable contracts and risk-averse sales representatives, he finds that firms delegate the pricing decision when price competition is intense (see also Gal-Or, 1991, Blair and Lewis, 1994, Martimort and Piccolo, 2010, for models with adverse selection, and Mishra and Prasad, 2005, for a moral hazard set-up).

In all these models, principals are able to align incentives (partially or in full) through monetary incentives, in contrast we focus on cases in which monetary incentives are not enforceable. In this sense, our model is closely related to, and builds on, the partial delegation literature initiated by Holmstrom (1977-1984). Following his seminal work, many scholars have investigated the determinants of delegation in the absence of monetary incentives and the conditions under which interval allocation is optimal (see, e.g., Amador and Bagwell, 2013, Alonso and Matouschek, 2008, Armstrong and Vickers, 2010, Dessein, 2002, Dessein and Santos, 2006, Frankel, 2014-2016, Martimort and Semenov, 2006, Melumad and Shibano, 1991, among many others). We contribute to this bulk of work by considering competing organizations and by characterizing the equilibrium interval delegation with and without information sharing.

In this latter respect, our analysis has obvious connections with the traditional information sharing literature in oligopoly. This literature shows that firms' incentives to share information about their common demand function (Novshek and Sonnenschein, 1982; Clarke, 1983; Vives, 1984; Gal-Or, 1985) or about their private costs of production (Fried, 1984; Gal-Or, 1986; Shapiro, 1986) depend on the nature of competition between them (Bertrand or Cournot). Raith (1996) rationalizes the results of this vast literature in a unified framework. We focus on information about demand and complement this bulk of work by casting the analysis in a delegation framework, an issue that (to the best of our knowledge) has been neglected so far.

Finally, our model is related to the ongoing literature on price caps and list prices. In a recent influential article, Rey and Tirole (2019) argue why authorities may want to consider allowing price-cap agreements when it is unclear whether products or services are substitutes or complements. The intuition for why price caps can be attractive is that they allow producers of complements to cooperate and solve Cournot's double-marginalization problem but do not allow competitors to collude and raise prices of substitutes. We find similar results in a different setting and, in addition, examine how the benefits of price-caps depend on the accuracy of the information shared between principals. Harrington and Ye (2017) also develop a theory to explain the welfare effects of list price coordination on transaction prices. They assume a deterministic link between list and transaction prices. We explain why this link can be stochastic and responsive to the competitive environment. Gill and Thanassoulis (2016) also consider upstream cooperation but, in contrast to Harrington and Ye (2017), assume that firms can coordinate on both list and transaction prices because both are verifiable (see also Raskovich, 2007, Lester et al., 2015, and Mallucci et al., 2019). Finally, Myatt and Ronayne (2019) show that in a standard search model where firms produce at different marginal costs, disclosing list prices to rivals and consumers intensifies competition and benefits consumer welfare because the announcement of these prices reduces search costs. Our model shows that this conclusion holds true even if search costs are zero, provided upstream principals face an agency problem with their downstream agents. The baseline model

3 The baseline model

Environment. Consider two principals (e.g., manufacturers), each denoted by P_i with $i = 1, 2$, distributing their products through exclusive agents (dealers, sales managers, retailers, etc.), each denoted by A_i with $i = 1, 2$, to whom they can grant price authority. Demand functions are derived from the preferences of a representative consumer with a Shubick-Levitan utility function (see, e.g., Motta, 2004, Ch. 8.4.2.) — i.e.,

$$D_i(\theta, p_i, p_{-i}) \triangleq a + \theta - p_i + d(p_{-i} - p_i) \qquad \forall i = 1, 2,$$

where $a > 0$ is the exogenous demand intercept, while θ is an additive shock distributed with equal probability on the support $\Theta \triangleq \{-\epsilon, \epsilon\}$.[3] The parameter $d \geq 0$ represents the degree of product differentiation: the larger d, the less differentiated (more homogenous) products are.

Agents are privately informed about the demand shock θ and condition their pricing decision (if they are entitled to do so) on its realization. Each principal is informed about θ with probability $\alpha \in [0, 1]$ and uninformed otherwise (an all-or-nothing information structure). For expositional purposes, we introduce a signal $s_i \in \{\varnothing, 1\}$ (for each $i = 1, 2$) describing the principals' information structure: $s_i = 1$ means that P_i is informed about θ, while $s_i = \varnothing$ means that it is uninformed and bases its decisions on the (common) prior. In the following we shall refer to $\alpha = \Pr[s_i = 1]$ as to principals' information accuracy.

Payoffs, conflict of interest and delegation. We now describe the payoffs, the conflict of interest and the idea of constrained delegation.

Following the delegation literature (e.g., Amador and Bagwell, 2013, Dessein, 2002, Holmstrom, 1977-1984, Martimort and Semenov, 2006, Melumad and Shibano, 1991) we rule out monetary incentives — i.e., there are institutional and/or contractual frictions that prevent principals to internalize the downstream profits through monetary incentives (e.g., fixed fees). Specifically, we assume that headquarters and

[3]See Section 6 for a discussion of the continuum of types.

salespeople have misaligned preferences. P_i maximizes profit, that is

$$\pi_i(\cdot) \triangleq D_i(\theta, p_i, p_{-i})\, p_i \qquad \forall i = 1, 2,$$

with technologies being linear and marginal costs normalized to zero without loss of generality.

A_i's objective function is, instead,

$$u_i(\cdot) \triangleq \pi_i(\cdot) - cD_i(\theta, p_i, p_{-i}) = D_i(\theta, p_i, p_{-i})(p_i - c) \qquad \forall i = 1, 2. \tag{1}$$

The parameter $c \geq 0$ can be interpreted as the distribution/marketing cost that an agent incurs to finalize a sale — e.g., the opportunity cost of the time required to convince a buyer to purchase the product, the cost of effort that must be invested in this negotiation process (which may depend, among other things, on the buyers' unverifiable propensity to acquire the product), the cost of targeting perspective buyers through informative and/or promotional activities, etc. Hence, de facto, c represents A_i's bias vis-à-vis P_i. If $c = 0$ their preferences are fully aligned; otherwise, A_i has an incentive to set a price higher than P_i's ideal price as we explain below.

We assume that c is a positive random variable (realized at the outset of the game) observed by both principals and agents but non-verifiable by the third-party, e.g., a Court of Law, in charge of enforcing contracts. Therefore, monetary transfers contingent on the realization of this uncertain parameter cannot be enforced — see, e.g., Green and Laffont (1994) and Aghion and Tirole (1994).[4] Hence, P_i can only limit A_i's discretion by determining the permission set $\mathcal{P}_i$ within which the price p_i must be chosen. Specifically, with a binary type-space, each principal P_i can pick one of the following strategies:

- it can fully delegate price authority to A_i — i.e., $\mathcal{P}_i = [0, +\infty)$;
- it can retain price control by setting a fixed (pooling) price that A_i must charge — i.e., $\mathcal{P}_i$ is a singleton;
- it can restrict A_i's authority within a given interval (partial delegation) — i.e., $\mathcal{P}_i \triangleq [\underline{p}_i, \overline{p}_i]$, with $\overline{p}_i > \underline{p}_i$;

The cap bounding the permission set from above can be interpreted as a list price, while the lower bound is a price floor that determines the maximal rebate that agents can offer to consumers. In Section 5.4 we discuss more at length the determinants of such rebates.

[4] Green and Laffont (1994) study a general model with pure non-verifiability where two players would ideally like to contract contingent on the state of nature that will become known to both of them in the future before any payoff-relevant actions must be taken. They assume that that the state of nature is not verifiable by any third party. Thus, although it is assumed that there is a third party present to enforce the contract, this third party has less information than either of the contracting players, and this fact may limit how the agreement can function in the mutual interest of the players. They identify conditions under which the first-best is achievable and show that, when these conditions are not satisfied, the only feasible solution to the problem is a delegation scheme where only one of the parties gets control of the payoff relevant actions.

Finally, notice that the above payoff formulation can be seen as a reduced form of a simple sharing agreement according to which principals and agents split the sales profit $\pi_i(\cdot)$ with fixed proportions (say with weights $\beta \in (0,1)$, and $1-\beta$, respectively). Both these shares do not affect our analysis. While the scalar β does not alter principals' decisions, we can redefine the agents' utility to embed the share $1-\beta$ into their distribution cost. To fix ideas, denote by $\hat{c}$ the true distribution cost, the utility of each agent would then be

$$u_i(\cdot) = (1-\beta) D_i(\theta, p_i, p_{-i})(p_i - c) \qquad \forall i = 1, 2,$$

where c in equation (1) is equal to $\frac{\hat{c}}{1-\beta}$. Then the coefficient $1-\beta$ is irrelevant for our analysis, and positive changes in the principals' bargaining position β can be just interpreted as increases of the cost parameter c.

Information sharing. We examine and compare two alternative information-sharing (IS) regimes:

a A regime in which principals do not share their demand information;

b A regime in which principals commit to share their demand information on an industry-wide basis.

Following the bulk of literature on information sharing in oligopoly (see, e.g., Calzolari and Pavan, 2006, Gal-Or, 1985-1986, Khun and Vives, 1994, Piccolo and Pagnozzi, 2013, Raith, 1996, Shapiro, 1986, Vives, 1984-2006, among many others) we assume that principals commit to share information ex-ante (before observing signals) and that only if both agree to do so, the information exchange takes place. As standard, we assume that principals cannot falsify the information they share. The idea behind this hypothesis is that the information exchange is coordinated by specialized intermediaries that certify the truthfulness of the data shared among rivals — e.g., auditors, data analytic companies, marketing information services firms, trade associations, etc. — who own the technology to discover the private information of the participants to the agreement and can commit to disclosure rules that disseminate this knowledge among them (see, e.g., Lizzeri, 1999). We discuss how these agreements can be implement in practice in Section 5.5.

Alternatively, the truthfulness of the shared data may be guaranteed by (un-modeled) reputation costs incurred by firms that falsify or misreport their private information — e.g., rivals may no longer trust them in the future — implying that the potential benefits of information sharing will be foregone in the future.

