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Upstream conduct and price authority with competing organizations

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Abstract

We characterize the degree of price authority that competing upstream principals award their downstream agents in a setting where these agents own private information about demand and incur nonverifiable distribution costs. Principals cannot internalize these costs through monetary incentives and design "permission sets" from which agents choose prices. The objective is to understand the forces shaping delegation and the constraints imposed on equilibrium prices. When principals behave noncooperatively, agents are biased toward excessively high prices because they pass on distribution costs to consumers. Hence, the permission set only features a price cap that is more likely to bind as products become closer substitutes, in sectors where distribution is sufficiently costly, and when demand is not too volatile. By contrast, when principals behave cooperatively, the optimal delegation scheme is richer and more complex. Because principals want to charge the monopoly price, the optimal permission set features a price floor when the distribution cost is sufficiently low, it features instead full discretion for moderate values of this cost, and only when it is high enough, a price cap is optimal. Surprisingly, while competition (as captured by stronger product substitutability) hinders delegation in the noncooperative regime, the opposite occurs when principals maximize industry profit.

1 | INTRODUCTION

Upstream principals (manufacturers or upstream suppliers) often delegate authority to their downstream agents (retailers or local distributors), who possess market knowledge critical for local pricing decisions (Joseph, 2001; Lai, 1986). Yet, the preferences of these agents do not always align with the objectives of their principals. As a result, they may exploit their informational advantage to abuse discretion and make choices suboptimal from the principals' standpoint. This misalignment of preferences gives rise to the so-called "delegation dilemma": giving up authority to gain flexibility or retain price control and implement rigid rules unresponsive to local market conditions?

The positive relationship between price delegation and firm performance has been documented in several prominent industries, with this link becoming stronger as market uncertainty and information asymmetry increase (see, e.g., Frenzen et al., 2010; Homburg et al., 2012; and Phillips et al., 2015, among others). Yet, the evidence on the relationship between competition and delegation is far from conclusive. While Acemoglu et al. (2007) and Bloom et al. (2009) document a positive correlation between competition and delegation, Marin and Verdier (2008) report evidence from Germany and Austria that firms tend to centralize decisions when competition intensifies.

What are the determinants of price delegation in competitive environments? How does this form of delegation depend on the principals' conduct in the upstream market? What types of constraints does it require? What managerial and policy lessons can be learned from the endogenous link between product market competition, upstream conduct, and price delegation?

To answer these questions, we follow Melumad and Shibano (1991) and apply the idea of constrained delegation to a framework where the principals of two competing vertical organizations (supply chains) grant price discretion to their exclusive agents, who are privately informed about an aggregate demand shock. To introduce a simple wedge between upstream and downstream objectives, we assume that agents incur a nonverifiable distribution cost to finalize a sale. These nonverifiable costs, together with agents' private information, create a natural misalignment of preferences. That is, agents are incentivized to pass on these costs to consumers and, therefore, charge excessive prices compared to what upstream competition mandates (a logic reminiscent of the double marginalization phenomenon).

This scenario is common in several prominent industries where multinational corporations centralize production and sell their products in many parts of the world (e.g., automotive, trucks, aerospace, digital devices, etc.). In these sectors, consumer prices in each location may have country-specific components (common to all distributors competing in a specific market) and product-specific distribution costs that may be difficult to estimate at the upstream level (see, e.g., Goldberg & Verboven, for evidence of local marginal cost components for car prices).[1]

Within this setting, we characterize the equilibrium permission set from which agents are entitled to choose prices, determine what constraints (if any) principals impose on their pricing choices, and examine how these constraints respond to industry characteristics such as product substitutability and demand uncertainty. We consider two alternative decision-making regimes. In the first regime, principals choose the permission set granted to their agents noncooperatively—that is, each principal maximizes her profit for given expectations about the rival's behavior. In the second regime, principals maximize industry profit—for example, because they agree on a code of conduct constraining pricing discretion on an industry-wide basis, merge into a single multiproduct monopolist delegating every product line to an agent, or form a cartel with the deliberate scope of harmonizing pricing decisions.

In the noncooperative regime, we show that agents are biased toward excessively high prices compared to the price their principals would choose in a noncooperative equilibrium of the hypothetical scenario where they can observe demand. The reason is that the pricing choices of these agents reflect their distribution cost, thereby creating a pass-through that lowers sales and hurts principals (as well as consumers). Hence, in the noncooperative regime, the equilibrium permission set only requires a price cap (or, equivalently, a list price) that limits from above the set of prices that agents can charge to final consumers to avoid that they appropriate excessive margins when demand conditions are favorable. Moreover, we show that the equilibrium price cap is more likely to bind when products are relatively closer substitutes and in sectors where distribution costs are sufficiently high. Instead, the price cap is less likely to bind in industries featuring higher demand volatility.

These findings are broadly consistent with customized pricing with discretion (see, e.g., Phillips, 2021), a practice that appears to be widespread in several 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.). However, downstream agents are allowed further discretion to negotiate rebates with customers off the list price set in advance upstream.

In the cooperative regime, which is the most interesting and novel aspect of our analysis, the optimal permission set features a richer and more complex structure than in the noncooperative regime: a counterbalancing force shapes the conflict of interest between principals and agents. The reason is that industry profit maximization (or firms' attempts to coordinate prices) requires prices to increase to the monopoly level. As a result, a moderate distribution cost may, ceteris paribus, align incentives within the competing organizations. The optimal permission set features a price floor rather than a list price when the distribution cost is sufficiently low. It features complete discretion for moderate values of this cost. Only when it is large enough it features a price cap. Furthermore, the region of parameters in which agents are granted full pricing discretion expands when demand is more uncertain and when the market becomes more competitive, as implied by greater product substitutability. Interestingly, these findings question the traditional view that upstream coordination is associated with tighter vertical price control and suggest that principals' cooperative conduct may partly explain observed patterns of price delegation rather than individual decision-making behavior.

Summing up, in addition to showing that collusion in the upstream market does not necessarily require price caps and may well be consistent with full delegation, another key message of our analysis is that the impact of competition on delegation depends, among other things, on the conduct of principals in the upstream market. The evidence of a negative relationship between competition and delegation offered by Marin and Verdier (2008) aligns with the noncooperative conduct of principals in the upstream market. Yet, the evidence of a positive relationship between competition and delegation offered by Acemoglu et al. (2007) and Bloom et al. (2009) is consistent with the results obtained in the cooperative regime. Therefore, controlling for principals' conduct in the upstream market when investigating the link between competition and delegation empirically might be essential in obtaining estimates more aligned to economic theory.

The rest of the paper is organized as follows. Section 2 lays down the model. In Section 3, we characterize the benchmark with informed principals. Section 4 characterizes the equilibrium permission set under each decision-making regime. In Section 5, we highlight the robustness and limitations of the baseline model. In Section 6, we summarize the connections between our model and the existing literature. Section 7 concludes. Proofs are in the appendix. Further material is available in the online appendix.

2 | THE MODEL

2.1 | Environment

Consider two competing organizations, each ruled by an upstream principal (female), manufacturing differentiated products that are distributed to final consumers by their exclusive downstream agents (male).[2] There is a single (representative) consumer whose preferences are described by a quadratic utility function à la Singh and Vives (1984)

$$U(\cdot) \triangleq (1+\theta)\sum_{i=1}^{2} q_i - \frac{1}{2}\sum_{i=1}^{2} q_i^2 - \gamma q_1 q_2 - \sum_{i=1}^{2} p_i q_i + I, \tag{1}$$

where $q_i \geq 0$ is firm-i's output and, as standard, $I \geq 0$ is the representative consumer's income. The parameter θ is uniformly distributed over the support $\Theta \triangleq [-\sigma, \sigma]$ and captures the consumer's stochastic willingness to pay for the products available in the market, with σ being its volatility. Agents, each denoted by A_i (with $i = 1, 2$), observe θ and condition their pricing decisions (if they are entitled to do so) on its realization (Joseph, 2001; Lai, 1986; Mishra & Prasad, 2004). Principals, each denoted by P_i (with $i = 1, 2$), are uninformed about θ. The parameter $\gamma \in [0, 1)$ is an inverse measure of the degree of differentiation between products: the larger γ, the more homogenous (less differentiated) products are.

Differentiating (1) with respect to outputs and inverting the implied system of first-order conditions, we obtain the following downward sloping demand functions

$$q_i = D_i(\theta, p_i, p_{-i}) \triangleq \frac{(1-\gamma)(1+\theta) - p_i + \gamma p_j}{(1-\gamma)(1+\gamma)}, \forall i = 1, 2. \tag{2}$$

Technologies are linear and are described below.

2.2 | Decision-making regimes

We examine and compare two alternative decision-making regimes:

(a) A *noncooperative* regime, in which principals maximize their own profit;
(b) A *cooperative* regime, in which principals maximize their joint profits.

The noncooperative regime reflects the standard case in which principals behave competitively and independently. The cooperative regime has several different interpretations and can be seen as: (i) an alliance according to which principals collectively agree on a code of conduct constraining their downstream pricing decisions (Rey & Tirole, 2019);

(ii) an upstream cartel coordinating the price restrictions imposed to the downstream agents; (iii) a multiproduct monopolist (say resulting from a merger) that delegates the distribution of each product line to a self-interested agent (representative).

Following the vertical contracting literature, we assume that downstream agents behave noncooperatively irrespective of the conduct of their principals.[3] A classical explanation for such an hypothesis is that downstream agents are more myopic than their upstream principals. In the online appendix, we discuss how results change when this hypothesis is relaxed. In particular, we argue that the case where principals behave noncooperatively while agents cooperate is equivalent to a common agency framework.

