Incomplete Contracts as a Screening Device in Competing Vertical Intra-Firm Relationships*

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Abstract

Recent research in industrial organization has emphasized the strategic value of incomplete contracts in vertical intra-firm relationships. This paper offers a screening rationale for contractual incompleteness in a class of producer-retailer economies under adverse selection and moral hazard. By means of a simple two-type agency model, we show that, when the agent (retailer) operates in an imperfectly competitive market, the principal (producer) may deliberately choose to exploit incomplete contracts to warrant truthful revelation of the retailer's private information. While the contractual provision of monitoring instruments to prevent agent's misbehavior may well fail to induce self-selection, equilibria with full separation always exist under incomplete contracts even in the presence of countervailing incentives.

Keywords: Vertically integrated firms; Asymmetric information; Incomplete contracts; Screening

JEL Classification: D21; D40; D82

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1 Introduction

Over the last years, the applied contract theory literature has paid a great deal of attention to the analysis of the strategic value of contractual incompleteness for the optimal design of industry relationships. In particular, in contrast to existing models arguing in favor of vertical price restrictions, several recent studies have shown that the exploitation of agreements which remain silent on some (verifiable) relationship-specific measures can improve upon the complete contracting scenario by positively influencing the market performance of competing vertical hierarchies (e.g. Martimort and Piccolo, 2010; Kastl et al., 2011).

The present paper aims at contributing to the analysis of the strategic role of incomplete contracts by focusing on the advisability of the latter as a screening device in the presence of asymmetric information. The existence of a close relationship between the degree of contractual completeness and their sorting efficacy in environments characterized by adverse selection problems has been only partially explored in the vertical contracting literature[1]. This lack of interest might be due to the standard tenet that a (sufficiently) complete contract, which provides the producer with several instruments to control the downstream agent, is more likely to favor the truthful revelation of private information and hence the separation of unobservable types.

The analysis developed in this paper offers a simple argument, based on the conventional theory of incentives, against this conjecture in a class of simple producers-retailers economies under adverse selection and moral hazard. Specifically, using a simple two-type agency model with competing vertical intra-firm relationships, we demonstrate that, while constraining the principal's control over potential agent's misbehavior, contractual incompleteness crucially influences the revelation strategies of the informed player, and hence serves as a powerful screening device when *both* the agent's types face misreporting incentives.

The intuition behind this counterintuitive result is as follows. It is well-known that the existence of a trade-off between efficiency and rent extraction in agency problems leads to distortions with respect to the first best equilibrium allocations (e.g. Holmstrom, 1982; Baron and Besanko, 1984; Laffont and Tirole, 1986; Caillaud and Hermalin, 2000). In the context of vertically related firms, the producer's decision to delegate a given task to an independent retailer is typically rationalized by the superior knowledge and expertise that the latter exhibits with respect to the peculiar features of the downstream market. On the other hand, however, the same elements, along with the existence of asymmetric information on the actual production structure of retailers, necessarily generates informational rents for the latter which must be accounted for within the delegation arrangement. The basic idea underlying the alleged superiority of complete contracts in this respect is that only detailed agreements, which are able to control for (almost) all the specific contingencies relevant to the transaction, allow the principal to curb agents' discretion and properly steer both behavior and revelation strategies. This presumption, however, has been invalidated by several studies showing that, when at least one of the relevant variables for the transaction can not be explicitly accounted for - since not observable by both the parties involved and/or verifiable by a third one - in the contract, the adoption of

[1]Our analysis treats *screening* and *sorting* as interchangeable terms: they both capture the design of a direct mechanism to elicit information from unobservable types.

complete arrangements does not offer an efficient solution to the problems arising from the asymmetric distribution of information (e.g. Holmstrom and Milgrom, 1992; Bernheim and Whinston, 1998).

The same conclusion applies, a fortiori, when the agent is acting in an (imperfectly) competitive market. In fact, while in the case of sequential monopolies the provision of contractual restriction over the agent's behavior lowers the informational rent to be granted to the latter (e.g. Gal-Or, 1991), under (imperfect) competition in the downstream market the employment of an inclusive agreement would adversely affect the ability of retailers to efficiently react to his competitor's decisions and, more generally, to possible changes in the market environment[2]. In this setting, the possibility for the retailer to incur losses in terms of profits or market share generates an incentive to falsely reveal private information with the aim of seizing the informational rent and (partially) narrowing the expected adverse outcome. When, by contrast, the agent enjoys greater discretion as granted by the contractual agreement and has a residual claim on the (net) profits from selling, the ability to engage properly in competitive behavior creates stronger incentives to truthful information disclosure. Under these circumstances, fewer (binding) incentive compatibility requirements will enter the second best contract and the resulting equilibrium allocation will be characterized by a weaker distortion with respect to the adoption of (more) complete contracts, which may rather fail to ensure self-selection.

The present paper addresses these issues within an agency framework which captures the relationship between a manufacturer (principal) which produces an intermediate good in an upstream market and a retailer (agent) that sells the same good in a downstream market where he competes with a vertically integrated structure. Retailers possess private knowledge about the uncertain downstream demands, which is payoff-relevant (adverse selection problem), while the agent in the hierarchy retains the right of engaging in unverifiable demand-enhancing activities (moral hazard problem). Optimal contracts are of two alternative forms, that differ with respect to the number of variables over which the principal holds direct and/or indirect control through contractual prescriptions. Under *Quantity Fixing*, the manufacturer imposes the achievement of specific sales targets on his partner. As a consequence, the agent is left free to set the selling price in the retail market and can exert the effort level that maximizes his utility. With *Resale Price Maintenance* contracts, by contrast, the principal also sets the price to be charged in the downstream market. Given the structure of the latter, the choice of a more complete arrangement entails an indirect constraint on the agent's discretion, since it endows the principal with a monitoring instrument on the level of effort exerted by the agent, actually mitigating the risk of opportunistic behavior.

The screening role of incomplete contracts in competing producer-retailer relationships is discussed by contrasting the self-selection effects of incomplete contracts in the standard two-type paradigm with those emerging in an alternative (immaterial) setting, where both the unobservable types face an incentive to misreport. The latter is simply characterized by the assumption of type-dependent reservation utilities, which can be simply motivated by the existence of a positive correlation between the agent's performance in the given principal-agent relationship and his outside opportunity. When the reservation utility of the high-demand type agent is high enough, to ensure participation in the

[2] In this respect, Rey and Tirole (1986) establish that, whenever the seller has superior information relative to the producer, imposing no price restriction for decision-making in the market for final goods can warrant the latter a larger surplus.

contract the principal may be forced to offer more attractive contractual terms, which could overturn the losses that the low-demand type incurs in the current relationship should he choose to falsely report his own type (countervailing incentives). Hence, both agents can in principle gain from falsely revealing their private information to the principal. As a main result, we will show that, while QF contracts always induce truthful revelation, irrespective of the presence of countervailing incentives, RPM arrangements fail to do so under several parameterizations of the model. Such contracts are well understood as useful devices to handle information free-riding by retailers or to help deal with double-marginalization issues; our findings suggest that RPM arrangements should not be used to deal with asymmetric information problems that may arise in complex industry relationships.