Timing. After the random variable c has been realized and observed by all players (except third-parties in charge of enforcing contracts), the sequence of moves unfolds as follows:

1. Principals choose wether to share information on a reciprocal basis;

2. The demand shock θ realizes. Each agent learns this realization with probability 1, while each principal learns it with probability α;

3. Principals share their private information if they committed to do so;
4. Principals choose their permission sets non-cooperatively;
5. Agents set prices simultaneously under the constraints determined by the permission sets designed by their principals;
6. Demand is allocated between the two products. Profits are made.

Equilibrium concept. The equilibrium concept is Perfect Bayesian Nash Equilibrium. We impose the refinement of 'passive beliefs', which is widely used in the vertical contracting literature (Hart and Tirole, 1990; McAfee and Schwartz, 1994; Rey and Tirole, 2007). With passive beliefs, an agent's conjecture about the permission sets offered to its rivals is not influenced by an out-of-equilibrium offer he receives: the so-called 'no signaling what you don't know' condition (see, e.g., Fudenberg and Tirole, 1988, Ch. 8). We restrict attention to pure strategy equilibria.

Throughout the analysis, in each information sharing regime, we will focus on the most interesting class of equilibria featuring partial delegation — i.e., equilibria in which principals partially delegate price authority to their agents. The reason why these equilibria are more interesting than equilibria in which agents are not granted price authority at all (pooling equilibria) is that in the latter class of equilibria principals de facto behave as integrated duopolists, exactly as in the traditional literature studying information sharing in oligopoly (for completeness, in Section 5.6 we examine pooling equilibria). Moreover, we assume that

$$a > \epsilon, \tag{\textbf{A1}}$$

which guarantees that demand functions are always positive, and that

$$c \leq \frac{a-\epsilon}{2+d}, \tag{\textbf{A2}}$$

which guarantees that downstream margins are positive irrespective of the demand shock and the information sharing regime.

4 Benchmarks and preliminary insights

Before characterizing the equilibrium of the game, we describe two useful benchmarks, namely the case in which principals are fully informed about the demand state ($\alpha = 1$), which allows us to pin down their ideal point (price), and that in which they are uninformed ($\alpha = 0$) and grant full price discretion to their agents — i.e., $\mathcal{P}_i = [0, +\infty)$ for every $i = 1, 2$. These benchmarks are then used to show that equilibria with full delegation cannot exist.

Fully informed principals. When principals are fully informed about the state of demand, they can force a price contingent on the state θ. Hence, P_i $(i = 1, 2)$ solves

$$\max_{p_i \geq 0} D_i (\theta, p_i, p_{-i}) p_i,$$

whose first-order condition yields a unique equilibrium price

$$p^P (\theta) \triangleq \frac{a + \theta}{2 + d} \qquad \forall \theta \in \Theta,$$

which determines the principals' ideal point in the non-cooperative equilibrium with full information. As expected, this price increases in the consumers' willingness to pay θ and decreases in the degree of product market competition, as reflected by higher product substitutability d.

Uninformed principals and full delegation. When principals are uninformed ($\alpha = 0$) but grant full price authority to the agents — i.e., $\mathcal{P}_i = [0, +\infty)$ for every $i = 1, 2$ — A_i solves

$$\max_{p_i \geq 0} D_i (\theta, p_i, p_{-i}) (p_i - c),$$

whose first-order condition yields a unique (symmetric) equilibrium price

$$p^A (\theta) \triangleq \frac{a + \theta}{2 + d} + \underbrace{\frac{1 + d}{2 + d}}_{\text{Pass-through}} c \qquad \forall \theta \in \Theta.$$

This expression determines the agents' ideal point which features a standard pass-through rate: agents have and incentive to pass on their distribution cost to consumers. Comparing $p^A (\theta)$ with $p^P (\theta)$ we obtain the agents' bias compared to the principals' ideal price — i.e.,

$$\Delta p (\theta) \triangleq p^A (\theta) - p^P (\theta) = \frac{1 + d}{2 + d} c \geq 0 \qquad \forall \theta \in \Theta. \tag{2}$$

This expression is increasing in d: the stronger competition, the higher the incentive of the agents to shift the burden of their distribution cost to consumers — i.e., the higher the pass-through is. This suggests that, as we show below, principals will have an incentive to cap the agents' pricing decisions rather than imposing a floor on these choices.

Impossibility of full delegation. Building on the benchmarks outlined above, we can already state the following lemma, which rules out equilibria with full delegation.

Lemma 1. *Assume $c > 0$. Then, full delegation never occurs in equilibrium irrespective of the information sharing regime.*

The reason why an equilibrium with full delegation never exists when agents have positive (even arbitrarily small) distribution costs is straightforward. Since $\Delta p(\theta) > 0$ for $c > 0$, principals always have an incentive to cap their agents' pricing choices because such constraint algins upstream and downstream incentives — i.e., it mitigates the negative effect of the pass-through on the sales volume in the high-demand state where profit margins are larger.

5 Equilibrium analysis

This section characterizes equilibria with partial delegation in each information sharing regime, establishes the conditions under which these equilibria exist, and finally examines the effects of information sharing on prices and principals' profits.

5.1 No information sharing regime

Suppose that principals do not share information. Consider a candidate (symmetric) equilibrium with the following properties:

N1 When principal P_i is informed ($s_i = 1$), it charges $p^N(\theta, s_i = 1)$ in state θ;

N2 When P_i is uninformed ($s_i = \varnothing$), it chooses a permission set that requires a binding price cap (list price) — i.e., $\mathcal{P}^N \triangleq [0, \overline{p}^N]$.[5] The cap $\overline{p}^S$ only binds in state $\theta = \epsilon$, while A_i sets a price $p^N(-\epsilon, s_i = \varnothing) < \overline{p}^N$ in state $\theta = -\epsilon$.

The analysis that follows is organized in two steps. We first characterize the candidate equilibrium described above and then, to establish its existence, we check that it is immune to principals' deviations.

5.1.1 Characterization

To characterize the above candidate equilibrium it is useful to distinguish between informed and uninformed principals.

Informed principal. Suppose that P_i is informed ($s_i = 1$). Given properties **N1-N2**, principal P_i solves the following maximization problem

$$\max_{p_i \geq 0} \mathbb{E}_{s_{-i}} \left[D_i \left(\theta, p_i, p^N(\theta, s_{-i}) \right) p_i \right] \qquad \forall \theta \in \Theta,$$

whose first-order condition yields the following best-reply function

$$p_i(\cdot) = \frac{a + \theta + d\mathbb{E}_{s-i} \left[p^N(\theta, s_{-i}) \right]}{2(1+d)} \qquad \forall \theta \in \Theta.$$

[5] We show in the Appendix that this is indeed the unique equilibrium.

Under passive beliefs, the following expectation must hold true

$$\mathbb{E}_{s_{-i}}\left[p^N\left(\theta, s_{-i}\right)\right] \triangleq \alpha p^N\left(\theta, s_{-i}=1\right)+(1-\alpha) p^N\left(\theta, s_{-i}=\varnothing\right).$$

Hence, for given $p^N\left(\theta, s_i=\varnothing\right)$, the equilibrium price $p^N\left(\theta, s_i=1\right)$ is such that

$$p^N\left(\theta, s_i=1\right)=\frac{a+\theta}{2(1+d)-\alpha d}+\frac{(1-\alpha) d}{2(1+d)-\alpha d} p^N\left(\theta, s_{-i}=\varnothing\right) \qquad \forall \theta \in \Theta,$$

which, as intuition suggests, converges to the principals' ideal point when $\alpha=1$ — i.e., when principals are informed.

Uninformed principal. Suppose now that P_i is uninformed ($s_i=\varnothing$) and assume that it grants A_i price authority within the set $\mathcal{P}_i=\left[0, \overline{p}_i\right]$, with $\overline{p}_i$ being binding in state $\theta=\epsilon$ only. We will check ex post that these properties are indeed optimal from P_i's standpoint given the rival's equilibrium behavior. A_i solves the following maximization problem in state $\theta=-\epsilon$,

$$\max_{p_i \geq 0} \mathbb{E}_{s_{-i}}\left[D_i\left(-\epsilon, p_i, p^N\left(-\epsilon, s_{-i}\right)\right)\left(p_i-c\right)\right],$$

whose first-order condition yields the following best-reply function

$$p_i(\cdot)=\frac{c}{2}+\frac{a-\epsilon+d \mathbb{E}_{s_{-i}}\left[p^N\left(-\epsilon, s_{-i}\right)\right]}{2(1+d)}, \tag{3}$$

which pins down A_i's optimal price when it expects the rival to face the equilibrium permission set $\mathcal{P}^N$ and to set the price $p^N\left(-\epsilon, s_{-i}\right)<\overline{p}^N$.

Again, under passive beliefs off the equilibrium path, the following holds

$$\mathbb{E}_{s_{-i}}\left[p^N\left(-\epsilon, s_{-i}\right)\right] \triangleq \underbrace{\left[\frac{a-\epsilon}{2(1+d)-\alpha d}+\frac{d(1-\alpha)}{2(1+d)-\alpha d} p^N\left(-\epsilon, s_i=\varnothing\right)\right]}_{=p^N\left(-\epsilon, s_i=1\right)}+(1-\alpha) p^N\left(-\epsilon, s_{-i}=\varnothing\right).$$

Substituting this expectation into condition (3), the equilibrium price $p^N\left(-\epsilon, s_i=\varnothing\right)$ solves

$$\begin{aligned} p^N\left(-\epsilon, s_i=\varnothing\right)= & \frac{a-\epsilon+c(1+d)}{2(1+d)}+\frac{(1-\alpha) d}{2(1+d)} p^N\left(-\epsilon, s_i=\varnothing\right) \\ & +\frac{\alpha d}{2(1+d)}\left(\frac{a-\epsilon}{2(1+d)-\alpha d}+\frac{d(1-\alpha)}{2(1+d)-\alpha d} p^N\left(-\epsilon, s_i=\varnothing\right)\right), \end{aligned}$$

which yields

$$p^N\left(-\epsilon, s_i=\varnothing\right)=p^P(-\epsilon)+\frac{2+d(2-\alpha)}{2(2+d)} c.$$

To complete the characterization we just need to find $\overline{p}^N$ and then check that it is higher than

$p^N(-\epsilon, s_i = \varnothing)$ and lower than that A_i's ideal price in state $\theta = \epsilon$ (so that the price cap actually binds). Since P_i's profit in state $\theta = -\epsilon$ does not depend on the cap $\overline{p}_i$ imposed in the high-demand state, this value solves the following maximization problem

$$\max_{\overline{p}_i \geq 0} \mathbb{E}_{s_{-i}} \left[D_i \left(\epsilon, \overline{p}_i, p^N(\epsilon, s_{-i}) \right) \overline{p}_i \right],$$

whose solution yields the following best-reply function

$$\overline{p}_i(\cdot) = \frac{a + \epsilon + d\mathbb{E}_{s_{-i}} \left[p^N(\epsilon, s_{-i}) \right]}{2(1+d)},$$

where, under passive beliefs off the equilibrium path, it must be

$$\mathbb{E}_{s_{-i}} \left[p^N(\epsilon, s_{-i}) \right] \triangleq \alpha \underbrace{\left(\frac{a+\epsilon}{2(1+d) - \alpha d} + \frac{d(1-\alpha)}{2(1+d) - \alpha d} \overline{p}^N \right)}_{= p^N(\epsilon, s_i = 1)} + (1-\alpha)\overline{p}^N.$$

Hence, in equilibrium, $\overline{p}^N$ is solution of

$$\overline{p}^N = \frac{a+\epsilon}{2(1+d)} + \frac{d}{2(1+d)} \left[\alpha \left(\frac{a+\epsilon}{2(1+d) - \alpha d} + \frac{d(1-\alpha)}{2(1+d) - \alpha d} \overline{p}^N \right) + (1-\alpha)\overline{p}^N \right],$$

yielding $\overline{p}^N = p^P(\epsilon)$ — i.e., under partial delegation principals force their ideal price in state $\theta = \epsilon$.