2.3 | Interval delegation, conflict of interest, and payoffs

To focus exclusively on the delegation aspect and its implications, we rule out monetary incentives—that is, frictions such as limited enforcement or high costs of writing complete contracts prevent principals from fully internalizing the downstream profits through appropriate monetary incentives.[4] In Section 5 we discuss the role of monetary incentives. We assume that while P_i maximizes sale profit

$$\pi_i(\cdot) \triangleq D_i(\cdot)p_i, \quad \forall i = 1, 2,$$

with technologies being linear and marginal costs normalized to zero, A_i's objective function is

$$u_i(\cdot) \triangleq \pi_i(\cdot) - cD_i(\cdot) = D_i(\cdot)(p_i - c), \quad \forall i = 1, 2. \tag{3}$$

The parameter $c \geq 0$ plays a key role in the analysis since it 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. It can be interpreted as the distribution cost that an agent incurs to finalize a sale. This cost is assumed to be nonverifiable in Court. For example, when multinational corporations with centralized production sell their products in many parts of the world, consumer prices in each location are likely to be determined by country- and product-specific components (e.g., distribution costs common to all producers competing in a specific market) that may be difficult to estimate at the upstream level since the (local) competitive environment may differ across countries or regions (in Section 5 we discuss the role of asymmetries in distribution costs).[5]

Since monetary transfers contingent on this parameter cannot be enforced–see, for example, also Green and Laffont (1994) and Aghion and Tirole (1994)[6]—P_i can only limit A_i's discretion by determining the permission set $\mathcal{P}_i$ within which A_i must choose his price p_i. We restrict attention to equilibria in pure strategies and focus, without loss of generality, on interval delegation equilibria. That is, we look for pure strategy equilibria in which every principal P_i offers a (connected) permission set $\mathcal{P}_i \triangleq [\underline{p}_i, \overline{p}_i]$, with $\overline{p}_i \geq \underline{p}_i \geq 0$.[7] The width of this segment represents a measure of the price authority delegated to A_i. The upper bound of the permission set can be interpreted as a price cap, while the lower bound is a price floor that determines the maximal rebate that agents can offer to consumers. In the cooperative regime, we assume that principals are able to coordinate on a single permission set $\mathcal{P} \triangleq [\underline{p}, \overline{p}]$, so that both agents face the same constraint.[8]

2.4 | Timing

Within each decision-making regime, the timing of the game is as follows:

1. Principals choose permission sets;
2. The demand shock θ realizes, and agents choose prices simultaneously and noncooperatively given their permission sets;
3. Demand is allocated between products. Profits are made.

2.5 | Equilibrium concept

The equilibrium concept is Perfect Bayesian Equilibrium. In the noncooperative regime we impose the refinement of "passive beliefs," which is the one most widely used in the vertical contracting literature (Hart & Tirole, 1990; McAfee & Schwartz, 1994; Rey & Tirole, 2007). With passive beliefs, an agent's conjecture about the permission sets offered to the rival 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 & Tirole, 1991, ch. 8). In the cooperative regime, both agents receive the same permission set. Hence, out of equilibrium beliefs require that each agent uses best replies to the permission set chosen by the principals' coalition and to his expectation about the rival's pricing behavior.

2.6 | Technical assumptions

We impose the following parametric restrictions.

A Demand is not too dispersed and c is not too large—that is, $\sigma \leq \frac{1}{2}$ and

$$c \leq \min\{1-\gamma, 1-\sigma\}.$$

This assumption guarantees that, in equilibrium, demand for both products is positive and that agents make a positive profit in every state θ.

3 | THE BENCHMARK OF INFORMED PRINCIPALS

To gain insights into the forces driving the equilibrium characterization with uninformed principals, it is helpful to briefly describe the case of informed principals, who can force a price contingent on the demand state.

3.1 | Noncooperative behavior

In the noncooperative regime, every principal P_i $(i = 1, 2)$ solves

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

It is immediate to show that the game has a unique Nash equilibrium in which each principal charges

$$p^N(\theta) \triangleq \frac{(1-\gamma)(1+\theta)}{2-\gamma}, \quad \forall \theta \in \Theta. \tag{4}$$

As expected, this price rises with consumers' willingness to pay (θ) and decreases with the degree of product substitutability (γ).

3.2 | Cooperative behavior

When principals maximize industry profit, they solve

$$\max_{(p_1,p_2)\in\Re_+^2} \sum_{i=1}^{2} D_i(\theta, p_i, p_{-i})p_i.$$

The solution of this problem yields the monopoly price

$$p^M(\theta) \triangleq \frac{1+\theta}{2}, \quad \forall\theta \in \Theta,$$

with

$$\Delta p(\theta) \triangleq p^M(\theta) - p^N(\theta) = \frac{\gamma}{2-\gamma} p^M(\theta) \geq 0, \quad \forall\theta \in \Theta.$$

Hence, with informed principals, prices are higher in the cooperative regime than in the noncooperative regime. The difference $\Delta p(\theta)$ between the monopoly and the competitive price is increasing in θ: the monopoly price is relatively more responsive to consumers' willingness to pay than the competitive price.

4 | UNINFORMED PRINCIPALS

We can now turn to examine the case of uninformed principals. We first characterize the equilibrium in the noncooperative regime and then turn to determine the permission set that maximizes the sum of the principals' profit.

4.1 | Noncooperative regime

Consider a candidate (symmetric) equilibrium in which principals choose the same permission set $\mathcal{P}^\star \triangleq [\underline{p}^\star, \overline{p}^\star]$, with $\underline{p}^\star \leq \overline{p}^\star$. Let

$$D_i(\theta, p_i, p^\star(\theta)) \triangleq \frac{(1-\gamma)(1+\theta) - p_i + \gamma p^\star(\theta)}{(1-\gamma)(1+\gamma)},$$

be A_i's demand when his rival faces $\mathcal{P}^\star$ and charges the state-contingent equilibrium price $p^\star(\theta) \in \mathcal{P}^\star$. When deciding which price to charge, A_i's unconstrained maximization problem is therefore

$$\max_{p_i \geq 0} D_i(\theta, p_i, p^\star(\theta))(p_i - c), \tag{5}$$

whose first-order condition yields a best-reply function

$$p_i(\theta, p^\star(\theta)) \triangleq \frac{c}{2} + \frac{(1-\gamma)(1+\theta) + \gamma p^\star(\theta)}{2}, \quad \forall\theta \in \Theta. \tag{6}$$

As expected, this function is increasing in the price $p^\star(\theta)$ that A_i expects the rival to charge, and is increasing in c since (other things being equal) A_i will partly pass on his distribution cost c to consumers. The next lemma then follows directly from (6).

Lemma 1. *Consider a demand state θ (if it exists) in which agents' pricing decisions are not constrained by the permission sets chosen by their principals. In this demand state, the equilibrium price must be*

$$\hat{p}(\theta) = \underbrace{p^N(\theta)}_{P_i\text{'s ideal point}} + \underbrace{\frac{c}{2-\gamma}}_{A_i\text{'s bias (pass-through)}}. \tag{7}$$

Moreover, assumption **A** *guarantees that demand is always positive when both agents charge $\hat{p}(\theta)$—that is, $D_i(\theta, \hat{p}(\theta), \hat{p}(\theta)) \geq 0$ for every θ and i—and that agents do not make losses—that is, $D_i(\theta, \hat{p}(\theta), \hat{p}(\theta))(\hat{p}(\theta) - c) \geq 0$ for every θ and i.*

This result shows that when agents are free to choose prices according to their preferences, the prevailing equilibrium price exceeds the principals' ideal point. This means that there is a misalignment of preferences between principals and agents measured by the bias

$$b^\star \triangleq \frac{c}{2-\gamma}.$$

Essentially, $b^\star$ corresponds to the pass-through that agents impose on consumers when principals do not restrict their choices. Interestingly, $b^\star$ is increasing in γ. Hence, ceteris paribus, intensified competition (as measured by greater product substitutability) exacerbates the agency conflict within the competing organizations. The intuition is as follows. When products become closer substitutes, each principal would like to reduce her price to avoid losing business to the rival. On the contrary, agents have a stronger incentive to pass on their distribution costs to consumers to protect their profit margins. This suggests that in more competitive environments delegation becomes harder to sustain.

Using the fact that the ideal point $\hat{p}(\theta)$ is increasing in θ, we can derive a few important properties of the equilibrium of the game. Given the (candidate) equilibrium permission set $\mathcal{P}^\star \subseteq [\hat{p}(-\sigma), \hat{p}(\sigma)]$, there exist two thresholds, $\bar{\theta}^\star$ and $\underline{\theta}^\star$, such that $\bar{\theta}^\star \triangleq \hat{p}^{-1}(\bar{p}^\star) > \underline{\theta}^\star \triangleq \hat{p}^{-1}(\underline{p}^\star)$. Hence, provided $\mathcal{P}^\star$ is an equilibrium of the game, the prevailing market price has the following step-wise shape

$$p^\star(\theta) \triangleq \begin{cases} \bar{p}^\star & \text{if } \theta \geq \bar{\theta}^\star, \\ \hat{p}(\theta) & \text{if } \theta \in [\underline{\theta}^\star, \bar{\theta}^\star], \\ \underline{p}^\star & \text{if } \theta \leq \underline{\theta}^\star, \end{cases}$$

with $p^\star(\theta)$ being (weakly) increasing in θ. We can then show the following result.

Lemma 2. *A_i's best-reply function $p_i(\theta, p^\star(\theta))$ is increasing in θ. For any nonempty permission set $\mathcal{P}_i \subseteq [\hat{p}(-\sigma), \hat{p}(\sigma)]$ chosen by P_i, the solution of A_i's constrained maximization problem*[9] *is*

$$\tilde{p}_i(\theta, p^\star(\theta)|\mathcal{P}_i) \triangleq \begin{cases} \bar{p}_i & \text{if } \theta \geq \bar{\theta}_i, \\ p_i(\theta, p^\star(\theta)) & \text{if } \theta \in (\underline{\theta}_i, \bar{\theta}_i), \\ \underline{p}_i & \text{if } \theta \leq \underline{\theta}_i. \end{cases}$$

The threshold $\bar{\theta}_i$ solves $\bar{p}_i = p_i(\theta, p^\star(\theta))$ while $\underline{\theta}_i$ solves $\underline{p}_i = p_i(\theta, p^\star(\theta))$, with $\bar{\theta}_i \geq \underline{\theta}_i$.

When conjecturing that the rival plays according to his equilibrium strategy, A_i chooses a price, that is, increasing in θ irrespective of the permission set $\mathcal{P}_i$ chosen by P_i. It then follows immediately that the best-reply function $p_i(\theta, p^\star(\theta))$ must hit the constraints imposed by $\mathcal{P}_i$ when demand is sufficiently low (i.e., in this case, the floor $\underline{p}_i$ binds) and when it is high enough (i.e., in this case, the price cap $\bar{p}_i$ binds).