The remaining paper proceeds as follows. The next section briefly reviews the theoretical contributions that have inspired the present analysis. Section 3 sets up the basic model; the complete information equilibrium, which serves as the natural benchmark for a critical evaluation of the paper's findings, is derived in section 4, while section 5 is devoted to the analysis of the classical asymmetric information case. Section 6 studies the countervailing incentives case. The strategic value of contractual incompleteness as a screening device is identified and discussed in section 7. Section 8 offers concluding remarks. For ease of exposition, all the proofs and other technical details are reported in the Appendix.

2 Reference literature

This paper is related to several strands of literature. A first one is represented by the studies on contracting in vertical intra-firm relations. Starting with Spengler (1950) and Telser (1960), the object of these analyses has mainly been the relationship between the existence of vertical restraints and the welfare properties of agreements between independent actors. The conclusions reached by scholarly work in the area over the years are far from being unambiguous; contributions showing that any type of restrictions imposed on downstream firms have the detrimental effect of hindering competition and creating substantial welfare losses, have been challenged by studies emphasizing the potential for beneficial effects of vertical restraints for both the contractual parties and the consumers of final goods[3]. On a different account, several recent contributions have focused on the relationship between vertical restrictions and the degree of the informational problem which characterizes the relationship. Gal-Or (1991) shows that, in a context of successive monopolies, price restrictions reduce the dimensionality of the adverse selection problem and help to improve production efficiency as well as consumer welfare.

New interesting results have been obtained in this area by considering the possibility of moral hazard. Martimort and Piccolo (2007) compare the (private and social) effects of the usage of contracts with varying degrees of completeness, and find that, although the manufacturer always prefers a more complete agreement, the effect of price restrictions on consumers welfare is ambiguous and depends on how the choice of contractual arrangements - via its effect on the agent's effort decisions - influences the willingness to pay for end users. Kastl et al. (2011) complement these findings by challenging

[3] A widespread argument in this regard is that price restrictions prevent the phenomenon of double marginalization which is typical of successive monopolies, and can therefore improve the production efficiency of the transaction.

the view that vertical price control proves beneficial to consumers as it generates lower input supply distortions. In this regard, our paper abstracts entirely from the analysis of the welfare implications of different contractual arrangements as its core objective is to emphasize the crucial role of contractual (in)completeness as a screening device in the presence of both adverse selection and moral hazard problems.

The main theoretical reference of the paper is naturally represented by the recent literature on the strategic value of contractual incompleteness in specific agency relationships (e.g. Martimort and Piccolo, 2010; Kastl et al., 2011). In contrast to the predictions of the conventional theory of incentives, according to which only a contingent agreement is able to replicate the first best outcome, these contributions emphasize the existence of the counteracting role of contractual incompleteness in providing the principal with crucial strategic advantages that might compensate him for any inefficiencies related to lower degrees of control over their partners.

The idea that the principal can take advantage of contractual incompleteness to influence the agent's conduct has received attention since the seminal contribution of Holmstrom and Milgrom (1992), who show that, in the presence of non-observability and/or non-verifiability of some of the relevant variables for the transaction, a greater degree of incompleteness may lessen the agent's incentive toward distorting his choices in favor of measurable aspects of performance and at the expense of the more important but not directly monitorable ones. In the same vein, Bernheim and Whinston (1998) argue that contractual incompleteness can lead to the adoption of more efficient choices because it promotes the functioning of the implicit component of the agreement and encourages cooperative behavior by both parties.

Even when the exploitation of less restrictive contract generates a higher risk of opportunistic behavior on the part of the agent, the principal may still benefit from strategically relinquishing one or more of the available screening/monitoring devices. Martimort and Piccolo (2010) demonstrate that, in the presence of an imperfectly competitive market for final goods, the principal might deliberately choose to abandon an instrument of control if the effort choices of the agent affect the willingness to pay of consumers in the downstream market and the behavior of competitors. The main insight is that, under these circumstances, the loss borne by the principal in terms of larger informational rent granted to the retailer may well be outweighed by a more advantageous distribution of market shares. The analysis in this paper borrows the model proposed by Martimort and Piccolo (2010) and the procedures used therein, yet it focuses on a quite different aspect of the agency relationships, namely the ability of contractual incompleteness to serve as a screening device by influencing the information revelation strategies of the agent, and the consequent opportunity of resorting to less binding agreements to promote the achievement of full separating equilibria.

The existing scholarly work on the linkage between the degree of contractual completeness and the disclosure of private information differ from the present one in several respects. This strand of literature provides an informational rationale for the use of incomplete contracts as the latter allow to sensibly reduce the opportunities of renogotiation of the original agreement, hence influencing positively the revelation strategies as well as the investment choices of parties (Dewatripont and Maskin, 1990, 1995). At the same time, contractual incompleteness minimizes the likelihood of sending an informative signal to others on the relevant features of the transaction and of the market in which the same takes place (Dessì, 2007). The basic idea behind these studies is that the amount of information which is (directly or indirectly) disclosed with the execution of the contract increases as the degree of contractual completeness deepens. The findings of this paper point exactly to the opposite direction, as they suggest that the use of less detailed contracts may foster the dissemination of new information in both direct (by encouraging the agent to truthfully report his private information), and indirect (by allowing ex-post deduction of new information on the agent via simple inspection of performance) ways.

The informative value of contractual incompleteness is underlined also by Allen and Gale (1992) and Spier (1992) in signaling models. In this context, a higher level of completeness can be interpreted by the agent as a signal of the principal's willingness to shield himself from potentially adverse scenarios by sharing the risk with his partner, while incomplete contracts may rather signal the willingness to bear any risk, which could be interpreted as a relatively low likelihood of negative events. In this paper, a screening model is considered, in which the designer of the contract is the uninformed party, and contractual incompleteness is exploited to induce truthful revelation of the agent's private information, by relying on the need for efficient competition on the downstream market.

The model's predictions also differ significantly from those of Allen and Gale (1992), in which the use of contracts with missing contingencies as a signaling mechanism necessarily causes a pooling-type equilibrium in the non-contingent contract. Our analysis, by contrast, shows that less binding agreements are able to guarantee the separation of unobservable types at equilibrium.