Finally, it is easy to show that A's unconstrained price choice in state $\theta = \epsilon$ would violate the cap $\overline{p}^N$. Indeed, given the equilibrium strategies, if A_i could set its price without restrictions it would post

$$p_i(\cdot) = \frac{c}{2} + \frac{a + \epsilon + d\mathbb{E}_{s_{-i}} \left[p^N(\theta, s_{-i}) \right]}{2(1+d)} = p^P(\epsilon) + \frac{c}{2} > p^P(\epsilon).$$

We can thus claim the following.

Proposition 1. *Suppose that an equilibrium exhibiting properties* **N1-N2** *exists in the regime without information sharing. The following is true:*

- *If $s_i = 1$, then P_i sets*

$$p^N(\theta, s_i = 1) \triangleq \begin{cases} p^P(\epsilon) & \text{if } \theta = \epsilon \\ p^P(-\epsilon) + \frac{d(1-\alpha)}{2+d} c & \text{if } \theta = -\epsilon \end{cases}.$$

- *If $s_i = \varnothing$, then $\overline{p}^N = p^P(\epsilon)$ and A_i chooses*

$$p^N(\theta, s_i = \varnothing) \triangleq \begin{cases} p^P(\epsilon) & \text{if } \theta = \epsilon \\ p^P(-\epsilon) + \frac{2+d(2-\alpha)}{2(2+d)} c & \text{if } \theta = -\epsilon \end{cases}$$

with $\overline{p}^N > p^N(-\epsilon, s_i = \varnothing)$ *if and only if*

$$c \leq \overline{c}_N \triangleq \frac{4\epsilon}{2 + d(2-\alpha)}.$$

Under partial delegation principals always force their ideal price when demand is high: in this state, agents would appropriate high margins if they could choose prices according to their objectives, thereby reducing sales at the expense of principals. By contrast, to gain flexibility, principals let agents distorting prices upward in the low demand state — i.e., where such a distortion impacts relatively less sales volumes. Clearly, partial delegation can occur in equilibrium only if the distribution cost c is not too high, since otherwise the price cap $\overline{p}^N$ would be lower than A_i's choice $p^N(-\epsilon, s_i = \varnothing)$ in state $\theta = -\epsilon$, contradicting property **N2** (see the Appendix).

5.1.2 Existence

We can now turn to study the conditions under which the candidate equilibrium characterized above exists. Clearly, an informed principal has no incentive to deviate from the above candidate equilibrium because the price $p^N(\theta, s_i = 1)$ maximizes its objective function in every state of nature given the rival's expected behavior. Hence, the only deviation that may disrupt the candidate equilibrium characterized in Proposition 1 is that of an uninformed principal. There are two possible deviations that such a principal may consider: (*i*) a deviation to full delegation, and (*ii*) a deviation to pooling — i.e., such that the deviating principal retains full price control. The first deviation is clearly unprofitable: for any $c > 0$, uninformed principals will always cap their agents' choices in the high-demand state in order to prevent them from passing on the distribution cost to consumers. Hence, the main conceivable deviation for an uninformed principal is the pooling one.

When retaining full price control, the deviating principal (say P_i) solves the following maximization problem

$$\max_{p \geq 0} \mathbb{E}_{s_{-i}} \left[D_i\left(\epsilon, p, p^N(\epsilon, s_{-i})\right) + D_i\left(-\epsilon, p, p^N(-\epsilon, s_{-i})\right) \right] p.$$

The first-order condition yields the fixed (deviation) price

$$\hat{p}^N = \mathbb{E}\left[p^P(\theta)\right] + \frac{d(1-\alpha)}{2(2+d)} c,$$

and the expected profit associated with such a deviation is therefore

$$\hat{\pi}^N \triangleq \frac{1}{2} \mathbb{E}_{s_{-i}} \left[D_i\left(\epsilon, \hat{p}^N, p^N(\epsilon, s_{-i})\right) + D_i\left(-\epsilon, \hat{p}^N, p^N(-\epsilon, s_{-i})\right) \right] \hat{p}^N.$$

Substituting the equilibrium and the deviation prices into the above expression and comparing it with the equilibrium profit

$$\begin{aligned}\pi^N(s_i=\varnothing) \triangleq\ & \frac{1}{2}\mathbb{E}_{s_{-i}}\left[D_i\left(\epsilon, p^N(\epsilon, s_i=\varnothing), p^N(\epsilon, s_{-i})\right) p^N(\epsilon, s_i=\varnothing)\right] \\ & +\frac{1}{2}\mathbb{E}_{s_{-i}}\left[D_i\left(-\epsilon, p^N(-\epsilon, s_i=\varnothing), p^N(-\epsilon, s_{-i})\right) p^N(-\epsilon, s_i=\varnothing)\right],\end{aligned}$$

we can show the following result.

Proposition 2. *Without information sharing, the symmetric equilibrium with partial delegation characterized above exists if and only if*

$$c \leq \underline{c}_N \triangleq \frac{2\epsilon}{d(1-\alpha)+(2+d)\sqrt{2}} < \overline{c}_N,$$

with the threshold $\underline{c}_N$ being decreasing in d and increasing in α.

The intuition is as follows. When the misalignment of preferences between principals and agents is sufficiently strong, as reflected by a high distribution cost, principals do not find it profitable to leave price authority to the agents because they would pass on this high cost to consumers, reducing sales and profits. The region of parameters in which partial delegation occurs in equilibrium shrinks when d increases: since the pass-through increases when products become closer substitutes, the conflict of interest between principals and agents worsens, which makes a pooling equilibrium relatively more likely since agents would make choices too distant from what the principals would like. Yet, as α and ϵ increase, the region of parameters in which partial delegation occurs in equilibrium expands. The higher the probability that principals are informed, the easier to sustain an equilibrium with partial delegation. Moreover, the more uncertain demand is, the higher the cost for the principals to implement a rigid pricing rule (pooling) that makes prices unresponsive to demand fluctuations.

5.2 Information sharing regime

Suppose now that principals share information, there are two relevant aggregate states of nature in this regime: (i) the state in which none of the principals is informed (hereafter denoted $\sigma = \varnothing$) whose probability is $(1-\alpha)^2$, and (ii) the state in which at least one of them is informed (hereafter denoted $\sigma = 1$) whose probability is $1-(1-\alpha)^2$. Consider a candidate (symmetric) equilibrium with the following properties:

S1 When both principals are informed ($\sigma = 1$), each charges $p^S(\theta, \sigma=1)$ in state θ;

S2 When no principal is informed ($\sigma = \varnothing$), each chooses a permission set that requires a binding price cap — i.e., $\mathcal{P}^S \triangleq [0, \overline{p}^S]$.[6] The cap $\overline{p}^S$ only binds in state $\theta = \epsilon$, while A_i sets a price $p^S(-\epsilon, \sigma=\varnothing) < \overline{p}^S$ in state $\theta = -\epsilon$.

[6] We show in the Appendix that this is indeed the unique equilibrium.

As before, we first characterize the candidate equilibrium described above and then find the conditions under which it exists.

5.2.1 Characterization

To characterize the above candidate equilibrium it is useful to distinguish between the state of nature in which principals are informed and that in which they are uninformed.

Informed principals. When principals are informed it is easy to show that

$$p^S(\theta, \sigma = 1) = p^P(\theta) \qquad \forall \theta \in \Theta.$$

That is, principals force a fixed price equal to their 'ideal point'.

Uninformed principals. Consider now the state of nature in which principals are uninformed. Suppose that P_i offers a permission set $\mathcal{P}_i = [0, \overline{p}_i]$, with $\overline{p}_i$ being binding in state $\theta = \epsilon$ only. Given property **S2,** A_i solves the following maximization problem in state $\theta = -\epsilon$

$$\max_{p_i \geq 0} D_i\left(-\epsilon, p_i, p^S(-\epsilon, \sigma = \varnothing)\right)(p_i - c).$$

The first-order condition yields the best-reply function

$$p_i(\cdot) = \frac{c}{2} + \frac{a - \epsilon + dp^S(-\epsilon, \sigma = \varnothing)}{2(1+d)}.$$

Hence, in a symmetric equilibrium, the following holds

$$p^S(-\epsilon, \sigma = \varnothing) = p^P(-\epsilon) + \frac{1+d}{2+d}c \qquad \forall i = 1, 2.$$

This expression is independent of α because every principal knows that the rival is uninformed in the state of nature under consideration.