Clearly, given A_i's best response to $\mathcal{P}_i$ and the rival's equilibrium behavior, P_i conforms to the prescribed equilibrium if and only if the maximization of her expected profit requires $\bar{\theta}_i = \bar{\theta}^\star$ and $\underline{\theta}_i = \underline{\theta}^\star$ (so that $\mathcal{P}_i = \mathcal{P}^\star$). Assuming interior solutions and operating a simple change of variables to optimize with respect to $\underline{\theta}_i$ and $\bar{\theta}_i$ rather than over the boundaries $\underline{p}_i$ and $\bar{p}_i$ of $\mathcal{P}_i$, it is immediate to show that P_i's maximization problem is

$$\max_{(\underline{\theta}_i,\bar{\theta}_i)\in\Theta^2} \int_{-\sigma}^{\sigma} D_i(\theta, \tilde{p}_i(\theta, p^\star(\theta)|\mathcal{P}_i), p^\star(\theta))\tilde{p}_i(\theta, p^\star(\theta)|\mathcal{P}_i)\frac{d\theta}{2\sigma},$$

subject to $\bar{\theta}_i \geq \underline{\theta}_i$, with

$$\int_{-\sigma}^{\sigma} D_i(\theta, \tilde{p}_i(\theta, p^\star(\theta)|\mathcal{P}_i), p^\star(\theta))\tilde{p}_i(\theta, p^\star(\theta)|\mathcal{P}_i)\frac{d\theta}{2\sigma} \triangleq \underbrace{\int_{-\sigma}^{\underline{\theta}_i} D_i(\theta, \hat{p}(\underline{\theta}_i), p^\star(\theta))\hat{p}(\underline{\theta}_i)\frac{d\theta}{2\sigma}}_{\text{Binding price floor}}$$
$$+\underbrace{\int_{\underline{\theta}_i}^{\bar{\theta}_i} D_i(\theta, p_i(\theta, p^\star(\theta)), p^\star(\theta))p_i(\theta, p^\star(\theta))\frac{d\theta}{2\sigma}}_{A_i \text{ is delegated pricing authority}} + \underbrace{\int_{\bar{\theta}_i}^{\sigma} D_i(\theta, \hat{p}(\bar{\theta}_i), p^\star(\theta))\hat{p}(\bar{\theta}_i)\frac{d\theta}{2\sigma}}_{\text{Binding price cap}}.$$

Solving this problem (see the appendix) we can then show the following result.

Proposition 1. *When principals behave noncooperatively, the game admits a unique symmetric equilibrium featuring partial delegation if and only if* $c \leq c^\star \triangleq \sigma(1-\gamma)$. *In this equilibrium both principals choose the same permission set* $P^\star$ *such that*

$$\hat{p}(\sigma) > \bar{p}^\star \triangleq \hat{p}(\bar{\theta}^\star) > \underline{p}^\star \triangleq \hat{p}(-\sigma),$$

with

$$\bar{\theta}^\star \triangleq \hat{p}^{-1}(\bar{p}^\star) = \sigma - \frac{2c}{1-\gamma}.$$

Moreover, $\bar{p}^\star$ *and* $\bar{\theta}^\star$ *are decreasing in* c *and* γ, *and increasing in* σ. *Otherwise—that is, for* $c > c^\star$*—a symmetric equilibrium can only feature pooling with both principals choosing a fixed price* $p^\star \triangleq \mathbb{E}[p^N(\theta)]$.

This proposition shows that if partial delegation occurs at equilibrium, it must feature a price cap but not a price floor. The reason is that, with full delegation, agents would always choose an excessive price compared to what competition between informed principals would mandate. Two contrasting forces shape the equilibrium price cap. On the one hand, reducing agents' discretion is costly to principals because they would like to tailor the price to demand fluctuations. On the other hand, granting discretion to the agents is equivalent to allow an excessive pass-through, which lowers sale volumes and thus harms principals. Figure 1 illustrates the equilibrium permission set: the

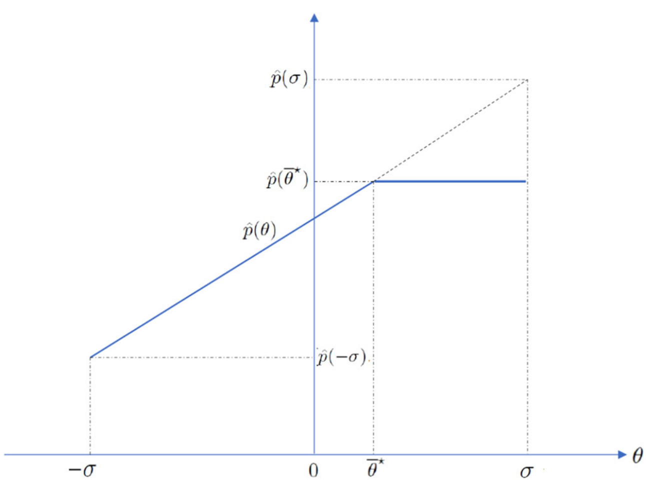


FIGURE 1 Equilibrium permission set in the noncooperative regime. [Color figure can be viewed at wileyonlinelibrary.com]

horizontal blue line corresponds to the price cap, while the increasing blue line corresponds to the agents' ideal point $\hat{p}(\theta)$.

As intuition suggests, the equilibrium price cap $\bar{p}^\star$ is decreasing in c. The higher the unverifiable distribution cost, the stronger the conflict of interest within each organization. As a result, the more binding the list price will be. The reason why $\bar{p}^\star$ is decreasing in γ is as follows: when products become closer substitutes, agents will tend to pass on their costs to consumers to protect their (profit) margins from intensified competition—that is, the pass-through increases with γ. Therefore, delegation becomes less attractive from the principals' point of view in more competitive environments.

4.2 | Comparative statics and the determinants of delegation

To understand how the model's parameters affect the amount of discretion (authority) granted to the agents in equilibrium, it is useful to determine the probability with which the (equilibrium) price cap does not bind—that is,

$$\Pr[\theta \leq \bar{\theta}^\star] = \frac{\bar{\theta}^\star + \sigma}{2\sigma} = 1 - \frac{c}{\sigma(1-\gamma)}.$$

Notice that, with a uniform distribution, the probability that an agent is allowed to pick his ideal price and the width of the range of θ in which this event occurs are two equivalent metrics of price discretion. Differentiating $\Pr[\theta \leq \bar{\theta}^\star]$ with respect to the model's parameters, it can be immediately seen that that this probability is increasing in σ and decreasing in γ and c.

Hence, other things being equal, agents are granted more price authority when products are more differentiated (lower γ) and if distribution costs are not too high (low c). By contrast, they are less likely to be awarded price authority in industries with low demand volatility (low σ). The intuition is as follows. Fiercer competition, as reflected by increased product substitutability, raises the pass-through, exacerbating the conflict of interest within each principal-agent pair. Low demand volatility makes it easier for principals to control their agents' behavior with rigid pricing rules because the gain from flexibility decreases with σ. Of course, the higher the distribution cost, the more severe the conflict of interest between principals and agents because this exacerbates the negative effect of the pass-through on the volume of sales.

4.3 | Cooperative regime

Consider now the decision-making regime in which principals behave cooperatively. Hence, while agents still play noncooperatively (they choose prices to maximize individual profits net of the distribution cost) the permission set that each of them faces maximizes expected industry profits (in Section 5 we discuss how results would change when agents also behave cooperatively).

The coalition of principals solves

$$\max_{\mathcal{P}} \int_{-\sigma}^{\sigma} \sum_{i=1}^{2} \pi_i(\cdot) \frac{d\theta}{2\sigma} \triangleq \max_{\mathcal{P}} \int_{-\sigma}^{\sigma} \sum_{i=1}^{2} D_i(\cdot) p_i \frac{d\theta}{2\sigma},$$

while A_i's unrestricted maximization problem is

$$\max_{p_i \geq 0} D_i(\theta, p_i, p(\theta|\mathcal{P}))(p_i - c),$$

where $p(\theta|\mathcal{P})$ denotes the price that A_i expects his rival to charge in state θ given the common permission set $\mathcal{P}$. The solution of this problem yields the same best-reply function as before—that is,

$$p_i(\theta, p(\theta|\mathcal{P})) \triangleq \frac{c}{2} + \frac{(1-\gamma)(1+\theta) + \gamma p(\theta|\mathcal{P})}{2}, \quad \forall \theta \in \Theta.$$

Thus, in any demand state θ where agents' choices are not restricted by $\mathcal{P}$, the prevailing market price is again $\hat{p}(\theta)$ stated in Equation (7).[10]

To gain insights on the structure of the optimal permission set in the cooperative regime, it is useful to construct a measure of the agents' bias for this regime—that is,

$$b^{\star\star}(\theta) \triangleq \hat{p}(\theta) - p^M(\theta) = b^\star - \Delta p(\theta), \quad \forall \theta \in \Theta.$$

This bias reflects two opposite forces. On the one hand, since agents have an incentive to mark up their distribution cost, there is an incentive to price above the monopoly price, which calls for introducing an endogenous price cap, as explained in the noncooperative regime. On the other hand, when principals cooperate, they would like to increase prices above the noncooperative level to soften competition. Hence, other things being equal, agents set a too low price compared to what principals would want, thereby calling for introducing a price floor. This second effect is zero when products are sufficiently independent—that is, when γ is close to zero—and becomes stronger as products become closer substitutes—that is, when γ increases. Moreover, in contrast to the noncooperative regime, this effect depends on the state of nature θ: the higher consumers' willingness to pay, the wider the wedge between the monopoly and the noncooperative price. As a result, for higher values of θ, agents are more biased toward excessively low prices in the cooperative regime.

We can thus state the following useful lemma.

Lemma 3. *The bias $b^{\star\star}(\theta)$ is decreasing in θ. Moreover, there exist two thresholds $\underline{c}$ and $\bar{c}$, with*

$$\underline{c} \triangleq \frac{\gamma(1-\sigma)}{2} < \bar{c} \triangleq \frac{\gamma(1+\sigma)}{2},$$

such that:

- *If $c \leq \underline{c}$, then $\hat{p}(\theta) \leq p^M(\theta)$ for every $\theta \in \Theta$;*
- *If $c \in (\underline{c}, \bar{c})$, there exits a unique demand state*

$$\hat{\theta} \triangleq \frac{2c}{\gamma} - 1 \in (-\sigma, \sigma),$$

such that $\hat{p}(\theta) \geq p^M(\theta)$ if and only if $\theta \leq \hat{\theta}$;
- *If $c \geq \bar{c}$, then $\hat{p}(\theta) \geq p^M(\theta)$ for every $\theta \in \Theta$.*

This result shows that the structure of the optimal permission set in the cooperative regime will be different and richer than in the noncooperative regime. The reason is as follows. When c is sufficiently low, if agents can set prices without any restriction, they would charge a price that is too low compared to what the coalition of their principals would want. Hence, the optimal permission set features a price floor and potentially converges to a singleton (pooling) price (as we will argue below). By contrast, when c is sufficiently large, the agent's ideal point exceeds the principals' one, so that the optimal permission set may still feature a price cap. Clearly, when c takes intermediate values, since $b^{\star\star}(\theta)$ is decreasing in θ, agents would like to price below the principals' ideal point when θ is sufficiently large, and above otherwise.