Another key difference lies in the channels through which contractual incompleteness influences the nature of equilibria. In Spier (1992), the degree of completeness configures a relevant constituent of agreements only for intermediate levels of transaction costs, since for extreme levels the trade-off between risk sharing and type reporting is addressed by the principal by means of different instruments. In our model, the informational value of incomplete contracts becomes relevant depending on the agent's effort cost, as well as on the (private versus cooperative) nature of the latter and the existing relationship between the goods sold in the downstream market.

3 The model

3.1 Basic setting and assumptions

We consider a simple industry consisting of two retailers $i = 1, 2$, each of which produces a final output using an intermediate input provided by exclusive upstream suppliers. The output is to be sold in the downstream market where the retailers compete using constant marginal costs technologies, which are normalized to zero. We assume that retailer $i = 1$ purchases the intermediate good from an independent manufacturer, while retailer $i = 2$ operates within a vertically integrated structure and hence obtains the input without bearing any cost[4].

[4]While the paper's focus is on the optimality of alternative contractual arrangements in a competitive environment, we emphasize that none of the results derived in this paper relies on retaining the vertically integrated retail operations alongside a vertically separated industry. Importantly, this assumption does not create any further information source

The election of this particular setting can be motivated as follows. On the one hand, introducing a manufacturer-retailer hierarchy allows to easily identify the internal effects of the asymmetric distribution of information and, in particular, of the trade-off between control and efficiency faced by the principal when determining the optimal degree of completeness of the delegation contract. On the other, the comparison with a vertically integrated structure, rather than with a competing hierarchical relationship, offers the twofold advantage of simplifying the analysis sensibly, also with no loss of generality, and quantifying the impact of the agency (contractual) problem on the equilibrium allocation, which in turn can be consistently contrasted with the benchmark case of complete information[5].

The system of (linear) inverse demand functions is given by:

$$p_1(\theta, e, q_1, q_2) = \theta + e(\theta) - q_1(\theta) + \rho q_2(\theta), \tag{1}$$

and

$$p_2(\theta, e, q_2, q_1) = \theta + \sigma e(\theta) - q_2(\theta) + \rho q_1(\theta), \tag{2}$$

where:

- p_i denotes the retail price level charged for product i in the downstream market, with $i = 1, 2$;
- θ is a demand parameter, which is observed by retailers only, with $\theta \in \Theta := \{\underline{\theta}, \overline{\theta}\}$ and $\Delta\theta := \overline{\theta} - \underline{\theta} > 0$;
- e captures an unverifiable activity (effort) performed by the agent to influence the demand for final goods. This variable captures a series of activities[6] that may affect the outcome of competition both directly, by acting on willingness to pay of consumers, and indirectly, by influencing the market performance of the competitor. We assume that the level of e is not observable by both the principal and the competitor, and that exerting a nonzero level of effort generates disutility $\Psi(e(\theta)) = \frac{\psi e^2(\theta)}{2}$, $\psi > 0$;
- σ is a parameter that captures the external effects of the agent's effort on the demand faced by the competitor. If $\sigma > 0$, the effort displays a cooperative value and therefore influences positively the competitor's demand of goods; if $\sigma < 0$, by contrast, the effort adversely affects the competitor's demand, while no effect arises when $\sigma = 0$. To guarantee that own-effort effects exceed cross ones in the competitor's demand (2), we assume that $|\sigma| \leq 1$;
- ρ is a parameter that measures the degree of product differentiation: $\rho > 0$ means that the goods are complements, whereas $\rho < 0$ defines substitutes. Under $\rho = 0$, the goods are in no relationship with each other and the two sellers operate as monopolists. Again, to ensure that own-price effects are larger than cross ones, it is assumed that $|\rho| \leq 1$.

For ease of exposition, given the two-type nature of the agency model, we will refer to the realized state of nature $\theta \in \Theta$ as the agent's low-demand ($\underline{\theta}$) or high-demand ($\overline{\theta}$) type.

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for the principal in the vertical hierarchy.

[5] In fact, the reaction function of the competitor is independent of alternative assumptions about the distribution of information within the hierarchy or about the contractual arrangement chosen by the principal, as the integrated structure does not face any agency problem.

[6] Consider, for example, investment in advertising and, more generally, all the activities that may influence the propensity of consumers to buy.

3.2 Incentive mechanisms within the hierarchy

We assume that the principal has two alternative contractual arrangements (direct mechanisms) available to set up the vertical relationship. Under *Quantity Fixing* (QF), the producer designs a menu of contracts of the form $\{q_1(\hat{\theta}), t_1(\hat{\theta})\}_{\hat{\theta}\in\Theta}$, where q_1 represents the quantity to be sold and t_1 denotes the transfer requested for the furniture of the intermediate good, both contingent on the agent's report about the realization of demand, captured by $\hat{\theta}$. Under *Resale Price Maintenance* (RPM), the principal offers a menu of contracts of the form $\{q_1(\hat{\theta}), p_1(\hat{\theta}), t_1(\hat{\theta})\}_{\hat{\theta}\in\Theta}$, where $p_1(\hat{\theta})$ is the price to be charged in the downstream market as a function of the agent's report about the realization of demand. Both the principal and the agent are risk-neutral.

Note that, while the RPM contract endows the principal with a twofold instrument to monitor the level of effort exerted by the agent, the QF arrangement does not constrain pricing decisions. Although more sophisticated, an RPM contract can not be regarded as a complete agreement; as emphasized by Martimort (1996), every secret contract between the producer and the retailer is necessarily incomplete because, while specifying the tasks of the agent, the competitor's choices cannot be contracted upon.

3.3 Timing

Once the contractual regime is chosen and announced[7], the timing of the principal-agent model is as follows:

- $t = 0$: the state of demand $\theta \in \Theta$ is realized and observed only by the agent and the integrated structure;
- $t = 1$: the principal offers a menu of contracts on a take-it-or-leave-it basis, which belong to the elected class (QF or RPM);
- $t = 2$: the agent either rejects or accepts the offer. In the former case, the seller obtains his reservation utility and the integrated structure operates as a monopolist on the market. In the latter case, the agent selects a specific item out of the menu contingent on the report $\hat{\theta}$ about the realization of demand; then, the optimal level of effort is exerted, retail market competition takes place and payments are made upon observation of selling performances.

4 Equilibrium under complete information

Let the demand parameter θ be common knowledge among all the actors involved. Irrespective of the actual contractual mode, the optimal contract will be type-dependent and yield the efficient outcome of vertical integration.