To complete the characterization we just need to find $\overline{p}^S$. Again, since P_i's profit in the low-demand state does not depend on the cap $\overline{p}_i$ imposed in the high-demand state, the maximization problem that determines this value is

$$\max_{\overline{p}_i \geq 0} D_i\left(\epsilon, \overline{p}_i, \overline{p}^S\right)\overline{p}_i,$$

whose first-order condition yields the best-reply function

$$p_i(\cdot) = \frac{a + \epsilon + d\overline{p}^S}{2(1+d)}.$$

Thus, in a symmetric equilibrium, it holds that $\overline{p}^S = p^P(\epsilon)$. Once again, principals force their ideal price in the high demand state, while agents are free to increase prices above the competitive level in the low demand state. Finally, it is easy to show that A's unconstrained choice in state $\theta = \epsilon$ would violate the cap $\overline{p}^S$. Indeed, it can be easily shown that if A_i could set its price without restrictions it would choose

$$p_i(\cdot) = \frac{c}{2} + \frac{a + \epsilon + dp^S(\theta, \sigma = \varnothing)}{2(1+d)} = p^P(\epsilon) + \frac{c}{2} > p^P(\epsilon).$$

We can thus claim the following.

Proposition 3. *Suppose that an equilibrium with properties* **S1-S2** *exists in the regime with information sharing. The following is true:*

- *If $\sigma = 1$, every principal P_i sets*

$$p^S(\theta, \sigma = 1) = p^P(\theta) \qquad \forall \theta \in \Theta.$$

- *If $\sigma = \varnothing$, the price cap is $\overline{p}^S = p^P(\epsilon)$ and A_i chooses*

$$p^S(\theta, \sigma = \varnothing) = \begin{cases} p^P(\epsilon) & \text{if } \theta = \epsilon \\ p^P(-\epsilon) + \frac{1+d}{2+d}c & \text{if } \theta = -\epsilon \end{cases}$$

with $\overline{p}^S > p^S(-\epsilon, \sigma = 1)$ if and only if ,

$$c \leq \overline{c}_S \triangleq \frac{2\epsilon}{1+d}.$$

Even with information sharing partial delegation requires principals to force their ideal price in the high demand state, while agents can distort prices upward in the low demand state. Moreover, as seen before, an equilibrium with partial delegation exists only if the distribution cost c is not too high.

5.2.2 Existence

Given the rival's equilibrium behavior, an informed principals has no incentive to deviate from the above candidate equilibrium because in this regime they achieve the ideal point (price). Hence, as before, the only deviation that may disrupt the above candidate equilibrium is that of an uninformed principal. As explained above, the only conceivable deviation for such a principal is a fixed (pooling) price that is solution of

$$\max_{p \geq 0} \left[D_i\left(\epsilon, p_i, p^S(\epsilon, \sigma = 0)\right) + D_i\left(-\epsilon, p_i, p^S(-\epsilon, \sigma = 0)\right) \right] p_i.$$

The first-order condition yields a deviation price

$$\hat{p}^S = \mathbb{E}\left[p^P(\theta)\right] + \frac{d}{4(2+d)}c,$$

so that the expected profit from such a deviation is

$$\hat{\pi}^S \triangleq \frac{1}{2}\left[D_i\left(\epsilon, \hat{p}^S, p^S\left(\epsilon, \sigma = 0\right)\right) + D_i\left(-\epsilon, \hat{p}^S, p^S\left(-\epsilon, \sigma = 0\right)\right)\right]\hat{p}^S.$$

Substituting the equilibrium and the deviation prices into the above expression and comparing it with the expected profit in the candidate equilibrium we have

$$\begin{aligned}
\pi^S\left(\sigma = \varnothing\right) \quad \triangleq \quad & \frac{1}{2}D_i\left(\epsilon, p^S\left(\epsilon, \sigma = \varnothing\right), p^S\left(\epsilon, \sigma = \varnothing\right)\right)p^S\left(\epsilon, \sigma = \varnothing\right) \\
& + \frac{1}{2}D_i\left(-\epsilon, p^S\left(-\epsilon, \sigma = \varnothing\right), p^S\left(-\epsilon, \sigma = \varnothing\right)\right)p^S\left(-\epsilon, \sigma = \varnothing\right),
\end{aligned}$$

we can show the following result.

Proposition 4. *With information sharing, the symmetric equilibrium with partial delegation characterized above exists if and only if*

$$c \leq \underline{c}_S \triangleq \frac{4(\sqrt{2}-1)\epsilon}{4-2\sqrt{2}+d} < \bar{c}_S,$$

with the threshold $\underline{c}_S$ being decreasing in d and increasing in ϵ.

The intuition for this result is as before, and will thus be omitted for brevity. Once again, as in the regime without information sharing, the equilibrium with partial delegation becomes relatively easier to sustain as demand uncertainty rises and more difficult to sustain as products become closer substitutes.

5.3 Sharing or not information?

We now compare expected prices and principals' equilibrium profits with and without information sharing. Consistently with the above analysis, we restrict attention to equilibria with partial delegation, which are the most interesting ones for our purposes (we discuss pooling equilibria in Section 5.6).

To gain insights on how information sharing affects the outcome of the game, we start with the following useful result.

Lemma 2. *The region of parameters in which an equilibrium with partial delegation exists is larger with information sharing than without information sharing — i.e., $\underline{c}_N < \underline{c}_S$.*

The higher the probability that principals are informed, the easier it is for them to sustain an equilibrium with partial delegation: since prices are strategic complements, a principal that expects its rival to be informed with higher probability will be keener to delegate because it expects the rival's price to be more aligned to what competition would mandate, which in turn lowers the price charged by its own agent, mitigating the agency conflict.

We then turn to assess the effect of information sharing on consumer welfare, which in our linear environment amounts to compare expected prices with and without information sharing.

When principals share information, the expected price charged by each principal is

$$\begin{aligned} p^N &\triangleq \frac{\alpha}{2}\left(p^P\left(\epsilon\right)+p^N\left(-\epsilon, s_i=1\right)\right)+\frac{1-\alpha}{2}\left(p^P\left(\epsilon\right)+p^N\left(-\epsilon, s_i=\varnothing\right)\right) \\ &= \mathbb{E}\left[p^P\left(\theta\right)\right]+\underbrace{\frac{\left(2+d\left(2+\alpha\right)\right)\left(1-\alpha\right)}{4\left(2+d\right)}c}_{\text{Price distortion without IS}}, \end{aligned}$$

which, as intuition suggests, is higher than the expected ideal price that principals would set when they are fully informed. The price distortion without information sharing is decreasing in α since the expected price falls when principals are more likely to be informed, and increasing in d because the pass-through rate rises with the degree of product substitutability.

The expected market price that each principal sets in the information sharing regime is

$$\begin{aligned} p^S &\triangleq \frac{1-\left(1-\alpha\right)^2}{2}\left(p^P\left(\epsilon\right)+p^P\left(-\epsilon\right)\right)+\frac{\left(1-\alpha\right)^2}{2}\left(p^P\left(\epsilon\right)+p^S\left(-\epsilon, \sigma=\varnothing\right)\right) \\ &= \mathbb{E}\left[p^P\left(\theta\right)\right]+\underbrace{\frac{\left(1-\alpha\right)^2\left(1+d\right)}{2\left(2+d\right)}}_{\text{Price distortion with IS}}c, \end{aligned}$$

which, once again, is higher than the expected ideal price that principals would set when they are fully informed. As intuition suggests, the price distortion with information sharing is decreasing d and α and vanishes when principals are fully informed ($\alpha \to 1$).

Taking the difference between these expressions, the following holds.

Proposition 5. *The expected equilibrium price is unambiguously lower with than without information sharing — i.e.,*

$$p^N - p^S = \frac{\alpha\left(1-\alpha\right)\left(2+3d\right)}{4\left(2+d\right)}c \geq 0.$$

This difference is equal to 0 *when* $\alpha \in \{0,1\}$. *Moreover, it is increasing in* c *and* d *and inverted-U shaped with respect to* α *(with a maximum at* $\alpha = \frac{1}{2}$*).*

This result shows that information sharing benefits consumers in our model. The reason is as follows. When principals share information, at least one of them is informed with positive probability. In this event, the information that they share will align their agents' incentives, inducing prices to drop at the benefit of consumers. The difference between the expected price in the two information-sharing regimes is zero when principals are fully informed ($\alpha = 1$) and when they are uninformed ($\alpha = 0$). The non-monotone effect of α can be explained as follows. When α is high, the difference in prices is negligible because principals are fully informed. In this case, reducing α below 1 tends to increase the difference between expected prices because, by dealing with relatively less informed principals, agents will exploit strategic complementarity (via a higher pass-through rate) to increase their prices in the regime without information sharing (recall that $p^N\left(-\epsilon, s_i=\varnothing\right)$ is decreasing in α). When α is small, this difference is negligible too because principals are uninformed, and sharing information has little impact on prices. In this case, increasing principals' information accuracy spurs the difference between expected prices because prices fall in the event that principals are informed, and this effect more than compensate the indirect price reduction effect of α on $p^N(-\epsilon, s_i = \varnothing)$ described above.

Finally, while the positive impact of c is obvious because, in expected terms, the conflict of interest between principals and agents is less strong with information sharing than without, the positive effect of d hinges on the fact that the pass-through rate is increasing in d as explained before. Agents, indeed, tend to shield against competition by passing on to consumers their cost to a greater extent as products become closer substitutes, and the likelihood that they can do so is higher when the information exchange is not in place.

We can now turn to evaluate whether principals prefer to share information or not. Let

$$\begin{aligned}\pi^N \triangleq\ & \alpha\mathbb{E}_\theta\mathbb{E}_{s_{-i}}\left[D_i\left(\theta, p^N(\theta, s_i = 1), p^N(\theta, s_{-i})\right)p^N(\theta, s_i = 1)\right] \\ & + (1-\alpha)\,\mathbb{E}_\theta\mathbb{E}_{s_{-i}}\left[D_i\left(\theta, p^N(\theta, s_i = \varnothing), p^N(\theta, s_{-i})\right)p^N(\theta, s_i = \varnothing)\right],\end{aligned}$$

be a principal's ex-ante expected profit without information sharing and, by the same token, let

$$\begin{aligned}\pi^S \triangleq\ & (1-(1-\alpha)^2)\mathbb{E}\left[D_i\left(\theta, p^P(\theta), p^P(\theta)\right)p^P(\theta)\right] \\ & + (1-\alpha)^2\,\mathbb{E}\left[D_i\left(\theta, p^S(\theta, \sigma = \varnothing), p^S(\theta, \sigma = \varnothing)\right)p^S(\theta, \sigma = \varnothing)\right],\end{aligned}$$

be a principal's ex-ante expected profit with information sharing.