Since $\hat{p}(\theta)$ is increasing in θ and both agents face the same permission set, for every nonempty $\mathcal{P}$, we can define $\bar{\theta} \triangleq \hat{p}^{-1}(\bar{p}) > \underline{\theta} \triangleq \hat{p}^{-1}(\underline{p})$. Thus, in the cooperative regime, the equilibrium price schedule induced by $\mathcal{P}$ must have the following step-wise shape

$$p(\theta|\mathcal{P}) \triangleq \begin{cases} \bar{p} & \text{if } \theta \geq \bar{\theta}, \\ \hat{p}(\theta) & \text{if } \theta \in [\underline{\theta}, \bar{\theta}], \\ \underline{p} & \text{if } \theta \leq \underline{\theta}. \end{cases}$$

Assuming interior solutions—that is, $\mathcal{P} \subset [\hat{p}(-\sigma), \hat{p}(\sigma)]$—which we will check ex post, and operating a simple change of variables to optimize over $\underline{\theta}$ and $\bar{\theta}$ rather than on the boundaries $\underline{p}$ and $\bar{p}$ of $\mathcal{P}$, the maximization problem solved by the principals' coalition is

$$\max_{(\underline{\theta},\bar{\theta})\in\Theta^2} \sum_{i=1}^{2} \int_{-\sigma}^{\sigma} D_i(\theta, p(\theta|\mathcal{P}), p(\theta|\mathcal{P}))p(\theta|\mathcal{P})\frac{d\theta}{2\sigma}, \tag{8}$$

subject to $\bar{\theta} \geq \underline{\theta}$, where

$$\int_{-\sigma}^{\sigma} D_i(\theta, p(\theta|\mathcal{P}), p(\theta|\mathcal{P}))p(\theta|\mathcal{P})\frac{d\theta}{2\sigma} \triangleq \underbrace{\int_{-\sigma}^{\underline{\theta}} D_i(\theta, \hat{p}(\underline{\theta}), \hat{p}(\underline{\theta}))\hat{p}(\underline{\theta})\frac{d\theta}{2\sigma}}_{\text{Binding floor}}$$

$$+\underbrace{\int_{\underline{\theta}}^{\bar{\theta}} D_i(\theta, \hat{p}(\theta), \hat{p}(\theta))\hat{p}(\theta)\frac{d\theta}{2\sigma}}_{\text{Agents are delegated pricing authority}} + \underbrace{\int_{\bar{\theta}}^{\sigma} D_i(\theta, \hat{p}(\bar{\theta}), \hat{p}(\bar{\theta}))\hat{p}(\bar{\theta})\frac{d\theta}{2\sigma}}_{\text{Binding list price}}, \quad \forall i = 1, 2.$$

The difference with the noncooperative regime is that the coalition of principals internalizes the impact of each product's price on the demand of the other product: a competition-softening effect.

Solving this problem (see the appendix) we can then show the following.

Proposition 2. *The permission set $\mathcal{P}^{\star\star}$ that maximizes principals' joint profits has the following features:*

(i) *Suppose that $\gamma \leq \frac{2}{3}$. Then, there exist two thresholds, $\underline{c}^-$ and $\bar{c}^+$, with*

$$\underline{c}^- \triangleq \underline{c} - \frac{\sigma(2-3\gamma)}{2} < \bar{c}^+ \triangleq \bar{c} + \frac{\sigma(2-3\gamma)}{2},$$

such that:

- *If $c \in (\underline{c}^-, \underline{c})$, $\mathcal{P}^{\star\star}$ features only a binding price floor—that is, $\bar{p}^{\star\star} \triangleq \hat{p}(\sigma) > \underline{p}^{\star\star} \triangleq \hat{p}(\theta_F^{\star\star}) > \hat{p}(\sigma)$—with*

$$\theta_F^{\star\star} \triangleq -\sigma + \frac{4(\underline{c} - c)}{2-3\gamma} \in (-\sigma, \sigma).$$

The values $\underline{p}^{\star\star}$ and $\theta_F^{\star\star}$ are decreasing in σ and c and increasing in γ.

- *If $c \in [\underline{c}, \bar{c}]$, $\mathcal{P}^{\star\star}$ features full delegation—that is, $P^{\star\star} = [\hat{p}(-\sigma), \hat{p}(\sigma)]$.*
- *If $c \in (\bar{c}, \bar{c}^+)$, $\mathcal{P}^{\star\star}$ features only a binding price cap—that is, $\underline{p}^{\star\star} \triangleq \hat{p}(-\sigma) < \bar{p}^{\star\star} \triangleq \hat{p}(\theta_L^{\star\star}) < \hat{p}(\sigma)$—with*

$$\theta_L^{\star\star} \triangleq \sigma - \frac{4(c - \bar{c})}{2-3\gamma} \in (-\sigma, \sigma).$$

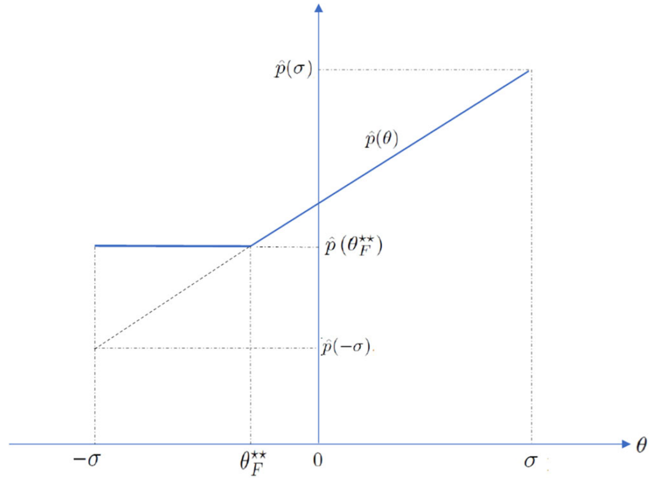
The values $\bar{p}^{\star\star}$ and $\theta_L^{\star\star}$ are decreasing in γ and c and increasing in σ.

- *Otherwise—that is, for $c \leq \underline{c}^-$ and $c \geq \bar{c}^+$—$\mathcal{P}^{\star\star}$ is a singleton and features a fixed price $p^{\star\star} \triangleq \mathbb{E}[p^N(\theta)]$.*

(ii) *Suppose that $\gamma > \frac{2}{3}$. Then, for every $c \in [\underline{c}, \bar{c}]$, full delegation is optimal—that is, $\mathcal{P}^{\star\star} = [\hat{p}(-\sigma), \hat{p}(\sigma)]$. Otherwise—that is, for $c \leq \underline{c}^-$ and $c \geq \bar{c}$—there is only a pooling equilibrium such that $\mathcal{P}^{\star\star}$ is a singleton and features a fixed price $p^{\star\star}$.*

This proposition shows that the optimal permission set in the cooperative regime is considerably more complex and rich than the permission set obtained in the equilibrium of the noncooperative game. Interestingly, while a noncooperative behavior by the principals either requires partial delegation implemented through a price cap or no delegation at all, in the cooperative regime it may be optimal for the coalition of principals to grant agents full price authority provided their distribution costs being neither too low nor too high.

FIGURE 2 Price-floor in the cooperative regime. [Color figure can be viewed at wileyonlinelibrary.com]



To explain the intuition behind the above characterization, it is useful to first discuss the region of parameters in which products are not too close substitutes ($\gamma \le \frac{2}{3}$). In this case, the coalition of principals may still find it profitable to implement partial delegation: the optimal permission set requires a price floor for medium-low values of c, while a price cap emerges when this cost takes medium-high values.

Specifically, when c is sufficiently low, agents would like to price more competitively than their principals—that is, their ideal point is close to $p^N(\theta)$, while principals' joint-profit maximization mandates the monopoly price $p^M(\theta)$. As a result, for c small enough, the optimal delegation form in the cooperative regime features either a price floor (illustrated in Figure 2) or no delegation at all.

By contrast, for relatively large values of c, agents are upward biased as in the noncooperative version of the game. Therefore, a price cap is still optimal in this region of parameters. Of course, the conflict of interest between principals and agents tends to weaken for intermediate values of the distribution cost since, in this case, the two forces illustrated above tend to balance out. Hence, for intermediate values of c, the optimal delegation scheme from the standpoint of the coalition of principals is full delegation, which never emerges in the noncooperative regime.

Consider now the case in which products are close substitutes—that is, $\gamma > \frac{2}{3}$. In this region of parameters, the cooperative regime either always features full delegation or no delegation at all. This is because competition exacerbates the conflict of interest between principals and agents when the latter would like to price below the monopoly price (as reflected by the fact that $\underline{c}^- > \underline{c}$) and softens the conflict of interest between them when agents would like to price above the monopoly price (as reflected by the fact that $\underline{c}^+ < \bar{c}$). This point can be better understood by differentiating the bias $b^{\star\star}(\theta)$ with respect to γ, yielding

$$\frac{\partial b^{\star\star}(\theta)}{\partial N} = \frac{\partial b^{\star}}{\partial \gamma} - \frac{\partial \Delta p(\theta)}{\partial \gamma} = -\frac{1+\theta-c}{(2-\gamma)^2} < 0, \quad \forall \theta \in \Theta.$$

The above derivative implies that when $b^{\star\star}(\theta)$ is positive, it falls with γ. By contrast, when it is negative, its absolute value increases with γ. Therefore, in this region of parameters, principals are more willing to delegate for higher values of c, and less willing to delegate for lower values of this parameter.

4.4 | Comparative statics and the determinants of delegation

We can finally turn to examine how the likelihood of delegation responds to changes in the model's parameters when principals maximize joint profits. As before, under the hypothesis that θ is uniformly distributed, the probability that an agent is allowed to pick his ideal price and the width of the range of θ in which this occurs are two equivalent metrics of price discretion. We stick with the former metric for consistency with the noncooperative analysis.