4.1 The vertically integrated structure

Under zero marginal production costs, the profits of the vertically integrated structure are simply given by the market revenues: for any pair $\{e(\theta), q_1(\theta)\}_{\theta\in\Theta}$ implemented by the competitor, the integrated

[7] The model considers secret contracts: only the choice of the contractual regime is publicly announced (or verifiable by the competitor), while the specific terms of the agreement are known to the contractual parties only.

structure solves the program:

$$P_2 : \max_{q_2(\theta)} \left[\left(\theta + \sigma e\left(\theta\right) - q_2\left(\theta\right) + \rho q_1\left(\theta\right) \right) q_2\left(\theta\right) \right],$$

which yields, contingent on the realization of $\theta \in \Theta$, the following reaction function:

$$q_2\left(\theta\right) = \frac{\theta + \sigma e\left(\theta\right) + \rho q_1\left(\theta\right)}{2}. \tag{3}$$

The cross-effects of the effort exerted by the agent in the hierarchy and the quantity sold by the latter on the demand are captured by the signs of the parameters σ and ρ. Remarkably, the choice of the contractual arrangement within the hierarchy has no impact on the reaction function of the integrated structure, which can then be exploited to derive the equilibrium levels of quantity and effort both under QF and RPM contracts.

4.2 The hierarchical producer-retailer relationship

The producer seeks to maximize his profit, given by the transfer received from the seller, under the latter's participation constraint (PC). The constant (type-independent) reservation utility is normalized to zero.

The agent's expected utility is represented by the revenues from selling in the downstream market net of the costs incurred to carry out the extra-production activities and to purchase the intermediate input in the upstream market. Specifically:

$$U\left(\theta\right) = p_1\left(\theta\right) q_1\left(\theta\right) - \Psi\left(e\left(\theta\right)\right) - t\left(\theta\right), \tag{4}$$

while the seller's PC is given by:

$$PC: \quad U\left(\theta\right) \geq 0.$$

Under either of the contractual arrangements, the principal is faced with the following program:

$$\begin{array}{lcl} P_1 & : & \max\limits_{e(\theta) q_1(\theta)} t\left(\theta\right) \\ s.t. & & \text{PC.} \end{array}$$

Quantity fixing Using (1) in (4), the agent's utility can be written as:

$$U\left(\theta\right) = \left[\left(\theta + e\left(\theta\right) - q_1\left(\theta\right) + \rho q_2\left(\theta\right) \right) q_1\left(\theta\right) - \Psi\left(e\left(\theta\right)\right) - t\left(\theta\right) \right], \tag{5}$$

from which the following first and second order conditions on the optimal level of effort are obtained:

$$e\left(\theta\right) = \frac{q_1\left(\theta\right)}{\psi} \tag{6}$$

and

$$\psi > \frac{1}{2}. \tag{7}$$

Making use of (5), the designed transfer can be expressed as a function of the agent's expected utility to yield:

$$P_1^Q : \max_{q_1(\theta)} [(\theta + e(\theta) - q_1(\theta) + \rho q_2(\theta)) q_1(\theta) - \Psi(e(\theta)) - U(\theta)]$$

$$s.t. \quad \mathrm{U}(\theta) \geq 0,$$

and, for any realization of $\theta \in \Theta$, the reaction function is given by:

$$q_1(\theta) = \frac{\theta + e(\theta) + \rho q_2(\theta)}{2}. \tag{8}$$

Apparently, the quantity sold in the downstream market is a function of the demand parameter, as well as of the effort exerted by the agent and the quantity offered by the competitor, whose effects are governed by the existing relationship between the two final goods.

Exploiting the reaction functions (3) and (8), and the optimal level of effort (6), it is straightforward to derive the equilibrium quantities and effort under complete information and QF contracts[8].

Resale price maintenance When the selling price in the downstream market is set by the principal, the optimal effort level can be readily obtained from the inverse demand function (1):

$$e(\theta) = p_1(\theta) + q_1(\theta) - \rho q_2(\theta) - \theta, \tag{9}$$

while the agent's utility can be expressed by integrating (1) and (9) into (4):

$$U(\theta) = [p_1(\theta) q_1(\theta) - \Psi(p_1(\theta) + q_1(\theta) - \rho q_2(\theta) - \theta) - t(\theta)]. \tag{10}$$

The first order conditions with respect to price and quantity are given by, respectively[9]:

$$q_1(\theta) = \Psi'(e(\theta))$$

and

$$p_1(\theta) = \Psi'(e(\theta)),$$

from which we obtain:

$$q_1(\theta) = p_1(\theta) = \psi e(\theta). \tag{11}$$

The principal's optimization program can be then recast in the following form:

$$P_1^R : \max_{q_1(\theta), p_1(\theta)} [p_1(\theta) q_1(\theta) - \Psi(p_1(\theta) + q_1(\theta) - \rho q_2(\theta) - \theta) - U(\theta)]$$

[8]See Appendix A.

[9]The second order condition is the same as under QF, see (7).

$$s.t. \quad \mathrm{U}(\theta) \geq 0.$$

The equilibrium levels of effort, price and quantity under complete information and RPM contracts are obtained using the reaction function of the vertically integrated structure (3) and the first order conditions for price and quantity (11)[10].

Proposition 1. *Let the superscript j denote the QF (j=Q) or the RPM (j=R) contractual regime, respectively. Under complete information, the following hold true:*
(i) $q_1^Q(\theta) = q_1^R(\theta) \;\; \forall\theta \in \Theta$;
(ii) $e^Q(\theta) \;\; = e^R(\theta) \;\; \forall\theta \in \Theta$;
(iii) $q_2^Q(\theta) = q_2^R(\theta) \;\; \forall\theta \in \Theta$.

The equilibrium allocation is not influenced by the degree of contractual completeness. Irrespective of the contractual arrangements in place, the agent's effort choices are always aligned with those of the principal and no loss of efficiency arises from keeping the contract silent with respect to the price instrument.

5 Equilibrium under asymmetric information

The asymmetric distribution of information introduces a vertical externality between the producer and the retailer whose main effect is essentially twofold (Martimort and Piccolo, 2010). On the one hand, the agency problem can not be solved by resorting to the (more) sophisticated RPM contracts. While the availability of additional screening and monitoring tools constrains the degree of discretion enjoyed by the agent, mitigating the asymmetric information problem, RPM contracts still entail efficiency distortions with respect to the first best outcome since, under private knowledge of the demand parameter θ, the direct control over the price instrument does not allow the principal to disentangle the effect of the latter from the effort choice of the agent on the market demand, and hence entails a nonzero information rent which is required for truthful information revelation. As we demonstrate in the following, although this conclusion holds true irrespective of the elected contractual arrangement, the specific design of the contract does influence the magnitude of the distortion induced in the equilibrium allocation.