Substituting the relevant equilibrium prices in the expressions above and computing the difference $\Delta\pi = \pi^S - \pi^N$ between them (see the Appendix) we have

$$\begin{aligned}\Delta\pi &= \frac{c\alpha(1-\alpha)\left[(4(1+d)^2 + d^2\alpha(1+d\alpha))c - 2d(3d+2)(a-\epsilon)\right]}{8(2+d)^2} \geq 0 \\ \Leftrightarrow &\qquad c \geq c^\star \triangleq \frac{2d(2+3d)(a-\epsilon)}{4(1+d)^2 + \alpha d^2(1+\alpha d)}.\end{aligned}$$

Clearly, sharing information has a neutral effect on principals' profits when they are fully informed ($\alpha = 1$), when they are uninformed ($\alpha = 0$) and when agents' preferences are fully aligned with profit maximization ($c = 0$). Yet, when $\alpha \in (0,1)$ and $c > 0$, the above condition implies that principals benefit from information sharing when the distribution cost is not too low. The reason hinges on the following two effects. First, when principals share information, each learns the demand shock with greater probability than without information sharing. Other things being equal, this effect benefits principals because it mitigates the conflict of interest with their agents. Second, when principals do not share information, expected prices increase because agents are more likely to pass on their distribution costs to final consumers. The impact of this effect on principals' expected profit is ambiguous. On the one hand, the fact that agents charge higher prices than what their informed principals would do increases profits since it moves the equilibrium outcome towards the monopoly benchmark. On the other hand, when distribution costs are relatively high, the pass-through rate is high, which creates an effect similar to the standard double marginalization phenomenon, reducing sales and thus profits.

On the net, information sharing will benefit principals if distribution costs are sufficiently high. In this case, the beneficial effect of information sharing and the negative effect on sales overwhelm the price-enhancing effect that increases expected profits without information sharing.

The condition $c \geq c^{\star}$, however, must also be compatible with $c \leq \underline{c}^N$ (recall that $\underline{c}^N < \underline{c}^S$) which guarantees the existence of an equilibrium with partial delegation in both information-sharing regimes. We can thus show the following.

Proposition 6. *Suppose that $c \leq \underline{c}^N$. There exists a threshold $\overline{d} > 0$ such that $c^{\star} < \underline{c}^N$ for every $d \leq \overline{d}$ and $\Delta\pi > 0$ if and only if $c \in \left[c^{\star}, \underline{c}^N\right]$. The threshold $c^{\star}$ is decreasing in α.*

Hence, in the region of parameters where agents are granted price direction in both regimes, information sharing benefits principals if products are sufficiently differentiated and the conflict of interest with agents is not negligible. The reason why products need to be sufficiently differentiated (d low) for information sharing to be beneficial to principals is as follows. If products are relatively close substitutes (d high) softening competition is relatively more important than solving internal agency problems: the price-enhancing effect discussed above allows principals to shield themselves from competition and protect market power. Finally, notice that $c^{\star}$ is decreasing in α — i.e., information sharing is relatively more likely to benefit principals when their information accuracy rises. This is because a higher information accuracy increases rivalry by making prices more aligned with what upstream competition would mandate.

5.4 List prices and rebates

One interesting feature of the equilibria with partial delegation studied above is that the price cap can be interpreted as a list price. As a result, the difference between this cap and the price that agents charge in the low state of demand can be interpreted as a rebate that consumers enjoy when their willingness to pay turns out to be low. Notably, this suggests that the link between list and transaction prices is not deterministic, but it depends on the relative probability of low- and high- demand states. In what follows, we study the determinants of these rebates and how they depend on the information-sharing regime.

Without information sharing, the rebate is

$$r^N \triangleq \overline{p}^N - p^N\left(-\epsilon, s_i = \varnothing\right) = \frac{2\epsilon}{2+d} - \frac{2 + d\left(2-\alpha\right)}{2\left(2+d\right)}c,$$

which is decreasing in the agents' distribution cost c and the degree of product substitutability d, while it rises with demand uncertainty ϵ and the principals' information accuracy α.

With information sharing, instead, the rebate is

$$r^S \triangleq \overline{p}^S - p^S\left(-\epsilon, \sigma = \varnothing\right) = \frac{2\epsilon}{2+d} - \frac{1+d}{2+d}c,$$

which is again increasing in ϵ and decreasing in c and d. However, in this case, the rebate does not depend on the principals' information accuracy α.

Straightforward algebra implies the following result.

Corollary 1. *Rebates are lower with than without information sharing — i.e.,*

$$r^N - r^S = \frac{d\alpha}{2\,(2+d)} > 0.$$

Even though information sharing reduces expected prices, consumers obtain higher discounts when principals do not exchange information, provided they are uninformed. The reason is simple: when principals do not share information, each agent (say A_i) must take an expectation over the price charged by the rival when it is granted price authority. This expectation weights with probability α the event in which P_{-i} is informed and lowers its price compared to the case in which it is uninformed. With information sharing, instead, every agent knows whether the rival principal is informed or not. When both are uninformed, each agent knows that the rival agent will increase the price above the principals' ideal point in the low-demand state (simply because agents learn form the principals choices). Strategic complementarity then implies that, conditional on principals not being informed, agents charge a higher price in the low demand state with than without information sharing. The policy implication of this result is that observing higher rebates in the no information sharing regime does not necessarily imply that consumers prefer this regime to one with information sharing from an ex-ante standpoint. Hence, even if ex-post consumers enjoy higher rebates without information sharing, ex-ante they prefer firms to exchange information. Interestingly, this may create a time inconsistency problem in the sense that consumers may be in favor of firms sharing information ex ante, but complain ex post once they obtain low rebates.

5.5 Implementation through disclosure of price intentions

To be effective, information sharing agreements require some degree of coordination between their members, especially in oligopolistic markets (see, e.g., Ziv, 1993, who shows why these agreements fall apart in the absence of coordination). Most of the existing models (see, e.g., Raith, 1996) assume that firms can commit themselves either to reveal their private information to other firms or to keep it private before receiving any private information. The implicit hypothesis is that these agreements are organized by certification intermediaries — e.g., auditors, data analytic companies, marketing information services firms, trade associations, etc. — who own the technology to discover the private information of the participants to the agreement and can commit to disclosure rules that disseminate this knowledge among them (see, e.g., also Lizzeri, 1999). Following such a 'reduced-form' approach, thus far, we have assumed that principals can freely exchange their demand information without specifying the communication protocol or the 'language' through which this information is shared.

In reality, however, firms do not communicate through a vague 'word of mouth' process, but signal their private information to rivals via their market choices — i.e., prices, investment decisions, output, etc. When this is the case, these variables de facto form the language through which firms communicate. In this section, we explain how an information-sharing agreement can be organized through the disclosure of price intentions in the context of our model. We will still rely on the presence of an informed certification intermediary as earlier models do. However, we show that once price intentions have been disclosed, such an intermediary will just need to approve or disprove the agreement instead of redistributing information among the agreement participants. This may contribute to understanding how firms communicate in practice and shed some light on the competitive and welfare effects of agreements where firms share information about (future) list prices (see, e.g., Harrington and Ye, 2017, for a survey of recent cases where this practice is under investigation).

Consider the following information sharing protocol:

- Before uncertainty realizes, principals commit on an industry-wide basis to either announce a fixed price within the set $\left\{p^P(\epsilon), p^P(-\epsilon)\right\}$ or a list price $\overline{p}^S$.
- Upon observing its private information, each principal P_i discloses its price intention.
- The intermediary certifies the agreement if and only if: (i) at least one principal has disclosed a fixed price $p^P(\theta)$ and the demand state is θ; (ii) principals that announce a list price $\overline{p}^S$ are de facto uninformed. Otherwise, the intermediary refuses to certify the agreement.
- Each principal updates its beliefs on the state of demand upon observing the rival and the intermediary's choice, and sets its actual pricing choice.
- The game then unfolds as before.

This protocol clearly allows principals to share their private information truthfully and implements the equilibrium outcome of the information sharing regime provided the conditions under which $\Delta\pi > 0$ stated in Proposition 6 hold. Indeed, the following is true: (i) when a principal announces a fixed price $p^P(\theta)$, and the intermediary certifies the agreement, even if the other principal has not announced the same price, that principal learns that the state of nature is θ irrespective of its announcement. Hence, both will opt for a fixed price $p^P(\theta)$; (ii) when both principals announce a list price $\overline{p}^S$, and the intermediary certifies the agreement, each principal learns that the rival is uninformed, and will accordingly not change its announced list price. As a result, under the conditions stated in Proposition 6 such that $\Delta\pi > 0$, principals will find it profitable to enter the information sharing protocol described above, which also benefits consumers. Of course, the presence of the certification intermediary is key for our mechanism to work, although its role simply amounts to approve or disprove the agreement upon verifying the information conveyed by the principals' choices. An alternative enforcement mechanism, often discussed in the literature, is reputation: when firms have sufficiently high reputation concerns and are not too myopic (perhaps because the game is repeated over time), they will not manipulate or misreport the information shared with rivals as long as the equilibrium strategy features a sufficiently long punishment phase where all players coordinate to play the equilibrium of the regime without information sharing.

Of course, a potential argument against price intentions disclosure is that they may foster collusion. Yet, Rey and Tirole (2019) are somewhat cautious about this possibility. As they argue, the issue is controversial: "one needs to understand the channel to know whether the communication involved in the price-cap setting is the actual driver of collusion..". For example, building on Cooper and Kühn (2014), Kühn and Tadelis (2017) suggests that sharing information on price intentions may not serve anticompetitive purposes. The argument is standard: collusive agreements are relatively more likely to be sustained when communication is about historical data rather than future actions since the transmission of historical data allows a proper punishment of deviations. Disclosure of price intentions may not be enough to enforce punishment codes as long as firms are free to change actual prices secretly.

Moreover, in the delegation context that we developed in this paper, it is not clear that industry profit maximization would require price caps. In a companion paper, Andreu et al. (2021) show that while principals' non-cooperative behavior leads to partial delegation equilibria featuring a binding list price: a cooperative behavior may need price floors for low distribution costs. Principals' communication may even mandate full price delegation when these costs take intermediate values. Hence, sharing information on future list prices may not necessarily be a symptom of principals' cooperation but rather a genuine competitive conduct that preserves consumer welfare by saving on agency costs.