Let us restrict attention to the most interesting region of parameters where products are not too close substitutes ($\gamma \leq \frac{2}{3}$), so that the permission set that maximizes the principals' joint profits either features a price cap or a price floor. It is immediate to show that

$$\Pr\left[\theta \geq \theta_F^{\star\star}\right] = 1 - \frac{2(\underline{c} - c)}{\sigma(2 - 3\gamma)},$$

and

$$\Pr\left[\theta \leq \theta_L^{\star\star}\right] = 1 - \frac{2(c - \bar{c})}{\sigma(2 - 3\gamma)}.$$

Differentiating these expressions with respect to the model's parameters, and accounting for the fact that $\bar{c}$ and $\underline{c}$ are functions of σ and γ, we can establish the following.

Corollary 1. *Suppose that $\gamma \leq \frac{2}{3}$. In the cooperative regime, the likelihood of (partial) delegation is:*

- *Increasing in γ and σ, and decreasing in c for every $c \in (\bar{c}, \bar{c}^{+})$;*
- *Decreasing in γ, and increasing in σ and c for every $c \in (\underline{c}^{-}, \underline{c})$.*

The intuition for the above comparative statics is the same as in the noncooperative regime when partial delegation requires a price cap. By contrast, when it is optimal to impose a price floor, the likelihood of delegation drops if competition intensifies, while it increases when demand becomes more uncertain, and the distribution cost rises. The reason is as follows. First, fiercer competition reduces the agents' ideal point, exacerbating the conflict of interest with principals when the monopoly price lies above the agents' ideal point (which drops as γ rises). Second, an increase in the distribution cost tends to align incentives within each principal-agent pair because the agents' bias toward higher prices increases, moving their ideal point towards the monopoly price. Finally, as in the noncooperative regime, high demand uncertainty tends to align incentives even with upstream coordination: when uncertainty diminishes, the flexibility gain implied by price delegation drops. Hence, principals prefer to enforce a tighter vertical control via a relatively more rigid delegation scheme.

Another interesting comparative statics exercise is to study how the model's parameters affect the region of parameters in which full delegation occurs—that is, the difference

$$\Delta c \triangleq \bar{c} - \underline{c} = \sigma\gamma.$$

It is immediate to see that the range of parameters in which the optimal permission set $\mathcal{P}^{\star\star}$ features full delegation expands as γ and σ increase. Notably, in sharp contrast with results obtained in the noncooperative regime, not only the cooperative regime features an equilibrium with full delegation, but it also turns out that the region of parameters in which such equilibrium exists expands with the competition intensity.

5 | ROBUSTNESS AND LIMITATIONS

The above analysis shows that when competing principals choose how much price authority to grant their agents, the delegation scheme emerging at equilibrium depends on their competitive conduct in the upstream market. Key, however, is to establish how this conclusion is robust to reasonable perturbations of the environment.

For instance, to what extent does the demand specification matter? Is it always true that product market competition increases the likelihood of delegation in the cooperative regime? How would the presence of monetary incentives change this view? To what extent do asymmetries between downstream agents impact these conclusions?

In this section, we informally discuss the strengths and limitations of the results obtained in the baseline model, drawing new research avenues whenever possible (the analytical treatment of such material is relegated to the online appendix).

5.1 | Demand specification

The observation that agents are incentivized to pass on their nonverifiable distribution cost to consumers at the expense of principals (and consumers) is relatively robust and holds with a general demand structure—that is, the so-called double marginalization result. We have chosen a simple linear formulation to obtain closed-form solutions and to perform comparative statics on the extent of demand uncertainty and the degree of product substitutability. In the online appendix, we show that the qualitative conclusions of the analysis remain valid when considering alternative linear and nonlinear demand specifications (Shubick-Levitan and CES preferences). Furthermore, in the working paper version, we also show that all insights discussed above are robust to the introduction of $N \geq 2$ principals, with the number of competing principals playing a role similar to that of the degree of product differentiation.

In the online appendix, we also examine Cournot competition. In that setting, we show that agents have an incentive to distribute less than what principals would like to sell. As a result, the optimal permission set will feature a minimal output requirement (i.e., a floor on the amount of output that agents must distribute). Interestingly, principals can implement this type of output restrictions through vertical price control: they can indeed impose a price cap above which agents cannot sell, which de facto implements a minimal output requirement.

5.2 | Asymmetries

A somewhat restrictive assumption of our analysis is that the demand shock is common to both agents. Would our conclusions change with iid shocks? In the online appendix, we show that the logic of our results for the noncooperative regime remains unaltered with iid demand shocks. Given expectations about the rival's demand shock and equilibrium behavior, every agent still has an incentive to price above the level that maximizes his principal's profit because of the need to pass on the distribution cost to consumers. Hence, a price cap is still optimal in the noncooperative regime. The interesting feature of such a model, though, is that in equilibrium, it might well happen that the price cap binds for one agent while it does not bind for the other when the former experiences a high demand shock while the other a low one. Hence, agents with relatively low demand apply discounts off their price caps, while agents with a relatively high demand do not.

Above we have also assumed that distribution costs are the same across both agents (e.g., because they are market specific). This hypothesis is certainly reasonable in markets where upstream manufacturers use similar technologies and raw materials so that their products have similar intrinsic quality (i.e., there is no vertical differentiation but only horizontal differentiation) and distributors incur symmetric distribution costs, but it is less compelling in industries where products are highly innovative and their quality may be different in some important dimensions (vertical differentiation). In the automotive industry, for example, it is reasonable to assume that distributors of competing brands, like Volkswagen, Peugeot and Renault, and others that employ similar mechanical parts face common distribution costs. Yet, these costs are likely to be less correlated for distributors of top brands, such as Audi, Jaguar, Maserati, Tesla and so on, who use innovative technologies and materials and hence sell cars of different quality. The different levels of quality must be advertised and clearly explained by distributors to final clients who might be interested in knowing the extent to which the car they buy is innovative compared to competing brands.

How would results change if the agents had different distribution costs (i.e., when these costs also reflect idiosyncratic agent- or product-specific components)? Assume, without loss of generality, that $c_1 \geq c_2 > 0$. Notice that principals' ideal points in both regimes are still $p^N(\theta)$ and $p^M(\theta)$, respectively. By contrast, it can be easily shown that agents' ideal points are now asymmetric and given by

$$\hat{p}_i(\theta) = p^N(\theta) + \underbrace{\frac{2c_i + \gamma c_{-i}}{(2-\gamma)(2+\gamma)}}_{A_i\text{'s bias}}, \quad \forall i = 1, 2,$$

with $\hat{p}_1(\theta) \geq \hat{p}_2(\theta)$ for every θ since $c_1 \geq c_2$.

With asymmetric distribution costs, every agent has an individual bias that depends positively on his own and the rival's cost. The reason is simple: since prices are strategic complements, A_i's bias also depends on c_j since an increase of this parameter raises A_j's price and therefore also A_i's price through the best reply function.

Since each agent's bias is positive, the result that in the noncooperative regime delegation is implemented via a price cap is still valid. Moreover, since the bias is again increasing in γ, also the comparative statics that greater competition hinders delegation holds true. Yet, since in the example at hand, A_1 has a greater incentive to price above principals' ideal point, it must be the case that A_1 will be delegated less authority than A_2—that is, the price cap faced by A_1 will bind a relatively larger subset of demand states than A_2.

Things are slightly less straightforward, though intuitive, in the cooperative regime. Clearly, when the difference $c_1 - c_2$ is sufficiently small, the cooperative regime has the same qualitative features as the baseline model. Yet, when the difference $c_1 - c_2$ is sufficiently high, an asymmetric outcome may emerge. This is because A_1 may have an incentive to price above $p^M(\theta)$ while A_2 has an incentive to price below this price. Hence, in this region of parameters, the delegation scheme that maximizes principals' joint profits is likely to require a cap on A_1 and a floor or full delegation for A_2. Once again, the interesting aspect of introducing asymmetries into the picture would be to obtain richer equilibrium outcomes. The richness of these outcomes may help explain why some firms employ specific delegation tools (e.g., a price cap) while others use different devices (e.g., a price floor). Deriving a formal analysis of this asymmetric outcome goes beyond the scope of the current paper and is deferred to future research.

5.3 | Monetary transfers and delegation

Following the delegation literature, in our environment, the only control variable that principals have to discipline their agents is the choice of the permission set. The total absence of money transfers is, however, admittedly a strong assumption. Monetary transfers align incentives when they can be made contingent upon the relevant characteristics of a contractual relationship (e.g., agents' performance under moral hazard and the reports they make on their private information under adverse selection). Hence, the extent to which these contracts can be implemented, and can thus be effective in aligning vertical incentives in practice, depends on the degree of sophistication of the enforcement environment and the extent to which the relevant contingencies of a relationship can be clearly described in a contract (see, e.g., Tirole, 1999).

In a frictionless environment, monetary transfers can take a complex form and delegation might not be an issue. In the screening literature, for instance, principals can use menus of two-part tariffs to screen their agents (see, e.g., Pagnozzi et al., 2016, inter alia for a competitive screening model). In these models, agents are asked to report their private information (about costs or demand) knowing that the monetary terms of the agreements with their principals will be based on these reports. Therefore, upstream principals can fully internalize downstream objectives and do not need to restrict agents' pricing authority since they can induce the optimal second-best prices by appropriately tailoring the linear component of the two-part tariff (e.g., wholesale prices or ad valorem fees) to the state of demand.[11] Agents, however, do not give up their private information for free. In models like ours, agents are incentivized to understate demand to grab a higher share of sales profits at principals' expenses. Specifically, pretending that demand is low when it is high allows an agent to obtain lower wholesale prices and grab the extra profit because demand is indeed high. To neutralize such opportunistic behavior, principals must grant them an information rent. However, to minimize this rent, they distort prices above their ideal point in low-demand states. Such price distortion reduces sales in these states and makes under-reporting in high-demand states less profitable: the so-called trade-off between efficiency and rent extraction (Laffont & Martimort, 2009).

A basic revealed preferences logic suggests that principals always have an incentive to use monetary incentives whenever they can since they can always replicate, by means of suitable transfers, the outcome of our delegation game. As a result, principals can only benefit from using monetary transfers. The question, however, is to what extent these complex monetary transfers are enforceable. Delegation schemes like those we have developed here are relatively easy to describe, implement and enforce.