The second implication of the vertical externality is that the principal can leverage strategically the agent's superior knowledge about the market demand and the resulting effort choices to gain influence on the competitor's behavior in the downstream market, and hence on the outcome of competition in terms of equilibrium market shares. This in turn creates an incentive to exploit a less binding agreement in the hierarchical relationship, which must be traded off against the higher information rent to be granted to the retailer.

Our model's predictions strongly support these findings. Most importantly, they also establish the existence of an additional strategic value of contractual incompleteness, namely the ability of incomplete (less complete) contracts to serve as a powerful screening device under joint presence of adverse selection and moral hazard problems. For ease of exposition, the following analysis assumes

[10] See Appendix A.

that both the principal (in the hierarchy) and the integrated structure assign the same probability weights to the occurrence of the possible states of nature, namely $Pr(\theta = \underline{\theta}) = Pr(\theta = \overline{\theta}) = \frac{1}{2}$. This assumption does not restrict the scope of the analysis and greatly simplifies the evaluation of the key results.

5.1 The vertically integrated structure

Under uncertainty over the realization of the demand parameter θ, for each pair $\{e(\theta), q_1(\theta)\}$ implemented by the agent, the vertical structure solves the problem:

$$\max_{q_2} \frac{1}{2}[(\overline{\theta} + \sigma e(\overline{\theta}) - q_2(\overline{\theta}) + \rho q_1(\overline{\theta})) q_2(\overline{\theta})] + \frac{1}{2}[(\underline{\theta} + \sigma e(\underline{\theta}) - q_2(\underline{\theta}) + \rho q_1(\underline{\theta})) q_2(\underline{\theta})], \quad (12)$$

whereas for each realization $\theta \in \Theta$, the reaction functions are given by:

$$q_2(\theta) = \frac{\theta + \sigma e(\theta) + \rho q_1(\theta)}{2}. \quad (13)$$

Since the uncertainty on the realization of the demand generates no incentive to deviate, the reaction functions are not modified with respect to the complete information case, while the distortions induced in the equilibrium demand depend exclusively on the cross-effects from the competitor's behavior and effort choices over the allocation of market shares.

5.2 The hierarchical producer-retailer relationship

Under asymmetric information, the principal is faced with the following optimization program:

$$\begin{aligned} P_1 &: \max_t \frac{1}{2} t(\overline{\theta}) + \frac{1}{2} t(\underline{\theta}) \\ s.t.\ PC &: U(\theta) \geq 0 \\ IC &: U(\theta) \geq U(\widetilde{\theta}), \end{aligned}$$

where $U(\widetilde{\theta})$ indicates the agent's utility from entering the contract and falsely reporting his (demand) type[11]. Remarkably, under this standard version of the problem, only the high-demand agent has an incentive to misreport his type, so as to take advantage of the resulting lower costs of effort: the relevant constraints for the optimal contracting problem under asymmetric information are then represented by the $\overline{\theta}$-agent's incentive constraint and the $\underline{\theta}$-agent's participation constraint, which must be binding at the optimum[12].

Quantity fixing Since the agent is aware of the realization of the demand θ when accepting the contract, his utility function is still represented by (5), and equivalent first and second order conditions on the optimal level of effort hold true (i.e. (6) and (7)).

[11] See Appendix B and Appendix C for the derivation of the IC constraints of the θ-type agent in the presence of QF and RPM contracts, respectively.

[12] This is a standard argument from the theory of incentives (e.g. Laffont and Martimort, 2002).

Using the agent's informational rent to pin down the level of the transfer and the IC constraint of the high-demand type, the principal's problem is[13]:

$$
\begin{aligned}
P_1^Q \quad : \quad \max_{q_1} & \frac{1}{2}[(\overline{\theta} + e(\overline{\theta}) - q_1(\overline{\theta}) + \rho q_2(\overline{\theta}))\, q_1(\overline{\theta}) - \Psi(e(\overline{\theta})) - q_1(\underline{\theta})(\Delta\theta + \rho\Delta q_2(\theta))] + \\
& \frac{1}{2}[(\underline{\theta} + e(\underline{\theta}) - q_1(\underline{\theta}) + \rho q_2(\underline{\theta}))\, q_1(\underline{\theta}) - \Psi(e(\underline{\theta}))]. \qquad (14)
\end{aligned}
$$

where $\Delta q_2(\theta) := q_2(\overline{\theta}) - q_2(\underline{\theta})$. The reaction functions are:

$$
q_1(\overline{\theta}) = \frac{\overline{\theta} + e(\overline{\theta}) + \rho q_2(\overline{\theta})}{2} \qquad (15)
$$

and

$$
q_1(\underline{\theta}) = \frac{\underline{\theta} + e(\underline{\theta}) + \rho q_2(\underline{\theta})}{2} - \frac{(\Delta\theta + \rho\Delta q_2(\theta))}{2}. \qquad (16)
$$

While the optimal level of effort is unaltered with respect to the complete information scenario, the principal is forced to introduce a distortion in the production level assigned to the low-type agent $\underline{\theta}$ to weaken the informational rent obtained by the high-demand type $\overline{\theta}$ when he misreports his private information. The magnitude and the sign of this distortion depend on both the extent of the asymmetric information problem and the effect that uncertainty about the state of demand entails on the production decisions of the vertically integrated structure. This alteration, in turns, rebounds on the competitor's market share and the effort choice of the low-demand agent[14]. Hence, the information rent does not depend exclusively on the level of production requested from the latter, and the sign of the distortion need not be negative for any parameterization of the model. This finding is clearly affected by the assumption of competitive downstream market and by the interaction between adverse selection and moral hazard. The following Lemma clarifies the circumstances under which, at the second best optimum, the menu of contracts involves a downturn output distortion for the low-type agent[15]:

Lemma 1. *Let $q_1^Q(\theta)$, $\theta \in \Theta$ be the output allocation under the QF contract. Then:*

$$
q_1(\overline{\theta}) > q_1(\underline{\theta}) \quad \Leftrightarrow \quad \Delta\theta + \rho\Delta q_2(\theta) > 0
$$

A direct implication of Lemma 1 is the monotonicity of the second-best schedule of outputs under the reported condition[16].

Resale Price Maintenance Assume now the contract explicitly imposes a pricing rule for the agent in the hierarchy. An RPM arrangement endows the principal with a monitoring tool on the level of effort to be exerted by his own agent. The price to be set is obtained from the inverse demand

[13] See Appendix D.

[14] The equilibrium allocation with QF contracts is reported in Appendix F.

[15] See Appendix F for the proof.

[16] However, as it will be made clear in the following, the monotonicity requirement is not necessary for the omitted IC constraint to be satisfied at the second best optimum. See Appendix L.

function (1) and is again given by (9). Since the agent's utility function remains unaltered (10), first order conditions (11) entail, for any $\theta \in \theta$, the equality between quantity and price.