5.6 Pooling equilibria

So far, we focused on equilibria featuring partial delegation. As explained above, the analysis of pooling equilibria — i.e., equilibria in which uninformed principals do not grant price discretion at all to their agents — is uninteresting for our purposes because these equilibria have already been studied in the literature dealing with information exchanges in oligopoly (principals de facto behave as integrated firms). Yet, for completeness, in this section we also examine pooling equilibria. To this purpose, we assume that $c > \underline{c}^S$ so that the only symmetric equilibrium that can emerge in both information sharing regimes must be a pooling one since we have already shown in Lemma 1 that equilibria with full delegation cannot exist. We shall discuss the case in which $c \in (\underline{c}^N, \underline{c}^S]$ in Section 5.6.1.

No information sharing. Consider a candidate equilibrium in which each uninformed principal sets a fixed price $\hat{p}^N$ — i.e., agents cannot offer any price different than this. Abusing slightly notation, let as before $p^N(\theta, s_i = 1)$ be the price charged by P_i in equilibrium conditional on being informed. P_i's best-reply function in state $s_i = 1$, is

$$p_i(\theta, s_i = 1) = \frac{a + \theta + d\left[\alpha p^N(\theta, s_{-i} = 1) + (1-\alpha)\hat{p}^N\right]}{2(1+d)} \qquad \forall \theta \in \Theta.$$

In a symmetric equilibrium, this yields

$$p^N(\theta, s_i = 1) = \frac{a + \theta + d(1-\alpha)\hat{p}^N}{2(1+d) - \alpha d} \qquad \forall \theta \in \Theta.$$

Suppose now that P_i is uninformed. Given the rivals' equilibrium strategy, P_i solves

$$\max_{p_i \geq 0} \mathbb{E}_{s_{-i}} \left[D_i \left(\epsilon, p_i, p^N(\epsilon, s_{-i}) \right) + D_i \left(-\epsilon, p_i, p^N(-\epsilon, s_{-i}) \right) \right] p_i,$$

whose first-order condition yields the following best reply function

$$p_i^\star(\cdot) = \frac{a + d\left[\alpha \mathbb{E}_\theta \left[p^N(\theta, s_{-i} = 1)\right] + (1-\alpha)\hat{p}^N\right]}{2(1+d)},$$

where, under passive beliefs off-equilibrium path, it holds that

$$\mathbb{E}_\theta \left[p^N(\theta, s_{-i} = 1)\right] \triangleq \frac{a + d(1-\alpha)\hat{p}^N}{2(1+d) - \alpha d}.$$

Solving for a symmetric fixed price equilibrium we have $\hat{p}^N = \mathbb{E}\left[p^P(\theta)\right]$. This result is rather intuitive: when principals refuse to grant price authority to the agents, under our linear specification, they will set a price equal to the expectation of the price they would charge under complete information since, de facto, they act as integrated and uninformed duopolists. The expected equilibrium price is therefore

$$p^N \triangleq \frac{\alpha}{2}\left(p^P(\epsilon) + p^N(-\epsilon, s_i = 1)\right) + (1-\alpha)\hat{p}^N = \mathbb{E}\left[p^P(\theta)\right],$$

which is lower than the expected price charged under partial delegation since agents cannot influence prices. Hence, consumers do not suffer from double marginalization.

Information sharing. Let $\hat{p}^S$ be the fixed (symmetric) price that principals are expected to charge when they are uninformed. As before, when both principals are informed it is easy to show that

$$p^S(\theta, \sigma = 1) = p^P(\theta) \qquad \forall \theta \in \Theta.$$

Consider now the state of nature in which both principals are uninformed. P_i solves

$$\max_{p_i \geq 0} \left[D_i \left(\epsilon, p_i, p^S(\epsilon, \sigma = 0) \right) + D_i \left(-\epsilon, p_i, p^S(-\epsilon, \sigma = 0) \right) \right] p_i,$$

whose first-order condition yields the following best-reply function

$$\hat{p}_i^S(\cdot) = \frac{a + d\hat{p}^S}{2(1+d)},$$

whose solution yields again $\hat{p}^S = \mathbb{E}\left[p^P(\theta)\right]$. The expected equilibrium price is

$$p^S \triangleq (1-(1-\alpha)^2)\mathbb{E}\left[p^P(\theta)\right] + (1-\alpha)^2\mathbb{E}\left[p^P(\theta)\right] = \mathbb{E}\left[p^P(\theta)\right].$$

Hence, when a pooling equilibrium exists under both regimes, expected prices are the same with and without information sharing (this result is discussed in Kuhn and Vives, 1995).

Profitability of information sharing. Finally, we can compare expected profits with and without information sharing. Let

$$\hat{\pi}^N \triangleq \mathbb{E}_\theta \mathbb{E}_{s_{-i}}\left[\alpha D_i\left(\theta, p^N(\theta, s_i=1), p^N(\theta, s_{-i})\right) p^N(\theta, s_i=1) + (1-\alpha) D_i\left(\theta, \hat{p}^N, p^N(\theta, s_{-i})\right)\hat{p}^N\right],$$

be a principal's ex-ante expected profit without information sharing and, by the same token, let

$$\hat{\pi}^S \triangleq (1-(1-\alpha)^2)\mathbb{E}\left[D_i\left(\theta, p^P(\theta), p^P(\theta)\right) p^P(\theta)\right] + (1-\alpha)^2\,\mathbb{E}\left[D_i\left(\theta, \hat{p}^S, \hat{p}^S\right)\hat{p}^S\right],$$

be a principal's ex-ante expected profit with information sharing.

Substituting the equilibrium values into the above expressions and computing the difference $\Delta\pi = \hat{\pi}^S - \hat{\pi}^N$ we have

$$\Delta\hat{\pi} = \frac{\epsilon^2\alpha(1-\alpha)(1+d)\left[\left(2d^2+8d+4\right) + d^2\alpha^2 + \left(5d^2+4d\right)(1-\alpha)\right]}{(2+d)^2\left(2(1+d)-d\alpha\right)^2} \geq 0,$$

which is positive and equal to zero when principals are fully informed ($\alpha = 1$) and when they are uninformed ($\alpha = 0$). Hence, when a pooling equilibrium emerges in both information regimes the agreement is neutral for consumers but unambiguously benefits principals. This is because, being informed allows principals to tailor prices to demand fluctuations.

5.6.1 A hybrid scenario

An interesting region of parameters is that in which $c \in (\underline{c}^N, \underline{c}^S]$. In this case, the no information sharing regime can only features a symmetric equilibrium in which principals pool — i.e., they never grant price authority to their agents — while under information the equilibrium features partial delegation. It then easily follows that, in this hybrid scenario, the expected equilibrium price is higher with information sharing than without information sharing — i.e.,

$$p^S = \mathbb{E}\left[p^P(\theta)\right] + \frac{(1-\alpha)^2(1+d)}{2(2+d)}c > \hat{p}^N = \mathbb{E}\left[p^P(\theta)\right].$$

As a result, in this region of parameters an information sharing agreements is detrimental to consumers. Yet, it is profitable if and only if the following holds

$$\pi^S - \hat{\pi}^N = \underbrace{\frac{(1+d)(1-\alpha)\left(4(1+2d)+d^2(4-\alpha)\right)}{(d+2)^2(2(1+d)-d\alpha)^2}\epsilon^2}_{\text{Flexibility gain}}$$
$$-\underbrace{\frac{(1-\alpha)^2(1+d)}{2(2+d)^2}c^2}_{\text{Loss of control}}+\underbrace{\frac{(1-\alpha)^2 d(1+d)(a-\epsilon-c)}{2(2+d)^2}c}_{\text{Competition softening}}$$

This condition reflects the following forces. First, information sharing leads to an equilibrium with partial delegation in the region of parameters under consideration. Therefore, it allows principals to target prices to consumers' willingness to pay, allowing them to gain flexibility compared to the regime without information sharing where principals pool when they are uninformed. This flexibility gain is captured by the first term in the above equation and is proportional to the volatility of demand, which is reflected by ϵ — i.e., the higher ϵ, the greater the benefit of flexibility. Second, since agents have biased preferences, they will price too high in the low demand state than what principals would do in a non-cooperative equilibrium, making information sharing less compelling. This loss of control effect is reflected in the second term in the above equation and vanishes when principals are fully informed — i.e., as $\alpha \to 1$. Third, since agents rise prices above the competitive level, principals can soften competition when granting them price authority. This competition softening effect is captured by the last term in the equation and vanishes when products are independent — i.e., as $d \to 0$.

We can thus claim the following:

Proposition 7. *For $c \in (\underline{c}^N, \underline{c}^S]$, principals' expected profit is higher with information than without information sharing if*

$$d \geq d^\star \triangleq \frac{c}{a-\epsilon-c},$$

or if $d < d^\star$ and ϵ is sufficiently large. Otherwise, principals' expected profit is higher without information sharing than with information sharing.

Since **A2** implies that $a - \epsilon > c$, when products are sufficiently close substitutes — i.e., $d \geq d^\star$ — the competition-softening effect dominates the loss of control effect. In other words, softening competition is relatively more important than losing control of agents' choices. By contrast, when products are sufficiently differentiated — i.e., $d < d^\star$ — the cost of losing control is relatively stronger than the competition-softening effect. In this region of parameters, information sharing still enhances principals' expected profit if demand is sufficiently volatile, and the opposite holds otherwise.

Hence, while information sharing agreements increase prices and reduce consumer surplus in the region of parameters under consideration, principals have no incentive to enter into these agreements when products are sufficiently differentiated, and demand is not too uncertain.

6 Additional remarks and robustness

We now discuss how our results could be extended to alternative demand specifications, competition forms and information structures.

Alternative demand specifications. We now explain why our results would still hold true under different demand specifications.

First, consider a representative consumer whose preferences are described by a quadratic utility function à la Singh and Vives (1984)

$$U(\cdot) \triangleq (a+\theta)\sum_{i=1}^{2} q_i - \frac{1}{2}\sum_{i=1}^{2} q_i^2 - dq_1q_2 - \sum_{i=1}^{2} p_iq_i + I, \tag{4}$$

where, as standard, $I \geq 0$ is the representative consumer's income. The random parameter θ is equally distributed over the support $\Theta \triangleq \{-\epsilon, \epsilon\}$ and, as before, it captures the consumer's stochastic willingness to pay. As in the baseline model, the parameter $d \in [0,1)$ is an inverse measure of the degree of differentiation between products: the larger d, the more homogenous (less differentiated) products are.