Of course, an interesting question would be to identify the potential frictions that make price delegation still compatible with forms of monetary transfers. This issue is addressed in the literature examining the link between moral hazard, delegation, and incentive pay. For instance, Bester and Krähmer (2008) consider a double moral hazard setting where, in addition to providing effort incentives, a principal must decide whether to delegate her agent the choice of the project type. In their environment, project choice delegation and monetary incentives might be compatible because the project selection stage takes place before effort is exerted. In their noncompetitive environment, the principal is less likely to delegate and, instead, uses transfers and her authority over the decision to induce effort from the agent. Bhardwaj (2001) also looks at a moral hazard setting where delegation is bundled with incentive pay.

Still, in contrast to Bester and Krähmer (2008), he considers vertical organizations competing in two dimensions: price and effort. By comparing the extreme cases of full price delegation and full centralization, he shows that the strategic nature of delegation depends on the relative intensity of competition along the price and effort dimensions. Specifically, in contrast to us, with unobservable contracts and risk-averse sales representatives, Bhardwaj (2001) finds that firms delegate the pricing decision when price competition is relatively more intense than effort competition. Lo et al. (2016) also studied theoretically and empirically the link between delegation and incentive pay and found evidence pointing in the direction of price delegation being increasing with the intensity of monetary incentives given to the agents (see, e.g., Lim & Ham, 2014, for experimental evidence coherent with this finding).[12]

This literature suggests that delegation is endogenously linked to incentive pay and that the more monetary transfers are effective in aligning incentives, the higher the benefit of delegation. Yet, this aspect cannot be addressed in our model as it stands because there is no moral hazard variable. In the online appendix, we build a simple variant of the baseline model where agents engage in demand-enhancing promotional activities (effort) to explore this point further. An interesting trade-off in this setting is that while distribution costs are still passed on to consumers, thereby increasing prices above what principals would like in a noncooperative equilibrium, these costs tend to depress effort because they reduce profit margins, which in turn tend to lower prices because effort and price are positively linked. Yet, a more intense incentive pay tends to minimize the conflict of interest between principals and agents because they align effort incentives. When agents enjoy a relatively higher share of profits, they are more willing to exert effort, which makes them less prone to pass on costs to consumers. Hence, delegation and incentive pay are complementary in that framework. We also show that the in the cooperative regime, it is still the case that agents want to price above the monopoly price for low values of demand and below it when demand is high. Hence, the same qualitative features of Proposition 2 are still likely to hold with incentive pay as long as a delegation problem remains. Although extremely interesting, this issue is outside the scope of the current paper and is, therefore, deferred to future research.

6 | CONTRIBUTION TO THE LITERATURE

Traditional models examining the pros and cons of delegation in vertical relationships plagued by asymmetric information assume that principals can align incentives (partially or in full) through monetary incentives (see, e.g., Blair & Lewis, 1994; Gal-Or, 1991; Martimort & Piccolo, 2007, 2010, for models with adverse selection, and Bhardwaj, 2001; Mishra & Prasad, 2004, 2005, for moral hazard). In contrast, we focus on cases where monetary incentives are not enforceable. Hence, our model is more closely related and builds on the partial delegation literature initiated by Holmström (1977), Holmstrom (1984), and Aghion and Tirole (1997). Following his work, many scholars have investigated the determinants of delegation in the absence of monetary incentives and the conditions under which interval delegation is optimal (see, e.g., Alonso & Matouschek, 2008; Amador & Bagwell, 2013; Armstrong & Vickers, 2010; Dessein, 2002; Dessein & Santos, 2006; Frankel, 2014, 2016; Martimort & Semenov, 2006; Melumad & Shibano, 1991, among many others).[13] These models characterize the trade-off between loss of information and loss of control in several different environments. We contribute to this bulk of work by considering competing organizations and by describing the equilibrium interval delegation in the two polar cases where principals behave cooperatively and noncooperatively (Kräkel & Schöttner, 2020, also look at cooperative equilibria but focus on collusion between salespeople and consumers rather than collusion among principals). Our novel result is that upstream cooperation does not necessarily imply tighter vertical control, especially in very competitive environments.

By exploring the determinants of price caps, our model is related to the burgeoning literature on list prices and their competitive effects. Harrington and Ye (2019) develop a theory to explain how coordination on list prices can raise transaction prices (see, e.g., also Harrington, 2022). The model developed in our paper differs in two fundamental ways from Harrington and Ye (2019). First, they assume a deterministic link between list and transaction prices, while in our model, there is a stochastic (endogenous) relationship between them driven by demand fluctuations. Second, their model assumes that principals are privately informed about a common product technology; we consider the equally plausible polar case where agents own private information on demand. In this context, we find that industry profit maximization may well require principals to grant agents full pricing authority, even though this authority would be constrained by the presence of a list price in the noncooperative equilibrium. Gill and Thanassoulis (2016) also consider upstream cooperation but, in contrast to Harrington and Ye (2019), they assume that firms can coordinate on both list and transaction prices because both are verifiable (see also Lester et al., 2017; Mallucci et al., 2019; Raskovich, 2007). In these models, coordination on transaction prices is viable because they do not consider privately informed salespeople;

in our model, instead, coordination on transaction prices is feasible only when principals give up the benefits of flexibility.

Moreover, while all these papers emphasize the adverse effects of list prices on consumer surplus, our model shows that list prices limit agents' incentive to pass their distribution costs to consumers. Myatt and Ronayne (2019) offer a result in this spirit, which shows that competition in list prices reduces search costs, thereby benefitting consumers. Our paper abstracts from search costs and focuses more on the internal agency conflict between principals and agents. In a companion paper (Andreu et al., 2021), we study the welfare effects of information sharing about price intentions in a similar delegation framework where principals learn the state of demand probabilistically. It is shown that equilibria featuring partial delegation are more likely to occur when principals share their price intentions (including list prices), that this practice is always procompetitive and beneficial to consumers, and that it is mutually profitable for the principals when products are sufficiently differentiated, and distribution costs are neither too high nor too low.

7 | CONCLUDING REMARKS

In a recent influential article, Rey and Tirole (2019) argued that economists have neither advocated voluntary price caps nor studied their competitive effects. This practice, however, has appeared repeatedly over the last years in the competition policy landscape on both sides of the Atlantic. Harrington and Ye (2019) and Boshoff and Paha (2021), for instance, survey some cartel cases where list prices (a particular form of price caps) have been strategically used for (implicit) collusive purposes. In the United States, list price coordination has attracted antitrust scrutiny since the 1970s, with Hay and Kelly (1974) presenting a range of examples suggesting that list prices were a prevalent competitive concern at the time of their study. A more recent example in the EU relates to a cartel in the truck industry: in 2016, six truck manufacturers were sanctioned by the European Commission for attempting to coordinating their list prices over the period 1997 to 2011.[14]

By framing the problem of how list prices are generated within a delegation context and comparing the standard noncooperative regime with a cooperative regime, our paper has contributed to this debate by offering an alternative view on the nature, determinants, and competitive effects of list prices. The analysis suggests that the emergence of list prices implements the equilibrium delegation form in an environment where principals behave noncooperatively. Yet, the same outcome does not necessarily emerge when they behave cooperatively. Hence, the presence of list prices is, in principle, not a symptom of consumer harm compared to instances where list prices are not imposed at all or where price floors are imposed. These instruments may reflect principals' genuine need to discipline their local representatives' incentive to pass on distribution costs to consumers.

From a managerial angle, our analysis has two critical implications. The first is that when principals behave noncooperatively, competition (as measured by greater product substitutability) hinders price delegation while uncertainty favors it. The second managerial implication is that when principals act cooperatively, competition favors price delegation. Notably, this finding questions the traditional view that upstream coordination is associated with tighter vertical price control and suggests that principals' cooperative conduct may partly explain observed patterns of price delegation rather than individual decision-making behavior. Finally, these results also provide important insights to understand better marketing alliances, multiproduct firms and cartels, their competitive strategies, and organizational architecture.

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ENDNOTES

[1] We would like to thank an anonymous referee for suggesting this interpretation.

[2] In the SSRN version of the paper we consider the more general case of $N \geq 2$ firms.

[3] See, for example, Harrington and Ye (2019), Jullien and Rey (2007), Nocke and White (2007), Piccolo and Miklós-Thal (2012), Piccolo and Reisinger (2011), among many others.

[4] For example, Amador and Bagwell (2013), Dessein (2002), Holmström (1977), Holmstrom (1984), Martimort and Semenov (2006), Melumad and Shibano (1991), among many others.

[5] Quérou et al. (2020) also talk about unverifiable downstream costs but in a moral hazard setting that applies to instances where agents are salespeople (see the online appendix for an exploration of such a model).

[6] Green and Laffont (1994) study a general model with pure nonverifiability 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 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.

[7] The restriction to interval delegation rests on Martimort and Semenov (2006) who show that, in a linear quadratic framework like ours, assuming a connected permission set is equivalent to allow principals to use general, continuous, truthful revelation mechanisms requiring each agent to report the state of demand. Specifically, each principal P_i chooses a direct mechanism $\mathcal{M}_i \triangleq \{p_i(m_i)\}_{m_i \in \Theta}$, with the mapping $p_i(\cdot) : \Theta \to \mathfrak{R}$ specifying a pricing rule $p_i(m_i)$ for any report $m_i \in \Theta$ made by A_i to P_i about the state of the world θ. Under the hypothesis of passive beliefs off the equilibrium path (which we shall discuss below), each principal takes as given the rivals' equilibrium behavior; therefore, the results of Martimort and Semenov (2006) directly apply to our competing-organizations framework, implying that the restriction to connected permission sets is without loss of generality.

[8] This assumption is made for expositional purposes only and is meant to rule out any other friction due to principals' lack of coordination—that is, if principals could, they would certainly agree to set a common permission set which grants the upstream coalition commitment power vis-à-vis agents.

[9] That is, (5) subject to $p_i \in \mathcal{P}_i$.

[10] In the proof of Lemma 1, we show that under **A** demand is positive and agents make positive profit when they both charge $\hat{p}(\theta)$. Since agents' ideal point does not change, the same is true here.

[11] Recall that there is a one-to-one mapping between wholesale and retail prices.

[12] See also De Varo and Prasad (2015) and Phillips et al. (2015).

[13] See, for example, Bendor and Meirowitz (2004) and Huber and Shipan (2006) for surveys of these models.