The principal's optimization program can be written as[17].

$$P_1^R \quad : \quad \max_{q_1, e} \frac{1}{2}[\left(\overline{\theta} + e\left(\overline{\theta}\right) - q_1\left(\overline{\theta}\right) + \rho q_2\left(\overline{\theta}\right)\right) q_1\left(\overline{\theta}\right) - \Psi\left(e\left(\overline{\theta}\right)\right) - [\Psi\left(e\left(\underline{\theta}\right)\right) - \Psi(e\left(\underline{\theta}\right) - (\Delta\theta + \rho\Delta q_2(\theta)))] + \frac{1}{2}[(\underline{\theta} + e\left(\underline{\theta}\right) - q_1\left(\underline{\theta}\right) + \rho q_2\left(\underline{\theta}\right))q_1\left(\underline{\theta}\right) - \Psi\left(e\left(\underline{\theta}\right)\right)]. \tag{17}$$

First order conditions with respect to effort and quantity are:

$$q_1\left(\theta\right) = \frac{\theta + e\left(\theta\right) + \rho q_2\left(\theta\right)}{2}, \quad \theta \in \Theta \tag{18}$$

and

$$e\left(\overline{\theta}\right) = \frac{q_1\left(\overline{\theta}\right)}{\psi}, \tag{19}$$

$$e\left(\underline{\theta}\right) = \frac{q_1\left(\underline{\theta}\right)}{\psi} - \frac{(\Delta\theta + \rho\Delta q_2(\theta))}{\psi}. \tag{20}$$

In order to extract the informational rent, the principal induces a distortion in the level of effort - and not in the quantity to be produced - of the agent who faces a low state of demand. Again, the actual sign of the effort distortion relies on the uncertainty about the realization of demand and the cross-effect of such uncertainty on the quantity sold by the vertically integrated structure. In equilibrium, the optimal effort decision will influence the output produced by the low-demand type, whereas the optimal effort exerted by the high-demand type as well as his output level will attain their first best levels[18]. Intuitively, this mechanism - which works differently under the two contractual arrangements - makes it less profitable the false revelation of the agent's private information.

We state then the following:

Corollary 1. *When the high-demand agent has an incentive to misreport his type, the low-demand type will face an output distortion under either contractual regime. This distortion will be negative as long as* $\Delta\theta + \rho\Delta q_2(\theta) > 0$.

6 Asymmetric information and countervailing incentives

This section studies the incidence of countervailing incentives (CI) on the revelation strategies of agents and hence on the optimal design of contractual arrangements. To this end, we slightly modify our basic framework of analysis to allow for type-dependent outside opportunities, i.e.:

$$PC\left(\underline{\theta}\right): \quad U\left(\underline{\theta}\right) \geq 0$$

$$PC\left(\overline{\theta}\right): \quad U\left(\overline{\theta}\right) \geq U_0 > 0$$

[17]See Appendix E.

[18]The equilibrium allocation with RPM contracts is presented in Appendix G.

$$U_0 > (\Delta\theta + \rho\Delta q_2(\theta))\, q_1\left(\overline{\theta}\right)^{CI}$$

where the superscript CI stands for *countervailing incentives*, and denotes the equilibrium allocation for the contractual problem under state-dependent outside opportunities.

In particular, under a sufficiently high reservation utility for the $\overline{\theta}$-agent, participation of latter in the contract may require better contractual terms which in turn become attractive for the low-demand type, who may now benefit from a strictly positive rent. As an example, consider the case where (screened) low-demand agents are precluded from participating into future relationships. If the gains from the possibility of future cooperation are sufficiently large, the low-demand agent may be induced to misreport his type to gain from repeated negotiations with the up-stream producer. In such a situation, (optimal) contract design is especially problematic as the set of incentive feasible contracts may be severely restricted. However, it is plausible to conjecture that a similar scenario generates also a countervailing effect on the high-demand type's revelation strategies as the latter might want to voluntarily give up some of the information rent - which would result in the current relationship from misreporting - to to take part into the continuation game and obtain a strictly positive payoff. The latter remark can be exploited for the optimal design of the incentive mechanism: if the gain from subsequent negotiations is sufficiently large to induce misreporting from the low-demand type, it should also counterbalance the high-demand type's incentive to untruthful revelation in the current relationship. Hence, the principal may conjecture that the relevant constraints for the contracting problem are represented by the high-demand agent's PC and the low-demand one's IC constraint.

We show that the actual effects of countervailing incentives on the equilibrium set crucially depend on the degree of contractual incompleteness. In particular, we establish that the use of QF contracts can always ensure self-selection under CI. In the presence of an RPM contractual regime, by contrast, the equilibrium allocation fails to be incentive compatible under several parameterizations of the basic model; as a consequence, pooling equilibria may arise under CI and RPM contracts.

6.1 The vertically integrated structure

For any $\theta \in \Theta$ and pair $\{e(\theta)\, q_1(\theta)\}$, the optimization program is the same as in the case of standard distortion (12) and then leads to the same reaction functions (13).

6.2 The hierarchical producer-retailer relationship

To show that, in the presence of CI, the principal can exploit contractual incompleteness as a screening device, we follow the standard route and consider the PC of the high-demand type and the IC constraint of the low-demand type as the only relevant constraints for the contractual problem. It will then be checked ex post, using the resulting allocation, that only QF contracts are able to ensure always - i.e., under any parameterization of the model - that the omitted constraints are satisfied. As a consequence, the nature of equilibria depends on the specific contractual arrangement chosen by the producer.

Quantity Fixing It is straightforward to note that the first and second order conditions for the optimal level of effort are unaltered and coincide with (6) and (7). The auxiliary program of the principal can be written as follows[19]:

$$\begin{aligned} P_1 \quad : \quad & \max_{q_1} \frac{1}{2}[\left(\overline{\theta} + e\left(\overline{\theta}\right) - q_1\left(\overline{\theta}\right) + \rho q_2\left(\overline{\theta}\right)\right) q_1\left(\overline{\theta}\right) - \Psi\left(e\left(\overline{\theta}\right)\right) - U_0] + \\ & \frac{1}{2}[\left(\underline{\theta} + e\left(\underline{\theta}\right) - q_1\left(\underline{\theta}\right) + \rho q_2\left(\underline{\theta}\right)\right) q_1\left(\underline{\theta}\right) - \Psi\left(e\left(\underline{\theta}\right)\right) - \left(U_0 - \left(\Delta\theta + \rho\Delta q_2(\theta)\right) q_1\left(\overline{\theta}\right)\right)]. \end{aligned} \tag{21}$$

The reaction functions associated with the previous problem are given, for any $\theta \in \Theta$, by:

$$q_1\left(\overline{\theta}\right) = \frac{\left(\overline{\theta} + e\left(\overline{\theta}\right) + \rho q_2\left(\overline{\theta}\right)\right)}{2} + \frac{\left(\Delta\theta + \rho\Delta q_2(\theta)\right)}{2} \tag{22}$$

and

$$q_1\left(\underline{\theta}\right) = \frac{\left(\underline{\theta} + e\left(\underline{\theta}\right) + \rho q_2\left(\underline{\theta}\right)\right)}{2}. \tag{23}$$

Unlike the standard case, the low-demand type agent is required the first best production quantity while the quantity for the high-demand type proves distorted. This distortion involves an indirect effect on the actual level of effort of the high-demand type, which stems from an independent adjustment of the retailer to the requested allocation rather than from a direct contractual provision[20].