Differentiating (4) with respect to q_i ($i = 1, 2$) and inverting the system of first-order conditions, we obtain the following demand functions

$$D_i(\theta, p_i, p_{-i}) \triangleq \frac{(a+\theta)(1-d) - p_i + dp_{-i}}{1-d^2} \qquad \forall i = 1, 2.$$

Under this specification, it can be shown that principals' ideal (equilibrium) price is

$$p^P(\theta) \triangleq \frac{(a+\theta)(1-d)}{2-d} \qquad \forall \theta \in \Theta,$$

while agents' ideal (equilibrium) price is

$$p^A(\theta) = p^P(\theta) + \underbrace{\frac{1}{2-d}c}_{\text{Bias}} \qquad \forall \theta \in \Theta.$$

As before, the agents' bias (pass-through) is increasing in c and d. Hence, the qualitative insights of the baseline model carry over to this alternative demand specification.

Next, suppose a demand system obtained by CES preferences (Dixit and Stiglitz, 1977)

$$D_i(\cdot) \triangleq \frac{p_i^{-\theta-1}}{\sum_{j=1}^{2} p_j^{-\theta}} \qquad \forall i = 1, 2. \tag{5}$$

The parameter θ represents a measure of product substitutability: the larger θ the closer substitutes products are. Suppose that agents are informed about θ and assume that c_0 is the principals' production cost, while c is the agents distribution cost.[7]

It is easy to show that when principals are informed about θ, their ideal (equilibrium) price is

$$p^P(\theta) \triangleq c_0 \frac{2+\theta}{\theta} \qquad \forall \theta \in \Theta,$$

whereas agents' ideal (equilibrium) price is

$$p^A(\theta) \triangleq p^N(\theta) + \underbrace{c\frac{2+\theta}{\theta}}_{\text{Bias}} \qquad \forall \theta \in \Theta.$$

In line with the baseline model, agents are biased towards excessively high prices. Hence, principals will still find it optimal to discipline their behavior through the imposition of a list price. Notice that the agents' bias decreases in θ, meaning that, in the spirit of the baseline model, imposing a price cap is more valuable when profit margins are high — i.e., when products are relatively more differentiated (low values of θ).

On intra-brand competition. Consider now the impact of intra-brand competition on the conflict of interest between principals and agents. Suppose that principals (each denoted by $k = 1, 2$) deals with two agents (each denoted by $i = 1, 2$). The pair (i, k) indicates agent i dealing with principal k. Consider a representative consumer with the following modified version of the Singh-Vives (1984) utility function

$$U(\cdot) \triangleq (a+\theta) \sum_{k=1,2} \sum_{i=1,2} q_{i,k} - \frac{1}{2} \sum_{k=1,2} \sum_{i=1,2} q_{i,k}^2 - h \sum_{k=1,2} q_{1,k} q_{2,k} + \\ - d \sum_{i=1,2} q_{i,1} \sum_{i=1,2} q_{i,2} - \sum_{k=1,2} \sum_{i=1,2} q_{i,k} p_{i,k} + I,$$

where, as before, $I > 0$ is the representative consumer's income. The parameter $h \in [0, 1)$ is a measure of *intra-brand competition*: the larger h, the more homogeneous (less differentiated) the products distributed by the agents within each distribution network. The parameter $d \in [0, h]$, instead, measures the degree of *inter-brand competition*: the larger d, the more homogeneous the products distributed by the two principals. Of course, we impose that $h \geq d$ because intra-brand competition creates stronger price externalities than inter-brand competition (the products manufactured by the same principal are closer substitutes than other products in the industry). Differentiating with respect to quantities and inverting the corresponding first-order conditions, we obtain the following system of demand functions

$$D_{i,k}(\cdot) \triangleq \frac{(a+\theta)(1-h)(1+h-2d) - \left(1+h-2d^2\right) p_{1,1} + \left(h(1+h)-2d^2\right) p_{2,1} + (1-h)\, d \sum_{i=1,2} p_{i,-k}}{(1-h)\left((1+h)^2 - 4d^2\right)},$$

[7] We introduce c_0 in order to avoid that in the non cooperative equilibrium principals choose $p^N(\theta) = 0$.

for every pair (i, k).

Focusing on a symmetric equilibrium, which is also unique with the linear demand specification under consideration, P_i solves the following maximization problem

$$\max_{p_{1,k}, p_{2,k}} \sum_{i=1,2} D_{i,k}(\cdot)\, p_{i,k}.$$

The first-order condition yields the principals' ideal (equilibrium) price

$$p^P(\theta) \triangleq \frac{(a+\theta)(1+h-2d)}{2(1+h-d)} \qquad \forall \theta \in \Theta.$$

By contrast, for given $k = 1, 2$, when entitled to choose the price, agent A_i solves

$$\max_{p_{i,k}} D_{i,k}(\cdot)\,(p_{i,k} - c).$$

The first-order condition yields the agents' ideal (equilibrium) price

$$p^A(\theta) \triangleq p^P(\theta) + \underbrace{\frac{1+h}{2(1+h-d)}c}_{\text{Bias with intra-brand competition}} \qquad \forall \theta \in \Theta.$$

Hence, as intuition suggests, agents still have an incentive to price above the principals' ideal price. The bias, however, now is increasing in d and decreasing in h. Hence, while inter-brand competition exacerbates the conflict of interest between principals and agents intra-brand competition tends to align upstream and downstream incentives.

As a result, for given information sharing regime, the equilibrium with partial delegation will be less likely to emerge in industries featuring stronger intra-brand competition. This implies that, while information sharing will still be likely to benefit consumers irrespective of the level of intra-brand competition, principals will be less likely to share information as h grows large because the competition softening effect gains weight as agents within each distribution network compete more fiercely.

Continuum of types. A simple way of introducing a continuum of types would be to assume that θ is uniformly distributed over the support $\Theta \triangleq [-\epsilon, \epsilon]$, and that each principal learns its realization with probability α and remains uninformed otherwise: the 'so called' all-or-nothing technology (see, e.g., Armstrong and Vickers, 2010). Our results extend immediately to this setting although the algebra complicates quite (see, e.g., Andreu et al., 2021, who characterize the optimal delegation scheme with competing principals in the case $\alpha = 0$ with a continuum of demand shocks). Specifically, for c not too high, there exists a symmetric equilibrium with partial delegation in which, irrespective of the information sharing regime, uninformed principals set a list price above which agents cannot price. To understand why, let $k \in \{N, S\}$ be an index denoting the information-sharing regime. Denote by $p_i^k\left(\theta, p^k(\theta)\right)$ agent

A_i's best reply to the rival's equilibrium price $p^k(\theta|s_i)$ and by $\overline{p}_i^k$ be the list price chosen by P_i in regime k. The cap will not bind for all θ such that the agents' ideal price is lower than the list price — i.e.,

$$p_i^k\left(\theta, \mathbb{E}_{s-i}\left[p^k(\theta|s_i)\,|s_i=\varnothing\right]\right) \leq \overline{p}_i^k,$$

otherwise the constraint will be binding.

The equilibrium list price will therefore still be chosen to trade off flexibility and loss of control. Notice that, with a linear demand system (either Singh-Vives or Shubick-Levitan), the best-reply function $p_i^k\left(\theta, \mathbb{E}_{s-i}\left[p^k(\theta|s_i)\,|s_i=\varnothing\right]\right)$ will be increasing in θ since prices are strategic complements. Hence, there will exist a unique threshold $\theta^k \in (-\epsilon, \epsilon)$, solving $p^k(\theta, s_i=\varnothing) = \overline{p}^k$, such that the list price binds in equilibrium if and only if $\theta > \theta^k$, and not otherwise (see, e.g., also Martimort and Semenov, 2006, for a characterization of equilibria in these games).

7 Concluding remarks

In this paper we offered new insights into how competing principals delegate price authority to their privately informed agents and into how an information-sharing agreement between principals affects such decisions. Under the natural hypothesis that downstream agents are privately informed about demand conditions, but principals can learn this state of nature probabilistically, the equilibrium delegation form features binding list prices that prevent agents from passing on their distribution costs to consumers. When principals share their information about demand, agents are more likely to be granted price authority. By learning demand with greater probability, the agreement relaxes the trade-off between flexibility and loss of control, thereby making principals more willing to award agents with price authority. Hence, expected prices are lower with information sharing than without and profitable from the principals' point of view when distribution costs are neither too high nor too low and products are sufficiently differentiated. This suggests that the coexistence of information-sharing agreements, either about demand or price intentions, and list prices, intended to align upstream and downstream incentives, is not necessarily a symptom of consumer harm.

8 Appendix

Proof of Lemma 1. Suppose that an equilibrium with full delegation exists. First, it is immediate that this cannot be true if a principal is informed. Therefore, if such an equilibrium exists, it must be such that agents are granted full price authority only when principals are uninformed — i.e., either $s_i = \varnothing$ or $\sigma = \varnothing$ depending on the information sharing regime.

Suppose that principals do not share information. Let $p^D(\theta, s_{-i})$ denote the equilibrium candidate. If an equilibrium with full delegation exists, then A_i solves the following maximization problem in every state θ when it is granted price authority:

$$\max_{p_i \geq 0} \mathbb{E}_{s_{-i}} \left[D\left(\theta, p_i, p^D(\theta, s_{-i})\right)(p_i - c)\right],$$

whose first-order condition yields

$$p_i(\cdot) = \frac{c}{2} + \frac{a + \theta + d\mathbb{E}_{s_{-i}}\left[p^D(\theta, s_{-i})\right]}{2(1+d)} \qquad \forall \theta \in \Theta,$$

with

$$\mathbb{E}_{s_{-i}}\left[p^D(\theta, s_{-i})\right] \triangleq \alpha p^D(\theta, s_{-i} = 1) + (1-\alpha) p^D(\theta, s_{-i} = \varnothing).$$

Hence, in a symmetric equilibrium it must be

$$p^D(\theta, s_{-i} = \varnothing) = \frac{a + \theta + c(1+d) + d\alpha p^D(\theta, s_{-i} = 1)}{2 + d(1+\alpha)} \qquad \forall \theta \in \Theta.$$

An informed principal, instead, solves the following maximization problem

$$\max_{p_i \geq 0} \mathbb{E}_{s_{-i}} \left[D\left(\theta, p_i, p^D(\theta, s_{-i})\right) p_i\right],$$

whose first-order condition yields immediately

$$p^D(\theta, s_i = 1) = \frac{a + \theta + (1-\alpha) dp^D(\theta, s_{-i} = \varnothing)}{2(1+d) - \alpha d} \qquad \forall \theta \in \Theta,$$

In a symmetric equilibrium this yields

$$p^D(\theta, s_i = 1) = p^P(\theta) + \frac{d(1-\alpha)}{2(2+d)}c \qquad \forall \theta \in \Theta,$$

and

$$p^D(\theta, s_i = \varnothing) = p^P(\theta) + \frac{2(1+d) - d\alpha}{2(2+d)}c \qquad \forall \theta \in \Theta,$$

with $p^D(\theta, s_i = \varnothing) > p^D(\theta, s_i = 1)$.