[14] https://ec.europa.eu/commission/presscorner/detail/es/IP_16_2582

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SUPPORTING INFORMATION

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APPENDIX

Benchmark. The first-order condition of P_i's maximization problem in the noncooperative regime is

$$\underbrace{D_i(\theta, p_i, p_j)}_{\text{Profit-margin effect}} + \underbrace{\frac{\partial D_i(\theta, p_i, p_j)}{\partial p_i} p_i}_{\text{Volume effect}} = 0, \quad \forall\,(i, j) = 1, \ldots, 2. \tag{A1}$$

This condition reflects the standard trade-off between the positive profit-margin effect and the negative volume effect—that is, a higher price benefits P_i because it increases her profit on the "infra-marginal" consumers, but it also reduces the "marginal" consumer—that is, when p_i rises, some consumers will purchases elsewhere—thereby reducing P_i's sale volume. Looking for a symmetric equilibrium this yields $p^N(\theta)$.

In the cooperative regime, the first-order condition is

$$\underbrace{D_i(\theta, p_i, p_j)}_{\text{Margin effect}(+)} + \underbrace{\frac{\partial D_i(\theta, p_i, p_j)}{\partial p_i} p_i}_{\text{Volume effect}(-)} + \underbrace{\frac{\partial D_j(\theta, p_j, p_i)}{\partial p_i} p_j}_{\text{Competition softening}(+)} = 0, \quad \forall\,(i, j) = 1, \ldots, 2. \tag{A2}$$

This expression reflects an additional effect compared to (A1). When prices are chosen cooperatively, headquarters internalize the effect of changing a price on the rivals' profits: a competition-softening effect. Solving equation (A2).

Proof of Lemma 1. Solving (6) for a symmetric equilibrium we immediately have $\hat{p}(\theta)$. Moreover,

$$D_i(\theta, \hat{p}(\theta), \hat{p}(\theta)) = \frac{1 + \theta - c}{(1 + \gamma)(2 - \gamma)},$$

and

$$\hat{p}(\theta) - c = \frac{(1 - \gamma)(1 + \theta - c)}{2 - \gamma}.$$

Both these terms are positive if and only if $c \leq 1 + \theta$. Hence, **A** guarantees positive demand and positive profits for the agents. □

Proof of Lemma 2. Showing that $p_i(\theta, p^\star(\theta))$ is increasing in θ is immediate since $\hat{p}(\theta)$ is increasing in θ and

$$\frac{\partial p_i(\theta, p^\star(\theta))}{\partial \theta} = \frac{1 - \gamma}{2} > 0.$$

Hence, for any given $\mathcal{P}_i$ the constrained pricing rule for A_i has a binding cap for $\theta \geq \overline{\theta}_i$ and a binding floor for $\theta \leq \underline{\theta}_i$. Finally, $\overline{\theta}_i \geq \underline{\theta}_i$ follows immediately from the hypothesis $\overline{p}_i \geq \underline{p}_i$. □

Proof of Proposition 1. We first show that if a symmetric equilibrium with partial delegation exists, then it features a price cap only—that is, there is neither a symmetric equilibrium with full delegation nor an equilibrium in which a price floor is imposed.

Let $\overline{\lambda}_i$ and $\underline{\lambda}_i$ be the Lagrangian multipliers associated to the constraints $\overline{\theta}_i \leq \sigma$ and $\underline{\theta}_i \geq -\sigma$, respectively. Differentiating with respect to $\underline{\theta}_i$ and $\overline{\theta}_i$ and imposing symmetry—that is, $\underline{\theta}_i = \underline{\theta}^\star \leq \overline{\theta}_i = \overline{\theta}^\star$—we have the following first-order conditions

$$\int_{\theta \leq \underline{\theta}^\star} \left[D_i(\theta, \underline{p}^\star, \underline{p}^\star) + \frac{\partial D_i(\theta, \underline{p}^\star, \underline{p}^\star)}{\partial p_i} \underline{p}^\star \right] \frac{d\theta}{2\sigma} = \underline{\lambda}^\star, \tag{A3}$$

$$\int_{\theta \geq \overline{\theta}^\star} \left[D_i(\theta, \overline{p}^\star, \overline{p}^\star) + \frac{\partial D_i(\theta, \overline{p}^\star, \overline{p}^\star)}{\partial p_i} \overline{p}^\star \right] \frac{d\theta}{2\sigma} = -\overline{\lambda}^\star. \tag{A4}$$

with

$$\overline{p}^\star \triangleq \hat{p}(\overline{\theta}^\star) \geq \underline{p}^\star \triangleq \hat{p}(\underline{\theta}^\star),$$

and associated complementary slackness conditions

$$\begin{aligned} \underline{\lambda}^\star \geq 0, \quad & \underline{\lambda}^\star [\underline{\theta}^\star + \sigma] = 0, \\ \overline{\lambda}^\star \geq 0, \quad & \overline{\lambda}^\star [\overline{\theta}^\star - \sigma] = 0. \end{aligned}$$

Suppose that a symmetric equilibrium exists and that it features interior solutions—that is, $\underline{\lambda}^\star = \overline{\lambda}^\star = 0$. We have

$$\begin{aligned} \overline{\theta}^\star &= \sigma - \tfrac{2c}{1-\gamma}, \\ \underline{\theta}^\star &= -\sigma - \tfrac{2c}{1-\gamma}. \end{aligned}$$

It is immediate to show that $\underline{\theta}^\star \leq -\sigma$ and $\overline{\theta}^\star \geq -\sigma$ if and only if $c \leq c^\star$. Hence, if a symmetric equilibrium with partial delegation exists, it either features a list price—that is, for $c \leq c^\star$—with $\overline{p}^\star = \hat{p}(\overline{\theta}^\star)$ and $\underline{p}^\star = \hat{p}(-\sigma)$, or a fixed price—that is, for $c = c^\star$—with $\overline{p}^\star = \underline{p}^\star = \hat{p}(-\sigma)$.

We now check deviations—that is, we show that given that her rival sets $\mathcal{P}^\star$, principal P_i cannot profit by choosing a permission set $\mathcal{P}_i \neq \mathcal{P}^\star$. Suppose that $c \leq c^\star$. In this region of parameters the candidate equilibrium is such that $\overline{p}^\star = \hat{p}(\overline{\theta}^\star)$. Hence, to define P_i's maximization problem we need to consider various types of deviations.

a. Suppose that P_i sets $-\sigma < \underline{\theta}_i \leq \overline{\theta}_i \leq \overline{\theta}^\star \leq \sigma$, her maximization problem is

$$\begin{aligned} \max_{(\underline{\theta}_i, \overline{\theta}_i) \in \Theta} & \int_{-\sigma}^{\underline{\theta}_i} D_i(\theta, p_i(\underline{\theta}_i, \hat{p}(\theta)), \hat{p}(\theta)) p_i(\underline{\theta}_i, \hat{p}(\theta)) \frac{d\theta}{2\sigma} + \int_{\underline{\theta}_i}^{\overline{\theta}_i} D_i(\theta, \hat{p}(\theta), \hat{p}(\theta)) \hat{p}(\theta) \frac{d\theta}{2\sigma} \\ & + \int_{\overline{\theta}_i}^{\overline{\theta}^\star} D_i(\theta, p_i(\overline{\theta}_i, \hat{p}(\theta)), \hat{p}(\theta)) p_i(\overline{\theta}_i, \hat{p}(\theta)) \frac{d\theta}{2\sigma} + \int_{\overline{\theta}^\star}^{\sigma} D_i(\theta, p_i(\overline{\theta}_i, \hat{p}(\overline{\theta}^\star)), \hat{p}(\overline{\theta}^\star)) p_i(\overline{\theta}_i, \hat{p}(\overline{\theta}^\star)) \frac{d\theta}{2\sigma}. \end{aligned}$$

The first order condition with respect to $\underline{\theta}_i$ is

$$\int_{-\sigma}^{\underline{\theta}_i} \left[\frac{\partial D_i(\theta, p_i(\underline{\theta}_i, \hat{p}(\theta)), \hat{p}(\theta))}{\partial p_i} p_i(\underline{\theta}_i, \hat{p}(\theta)) + D_i(\theta, p_i(\underline{\theta}_i, \hat{p}(\theta)), \hat{p}(\theta)) \right] \frac{d\theta}{2\sigma} = 0,$$

whose solution yields $\underline{\theta}_i = \underline{\theta}^\star < -\sigma$: a contradiction. It can be immediately shown that the same conclusion applies when P_i sets $\underline{\theta}_i \leq \overline{\theta}^\star$.

b. Suppose that P_i sets $-\sigma < \bar{\theta}^\star \le \underline{\theta}_i \le \bar{\theta}_i \le \sigma$, her maximization problem is

$$\max_{(\underline{\theta}_i,\bar{\theta}_i)\in\Theta} \int_{-\sigma}^{\bar{\theta}^\star} D_i(\theta, p_i(\underline{\theta}_i, \hat{p}(\theta)), \hat{p}(\theta)) p_i(\underline{\theta}_i, \hat{p}(\theta)) \frac{d\theta}{2\sigma} + \int_{\bar{\theta}^\star}^{\underline{\theta}_i} D_i(\theta, p_i(\underline{\theta}_i, \hat{p}(\bar{\theta}^\star)), \hat{p}(\bar{\theta}^\star)) p_i(\underline{\theta}_i, \hat{p}(\bar{\theta}^\star)) \frac{d\theta}{2\sigma}$$
$$+ \int_{\underline{\theta}_i}^{\bar{\theta}_i} D_i(\theta, \hat{p}(\theta), \hat{p}(\theta)) \hat{p}(\theta) \frac{d\theta}{2\sigma} + \int_{\bar{\theta}_i}^{\sigma} D_i(\theta, p_i(\bar{\theta}_i, \hat{p}(\bar{\theta}^\star)), \hat{p}(\bar{\theta}^\star)) p_i(\bar{\theta}_i, \hat{p}(\bar{\theta}^\star)) \frac{d\theta}{2\sigma}$$