Resale Price Maintenance The level of effort exerted by the agent is obtained from the inverse demand function (1), and hence remains identical to that derived in the full information case (see (9)), as do the agent's expected utility (10) and first order conditions (11). The auxiliary program of the principal is then[21]:

$$\begin{aligned} P_1^R \quad : \quad & \max_{q_1(\cdot), e(\cdot)} \frac{1}{2}[\left(\overline{\theta} + e\left(\overline{\theta}\right) - q_1\left(\overline{\theta}\right) + \rho q_2\left(\overline{\theta}\right)\right) q_1\left(\overline{\theta}\right) - \Psi\left(e\left(\overline{\theta}\right)\right) - U_0] + \\ & \frac{1}{2}[\left(\underline{\theta} + e\left(\underline{\theta}\right) - q_1\left(\underline{\theta}\right) + \rho q_2\left(\underline{\theta}\right)\right) q_1\left(\underline{\theta}\right) - \left(e\left(\underline{\theta}\right)\right) \\ & \Psi - \left(U_0 + \Psi\left(e\left(\overline{\theta}\right)\right) - \Psi(e\left(\overline{\theta}\right)) + \left(\Delta\theta + \rho\Delta q_2(\theta)\right) q_1(\overline{\theta})\right)], \end{aligned} \tag{24}$$

and for any $\theta \in \Theta$, the first order conditions with respect to effort and quantity are:

$$q_1\left(\theta\right) = \frac{\theta + e\left(\theta\right) + \rho q_2\left(\theta\right)}{2}, \tag{25}$$

$$e\left(\overline{\theta}\right) = \frac{q_1\left(\overline{\theta}\right)}{\psi} + \frac{\left(\Delta\theta + \rho\Delta q_2(\theta)\right)}{\psi} \tag{26}$$

and

$$e\left(\underline{\theta}\right) = \frac{q_1\left(\underline{\theta}\right)}{\psi}. \tag{27}$$

[19] See Appendix D.
[20] The equilibrium allocation with QF contracts in the presence of CI is reported in Appendix H.
[21] See Appendix E.

As in the standard asymmetric information case, when using RPM contracts the principal relies on the effort requirement rather than on quantity provisions to extract the informational rent. However, the presence of CI induces an effort distortion for the high-demand type, as well as a shift (in the same direction) of the quantity required to the latter[22].

The following corollary summarizes these observations:

Corollary 2. *When the low-demand agent has an incentive to misreport his type, the high-demand type will face an output distortion under either contractual regime. This distortion will be positive as long as* $\Delta\theta + \Delta\rho q_2(\theta) > 0$.

Note that the previous result holds true irrespective of the contractual arrangement in place, i.e. of whether the principal exercises direct control on the quantity or rather on the effort requirement.

7 Contractual incompleteness and screening

This section discusses the nexus between the degree of contractual completeness and the characterization of equilibria. To this end, we need to verify ex post that the omitted constraints from the auxiliary programs studied in the previous sections, i.e. those not relevant for the contractual problem, are indeed fulfilled. This process will unambiguously identify the circumstances under which a less binding arrangement such as the QF contract grant the principal efficiency gains - arising from its screening ability - which balance the loss incurred from relinquishing on an available monitoring tool.

The next propositions posit the main findings of our analysis[23]:

Proposition 2. *In the presence of standard distortion,* $U(\theta) \geq U(\widetilde{\theta})$ $\forall \theta \in \Theta$, *irrespective of the elected contractual arrangement.*

The interpretation of this result is straightforward. Under standard distortion, the low-demand type has no incentive to misrepresent his private information, as claiming to cope with a high level of demand, he would need to exert a level of effort which proves different from the optimal one and hence incur into excessive losses. This effect is further amplified when the distortion introduced by the principal generates an underproduction equilibrium result for the low-demand type. As a consequence, regardless of the contractual arrangement employed by the principal, truthful information disclosure represents an optimal strategy for the agent operating in a market characterized by a low realization of demand and no incentive mechanism for correct reporting is needed.

Proposition 3. *In the presence of countervailing incentives,* $U(\theta) \geq U(\widetilde{\theta})$ $\forall \theta \in \Theta$ *obtains:*
· *for any model's parameterization, with QF contracts;*
· *if and only if* $\psi > \max\{\frac{1}{2}, \frac{\rho - 4\sigma\rho - 2\rho^2 + 2}{2(2+\rho)}\}$, *with RPM contracts.*

The incentive effect for the revelation strategies of agents is strongly influenced by the choice of the contractual regime. With QF contracts, the agent has no bounds on the level of effort to exert,

[22] The equilibrium allocation with RPM contracts in the presence of CI is reported in Appendix I.
[23] See Appendix L for a formal proof of Propositions 2 and 3.

given the quantity required in the contract. In this case, the distortion in the equilibrium quantity of the high-demand retailer has the same effect of the standard distortion introduced in the second best contract: when the gap between the production levels associated with the two possible states of nature changes, the informational rent enjoyed by the agent under false revelation is modified accordingly. In fact, when the retailer is left free to select the optimal level of effort, the gain from lowering the effort exertion are outweighed by the gain resulting from a more advantageous distribution of market shares. Since the agent is residual claimant of the outcome of the extra-production activities intended to increase the demand in the retail market, a strong incentive exists to exert a larger level of effort.

In the case of RPM contracts, by contrast, the level of effort exercised by the agent is indirectly controlled by the principal and can not be modified by the former. Under these circumstances, the revelation strategy of the high-demand type is ambiguous and truthful information disclosure obtains if and only if the net gain from exerting a higher level of effort outperforms the informational rent from misreporting; conversely, when the exertion of a lower level of effort allows a reduction of the connected disutility, false revelation can grant a higher profit that might counterbalance the potential loss arising from non-participation in the subsequent relationship(s). This condition in turn relies on the (private or cooperative) nature of the effort and the market relation between the competing goods. In particular, when ρ and σ have the same sign, the gains from a more profitable allocation of market shares exceed the costs from effort disutility, and truthful revelation occurs[24].