Consider now a deviation from this candidate equilibrium by an uninformed principal (say P_i). Suppose, for example that it imposes a list price $\overline{p}_i$ binding in the high-demand state only. Then, this deviation would solve

$$\max_{\overline{p}_i \geq 0} \mathbb{E}_{s_{-i}} \left[D\left(\epsilon, \overline{p}_i, p^D\left(\epsilon, s_{-i}\right)\right) \overline{p}_i \right],$$

whose first-order condition immediately yields

$$\overline{p}_i = p^P\left(\epsilon\right) + \frac{d\left(1-\alpha\right)}{2\left(2+d\right)} c < p^D\left(\epsilon, s_i = \varnothing\right),$$

which shows that full delegation cannot be an equilibrium in the regime without information sharing.

Suppose now that principals share information. In this regime, it is straightforward to show that when principals are informed they set $p^P(\theta)$ for every $\theta \in \Theta$, while, in an equilibrium with full delegation agents would set

$$p^A\left(\theta\right) \triangleq p^P\left(\theta\right) + \frac{1+d}{2+d} c \qquad \forall \theta \in \Theta.$$

Consider the again a deviation by an uninformed principal (say P_i again). The deviation price cap solves

$$\max_{\overline{p}_i \geq 0} D\left(\epsilon, \overline{p}_i, p^A\left(\epsilon\right)\right) \overline{p}_i,$$

yielding

$$\overline{p}_i = p^P\left(\theta\right) + \frac{d}{2\left(2+d\right)} c < p^A\left(\epsilon\right),$$

which shows that full delegation cannot be an equilibrium with information sharing either. ■

Proof of Proposition 2. The equilibrium characterization follows immediately from the analysis developed in the text. The necessary condition for this equilibrium to exist is

$$0 \leq \overline{p}^M - p^N\left(-\epsilon, s_i = \varnothing\right) = \frac{2\epsilon}{2+d} - \frac{2+d\left(2-\alpha\right)}{2\left(2+d\right)} c \qquad \Leftrightarrow \qquad c \leq \overline{c}_N \triangleq \frac{4\epsilon}{2+d\left(2-\alpha\right)},$$

which concludes the proof. ■

Proof of Proposition 3. First, notice that

$$\hat{\pi}^N = \frac{\left(1+d\right)\left(2a + cd\left(1-\alpha\right)\right)^2}{4\left(2+d\right)^2},$$

and that

$$\pi^S\left(s_i = \varnothing\right) = \left(1+d\right)\left(\frac{a^2+\epsilon^2}{\left(2+d\right)^2} + \frac{\left(1-\alpha\right)\left(a-\epsilon\right)d}{\left(2+d\right)^2} c - \frac{\left(2+d\alpha\right)\left(2\left(1+d\right)-d\alpha\right)}{2\left(2+d\right)^2} c^2\right).$$

Taking the difference we have

$$\pi^S(s_i=\varnothing)-\hat{\pi}^N = (1+d)\frac{4\epsilon^2-4cd\epsilon(1-\alpha)+\left(d^2\alpha^2-2d^2\alpha-\left(d^2+8(1+d)\right)\right)c^2}{4(2+d)^2}\geq 0$$
$$\Leftrightarrow \qquad c\leq \underline{c}_N\triangleq\frac{2\epsilon}{d(1-\alpha)+(2+d)\sqrt{2}},$$

with

$$\overline{c}_N-\underline{c}_N=\frac{2\epsilon(2(2\sqrt{2}-1)+(2\sqrt{2}-\alpha)d)}{((1-\alpha)d+(2+d)\sqrt{2})(2+d(2-\alpha))}>0$$

Finally, following the logic of the proof of Lemma 1, showing that a deviation to full delegation is not profitable is immediate because in the high-demand state P_i has always an incentive to cap A_i's choice and that this cap is binding. ■

Proof of Proposition 4. The equilibrium characterization follows immediately from the analysis developed in the text. The necessary condition for this equilibrium to exist is

$$0\leq\overline{p}^M-p^S(-\epsilon,\sigma=\varnothing)=\frac{2\epsilon}{2+d}-\frac{1+d}{2+d}c \qquad\Leftrightarrow\qquad c\leq\overline{c}_S\triangleq\frac{2\epsilon}{1+d}.$$

Finally which concludes the proof. ■

Proof of Proposition 5. First, notice that the deviation profit is

$$\hat{\pi}^S=\frac{(1+d)(4a+cd)^2}{16(d+2)^2},$$

while the candidate equilibrium profit is

$$\pi^S(\sigma=\varnothing)=\frac{(1+d)\left(a^2+\epsilon^2\right)}{(2+d)^2}+\frac{d(a-\epsilon)(1+d)}{2(2+d)^2}c-\frac{(1+d)^2}{2(2+d)^2}c^2,$$

Comparing these expressions, we have

$$\pi^S(\sigma=\varnothing)-\hat{\pi}^S = (1+d)\frac{4\epsilon^2-\left(2d(4+d\alpha)+8d^2\left(1-\alpha^2\right)\right)c^2-4d\epsilon(1-\alpha)c}{4(2+d)^2}\geq 0$$
$$\Leftrightarrow \qquad c\leq\underline{c}_S\triangleq\frac{4(\sqrt{2}-1)\epsilon}{4-2\sqrt{2}+d},$$

with

$$\overline{c}_S-\underline{c}_S=\frac{2(3-2\sqrt{2})(2+d)\epsilon}{(d+2(2-\sqrt{2}))(d+1)}>0.$$

Finally, following the logic of the proof of Lemma 1, showing that a deviation to full delegation is not profitable is immediate because in the high-demand state P_i has always an incentive to cap A_i's choice and that this cap is binding. ■

Proof of Lemma 2. Taking the difference between $\underline{c}_N$ and $\underline{c}_S$ we have

$$\underline{c}_N - \underline{c}_S = -2\epsilon \frac{4 + d - 2\sqrt{2} - 2d\alpha(\sqrt{2} - 1)}{(4 - 2\sqrt{2} + d)(d\,(1 - \alpha) + (2 + d)\,\sqrt{2})},$$

which is negative since

$$4 + d - 2\sqrt{2} - 2d\alpha(\sqrt{2} - 1) \geq 4 + d - 2\sqrt{2} - 2d(\sqrt{2} - 1) > 0. \qquad \blacksquare$$

Proof of Proposition 3. Taking the difference between expected prices we have

$$p^N - p^S = \frac{\alpha\,(1 - \alpha)\,(2 + 3d)}{4\,(2 + d)} c,$$

which yields immediately the result. $\blacksquare$

Proof of Proposition 6. Assume $c < \underline{c}_N$ so that in both information-sharing regimes there a symmetric equilibrium with partial delegation exists. Substituting the equilibrium values into expected profits (from an ex ante standpoint) and taking the difference we obtain

$$\Delta\pi \triangleq \pi^S - \pi^N = \frac{c\alpha\,(1 - \alpha)\left[(4\,(1 + d)^2 + d^2\alpha\,(1 + d\alpha))c - 2d\,(3d + 2)\,(a - \epsilon)\right]}{8\,(2 + d)^2}.$$

This expression is zero when $c = 0$ and/or when $\alpha \in \{0, 1\}$. When none of these cases is verified, solving $\Delta\pi = 0$ with respect to c we have

$$\Delta\pi \geq 0 \quad \Leftrightarrow \quad c \geq c^\star \triangleq \frac{2d\,(2 + 3d)\,(a - \epsilon)}{4\,(1 + d)^2 + \alpha d^2\,(1 + \alpha d)}.$$

Notice that $\lim_{d \to 0} c^\star = 0$ while

$$\lim_{d \to 0} \underline{c}_N = \frac{\epsilon}{\sqrt{2}} > 0.$$

Hence, there exists a $\overline{d} > 0$ such that for $d < \overline{d}$ not too large $c^\star < \underline{c}_N$ and $\Delta\pi \geq 0$ if and only if $c \in [c^\star, \underline{c}_N)$, which concludes the proof. $\blacksquare$

Proof of Corollary 1. The proof follows immediately from taking the difference $r^N - r^S$. $\blacksquare$

Proof of Proposition 7. Substituting the equilibrium values into expected profits (from an ex ante standpoint) and taking the difference between expected profits with and without information sharing we obtain

$$\pi^S - \hat{\pi}^N = \frac{(1 + d)\,(1 - \alpha)\left(4\,(1 + 2d) + d^2\,(4 - \alpha)\right)}{(2 + d)^2\,(2\,(1 + d) - d\alpha)^2}\epsilon^2 + \frac{(1 - \alpha)^2\,(1 + d)\,(d\,(a - c - \epsilon) - c)}{2\,(2 + d)^2} c.$$

Notice that for $d \geq d^{\star} \triangleq \frac{c}{a-c-\epsilon}$ this expression is certainly positive. Suppose then that $d < d^{\star}$. Solving for ϵ, we have $\pi^{S} \leq \hat{\pi}^{N}$ if and only if

$$\epsilon \leq \epsilon^{\star} \triangleq \sqrt{\frac{(1-\alpha)^{2}(1+d)(c-d(a-c-\epsilon))(2(1+d)-d\alpha)^{2}}{2(1+d)(1-\alpha)(4(1+2d)+d^{2}(4-\alpha))}}c,$$

which proves the result. ■

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