The derivative with respect to $\underline{\theta}_i$ is

$$\frac{\partial p_i(\underline{\theta}_i, \hat{p}(\theta))}{\partial \underline{\theta}_i} \int_{-\sigma}^{\bar{\theta}^\star} \left[\frac{\partial D_i(\theta, p_i(\underline{\theta}_i, \hat{p}(\theta)), \hat{p}(\theta))}{\partial p_i} p_i(\underline{\theta}_i, \hat{p}(\theta)) + D_i(\theta, p_i(\underline{\theta}_i, \hat{p}(\theta)), \hat{p}(\theta)) \right] \frac{d\theta}{2\sigma}$$
$$+ \frac{\partial p_i(\underline{\theta}_i, \hat{p}(\bar{\theta}^\star))}{\partial \underline{\theta}_i} \int_{\bar{\theta}^\star}^{\underline{\theta}_i} \left[\frac{\partial D_i(\theta, p_i(\underline{\theta}_i, \hat{p}(\bar{\theta}^\star)), \hat{p}(\bar{\theta}^\star))}{\partial p_i} p_i(\underline{\theta}_i, \hat{p}(\bar{\theta}^\star)) + D_i(\theta, p_i(\underline{\theta}_i, \hat{p}(\bar{\theta}^\star)), \hat{p}(\bar{\theta}^\star)) \right] \frac{d\theta}{2\sigma}$$
$$+ \frac{D_i(\underline{\theta}_i, p_i(\underline{\theta}_i, \hat{p}(\bar{\theta}^\star)), \hat{p}(\bar{\theta}^\star)) p_i(\underline{\theta}_i, \hat{p}(\bar{\theta}^\star))}{2\sigma} - \frac{D_i(\underline{\theta}_i, \hat{p}(\underline{\theta}_i), \hat{p}(\underline{\theta}_i)) \hat{p}(\underline{\theta}_i)}{2\sigma},$$

Evaluating this derivative at $\underline{\theta}_i = \bar{\theta}^\star$, we have

$$\frac{\partial p_i(\bar{\theta}^\star, \hat{p}(\theta))}{\partial \underline{\theta}_i} \int_{-\sigma}^{\bar{\theta}^\star} \left[\frac{\partial D_i(\theta, p_i(\bar{\theta}^\star, \hat{p}(\theta)), \hat{p}(\theta))}{\partial p_i} p_i(\bar{\theta}^\star, \hat{p}(\theta)) + D_i(\theta, p_i(\bar{\theta}^\star, \hat{p}(\theta)), \hat{p}(\theta)) \right] \frac{d\theta}{2\sigma}$$
$$= \frac{c - \sigma(1-\gamma)}{2(1+\gamma)},$$

which is negative for $c \le c^\star$, yielding the desired contradiction.

Therefore, for $c \le c^\star$, the permission set $\mathcal{P}^\star$ is the unique symmetric equilibrium of the game featuring partial delegation. Differentiating $\bar{\theta}^\star$ with respect to σ, c, and γ, and exploiting the fact that $\hat{p}(\cdot)$ is increasing in θ, it is immediate to obtain that $\bar{p}^\star$ and $\bar{\theta}^\star$ are decreasing in c and γ, and increasing in σ. Finally, showing that for every $c > c^\star$, a symmetric equilibrium of the game must be such that all principals set a fixed price $p^{\star\star} = \mathbb{E}[p^N(\theta)]$ is immediate given linearity of demand. □

Proof of Lemma 3. The proof follows immediately from the fact that $b^{\star\star}(\theta)$ is decreasing in θ and that $b^{\star\star}(\theta) < 0$ for $c = 0$. The threshold $\hat{\theta}$ solves $b^{\star\star}(\theta) = 0$, while $\underline{c}$ and $\bar{c}$ are the solutions with respect to c of $\hat{\theta} = -\sigma$ and $\hat{\theta} = \sigma$, respectively. □

Proof of Proposition 2. Let $\bar{\lambda}$ and $\underline{\lambda}$ be the multipliers associated to the constraints $\bar{\theta} \le \sigma$ and $\underline{\theta} \ge -\sigma$, respectively. Differentiating with respect to $\underline{\theta}$ and $\bar{\theta}$, the optimal permission set in the cooperative regime, hereafter $\mathcal{P}^{\star\star} \triangleq [\underline{p}^{\star\star}, \bar{p}^{\star\star}]$, solves the following first-order conditions

$$\int_{\theta \le \underline{\theta}^{\star\star}} \left[\left(\frac{\partial D_i(\theta, \underline{p}^{\star\star}, \underline{p}^{\star\star})}{\partial p_i} + \frac{\partial D_i(\theta, \underline{p}^{\star\star}, \underline{p}^{\star\star})}{\partial p_j} \right) \underline{p}^{\star\star} + D_i(\theta, \underline{p}^{\star\star}, \underline{p}^{\star\star}) \right] \frac{d\theta}{2\sigma} = \bar{\lambda}^{\star\star}, \tag{A5}$$

$$\int_{\theta \ge \bar{\theta}^{\star\star}} \left[\left(\frac{\partial D_i(\theta, \bar{p}^{\star\star}, \bar{p}^{\star\star})}{\partial p_i} + \frac{\partial D_i(\theta, \bar{p}^{\star\star}, \bar{p}^{\star\star})}{\partial p_j} \right) \bar{p}^{\star\star} + D_i(\theta, \bar{p}^{\star\star}, \bar{p}^{\star\star}) \right] \frac{d\theta}{2\sigma} = -\bar{\lambda}^{\star\star}, \tag{A6}$$

with

$$\bar{p}^{\star\star} \triangleq \hat{p}(\bar{\theta}^{\star\star}) \ge \underline{p}^{\star\star} \triangleq \hat{p}(\underline{\theta}^{\star\star}),$$

and associated complementary slackness conditions

$$\underline{\lambda}^{\star\star} \geq 0, \underline{\lambda}^{\star\star}[\underline{\theta}^{\star\star} + \sigma] = 0,$$
$$\bar{\lambda}^{\star\star} \geq 0, \bar{\lambda}^{\star\star}[\bar{\theta}^{\star\star} - \sigma] = 0.$$

Solving the first-order conditions (A5) and (A6), in an interior solution we have

$$\bar{\theta}^{\star\star} = \sigma - 2\frac{2c - \gamma(1+\sigma)}{2 - 3\gamma},$$

and

$$\underline{\theta}^{\star\star} = -\sigma + 2\frac{\gamma(1-\sigma) - 2c}{2 - 3\gamma}.$$

To begin with, it can be immediately shown that this cannot be a solution for $\gamma > \frac{2}{3}$ since

$$\bar{\theta}^{\star\star} - \underline{\theta}^{\star\star} = \frac{2\sigma(2-\gamma)}{2 - 3\gamma}.$$

Next, consider $\gamma \leq \frac{2}{3}$. It can be shown that such a solution does not satisfy the second-order conditions for a maximum—that is, the Hessian matrix is not negative semidefinite at $(\bar{\theta}^{\star\star}, \underline{\theta}^{\star\star}) \in (-\sigma, \sigma)$. Specifically, letting

$$\pi(\bar{\theta}, \underline{\theta}) \triangleq \int_{-\sigma}^{\underline{\theta}} \frac{1 + \theta - \hat{p}(\underline{\theta})}{1+\gamma}\hat{p}(\underline{\theta})\frac{d\theta}{2\sigma} + \int_{\underline{\theta}i}^{\bar{\theta}} \frac{1 + \theta - \hat{p}(\theta)}{1+\gamma}\hat{p}(\theta)\frac{d\theta}{2\sigma} + \int_{\bar{\theta}}^{\sigma} \frac{1 + \theta - \hat{p}(\bar{\theta})}{1+\gamma}\hat{p}(\bar{\theta})\frac{d\theta}{2\sigma}.$$

we have

$$\frac{\partial^2\pi(\bar{\theta}^{\star\star}, \underline{\theta}^{\star\star})}{\partial\bar{\theta}^2} = -\frac{(2c - \gamma(1+\sigma))(1-\gamma)}{2\sigma(2-\gamma)^2} \quad \Leftrightarrow \quad c \geq \bar{c}, \tag{A7}$$

$$\frac{\partial^2\pi(\bar{\theta}^{\star\star}, \underline{\theta}^{\star\star})}{\partial\underline{\theta}^2} = \frac{(2c - \gamma(1-\sigma))(1-\gamma)}{2\sigma(2-\gamma)^2} \quad \Leftrightarrow \quad c \leq \underline{c}, \tag{A8}$$

$$\frac{\partial^2\pi(\bar{\theta}^{\star\star}, \underline{\theta}^{\star\star})}{\partial\underline{\theta}\,\partial\bar{\theta}} = 0. \tag{A9}$$

The Hessian matrix is thus negative semidefinite at $(\bar{\theta}^{\star\star}, \underline{\theta}^{\star\star}) \in (-\sigma, \sigma)$ if and only if $c \geq \bar{c}$ and $c \leq \underline{c}$, which are indeed incompatible since $\bar{c} > \underline{c}$. As a result, the permission set that maximizes industry profit either features a cap, a floor, full delegation or full pooling.

Consider first, $\gamma \leq \frac{2}{3}$. In this region of parameters $\bar{c}^{+} > \bar{c} > \underline{c} > \underline{c}^{-}$. Then, the result follows immediately since: $(i)\bar{\theta}^{\star\star} \leq \sigma$ for $c \geq \bar{c}$ and $\bar{\theta}^{\star\star} \geq -\sigma$ for $c \leq \bar{c}^{+}$; $(ii)\underline{\theta}^{\star\star} \geq -\sigma$ for $c \leq \underline{c}$ and $\underline{\theta}^{\star\star} \leq \sigma$ for $c \geq \underline{c}^{-}$. Second-order conditions are satisfied in all these equilibria and are given by (A7) when $\mathcal{P}^{\star\star}$ features a cap and by (A8) when $\mathcal{P}^{\star\star}$ features a floor.

Next, suppose that $\gamma > \frac{2}{3}$. In this region of parameters, $\bar{c} > \bar{c}^{+} > \underline{c}^{-} > \underline{c}$. Hence, the maximization problem always features corner solutions. That is: (i) $\bar{\theta}^{\star\star} = \underline{\theta}^{\star\star} = -\sigma$ for $c \geq \bar{c}$, implying that $\bar{p}^{\star\star} = \underline{p}^{\star\star} = \hat{p}(-\sigma)$; (ii) $\bar{\theta}^{\star\star} = \underline{\theta}^{\star\star} = \sigma$ for $c \leq \underline{c}$, implying that $\bar{p}^{\star\star} = \underline{p}^{\star\star} = \hat{p}(\sigma)$; (iii) $\underline{\theta}^{\star\star} = -\sigma$ and $\bar{\theta}^{\star\star} = \sigma$ for $c \in (\underline{c}, \bar{c})$, implying that $\mathcal{P}^{\star\star} = [\hat{p}(-\sigma), \hat{p}(\sigma)]$.

The comparative statics follows from direct differentiation of the equilibrium values. □

Proof of Corollary 1. The proof follows immediately by the definition of $\underline{c}$ and $\bar{c}$. □