This simple result can also be related to the notion of *ratchet effect* (e.g. Baron and Besanko, 1987; Laffont and Tirole, 1988). When defining his revelation strategies, the agent anticipates the possibility that the principal may use the information disclosed to design a new continuation equilibrium for the subsequent relationship(s); hence, a truthful revelation in the first period may nullify the informative advantage of the agent in all the possible following phases of the game. When no informative advantage in the second period is related to the agent's type, participation in the subsequent relationship(s) is not able to compensate the loss generated by the non-optimal level of effort exerted in the first one and, hence, untruthful disclosure can still configure a dominant strategy[25]. The following Corollary summarizes our main finding:

Corollary 3. *When $\frac{1}{2} < \psi < \frac{\rho - 4\sigma\rho - 2\rho^2 + 2}{2(2+\rho)}$, full separating equilibria can fail to exist under RPM contracts*[26].

8 Conclusion

This paper analyzes the screening role of incomplete contracts in a simple producer-retailer economy characterized by adverse selection, moral hazard and (imperfect) competition in the downstream

[24] As shown in Martimort and Piccolo (2010), when ρ and σ have the same sign, QF contracts yield larger profits to the principal than RPM arrangements; hence, even when the latter can be used to separate different types of agents, the principal may still wish to exploit QF contracts to set up the hierarchical relationship.

[25] A fortiori, the same consideration applies for the case of QF contracts. In this case, however, the agent is residual claimant of the benefits from the demand-enhancing activities, and hence can still obtain positive profits from all the relationships while not enjoying any informative advantage in the subsequent one(s).

[26] Given the assumed ranges for the involved parameters, this condition can occur only when $\rho > 0$ and $\sigma < -1/2$ or when $\rho < 0$ and $\sigma > 1/2$.

market. As a main result, it is shown that the design of the contractual arrangement has an inherent strategic value as a screening device. In fact, while a less restrictive contractual regime may promote agent's misbehavior and amplify the information rent problem, it can also exploit the agent's superior knowledge of market conditions to foster the adoption of more efficient production and effort choices. This in turn generates stronger incentives to truthful information disclosure and hence ensures self-selection of unobservable types, even when both face misreporting incentives.

When, by contrast, the agent's effort choices are (indirectly) determined by contractual provisions, the high-demand type may prove unable to take advantage of the positive externalities prevailing in the downstream market, and hence choose to falsely report his type. As a consequence, (more) complete contracts may well fail to separate unobservable types, exacerbating the efficiency loss of the transaction.

The model is written in the simplest form that still conveys the key message. Nonetheless, while able to generate interesting predictions for the design of optimal contracts in (a class of) producer-retailer economies, the simplicity of the two-type setup is not without cost, as its basics prescriptions may not fully generalize to screening problems in more complex relationships. We believe this aspect can represent a fruitful venue for future research.

Appendix

Appendix A: Equilibrium with complete information For any $\theta \in \Theta$, the equilibrium allocation under QF contracts is obtained using the reaction functions of the two competitors (3)-(8) and the first order condition on the effort (6), while in the case of RPM contracts is is obtained using (3) and the first order conditions for price and quantity (11):

$$q_1^Q(\theta) = q_1^R(\theta) = \frac{\theta(2+\rho)\psi}{(4\psi - \psi\rho^2 - \rho\sigma - 2)},$$

$$e_1^Q(\theta) = e_1^R(\theta) = \frac{\theta(2+\rho)}{(4\psi - \psi\rho^2 - \rho\sigma - 2)},$$

$$q_2^Q(\theta) = q_2^R(\theta) = \frac{\theta(2\psi + \psi\rho + \sigma - 1)}{(4\psi - \psi\rho^2 - \rho\sigma - 2)}.$$

Under complete information, the degree of contractual completeness has no role on the equilibrium allocation.

Appendix B: Derivation of the IC constraints with QF contracts Given the agent's utility function (5), the IC constraint is:

$$\begin{aligned} IC(\theta) \quad &: \quad [(\theta + e(\theta) - q_1(\theta) + \rho q_2(\theta))\, q_1(\theta) - \Psi(e(\theta)) - t(\theta)] \\ &\geq \quad [(\theta + e(\widetilde{\theta}) - q_1(\widetilde{\theta}) + \rho q_2(\theta)) q_1(\widetilde{\theta}) - \Psi(e(\widetilde{\theta})) - t(\widetilde{\theta})], \end{aligned}$$

where θ represents the actual realization of demand and $\widetilde{\theta}$ denotes the false agent's report. Hence, the high-demand agent's IC constraint is:

$$\begin{aligned} IC(\overline{\theta}) \quad &: \quad [(\overline{\theta} + e(\overline{\theta}) - q_1(\overline{\theta}) + \rho q_2(\overline{\theta})) q_1(\overline{\theta}) - \Psi(e(\overline{\theta})) - t(\overline{\theta})] \\ &\geq \quad [(\overline{\theta} + e(\underline{\theta}) - q_1(\underline{\theta}) + \rho q_2(\overline{\theta})) q_1(\underline{\theta}) - \Psi(e(\underline{\theta})) - t(\underline{\theta})]. \end{aligned}$$

The left-hand side is the utility from truthful type revelation. The right-hand side can be rewritten as a function of the low-demand agent's utility and of a term capturing the scope and impact of the asymmetric distribution of information, i.e.:

$$U_1^Q(\overline{\theta}) \geq U^Q(\underline{\theta}) + (\Delta\theta + \rho\Delta q_2(\theta))\, q_1(\underline{\theta}). \tag{28}$$

It must be emphasized that the term $\Delta\theta + \rho\Delta q_2(\theta)$ captures two distinct features of the model: first, the standard information rent, that the $\overline{\theta}$-agent benefits from thanks to his ability to possibly mimic the low-demand type; second, the information rent which stems from the competitive environment in which the retailer operates, and represented by the differences in the competitor's production levels with respect to the different states of natures $\theta \in \Theta$. Remarkably, even when the contract entails a non-zero quantity for the low-demand type, i.e. $q_1(\underline{\theta}) > 0$, the overall term capturing the information rent problem need not be strictly positive for any parameterization of the model.

Similarly, the low-demand agent's IC constraint is:

$$U^Q(\underline{\theta}) \geq U^Q(\overline{\theta}) - (\Delta\theta + \rho\Delta q_2(\theta))\, q_1(\overline{\theta}). \tag{29}$$

Appendix C: Derivation of the IC constraints with RPM contracts The generic formulation of the IC constraint is:

$$\begin{aligned} IC(\theta) \quad &: \quad p_1(\theta)\, q_1(\theta) - \Psi(p_1(\theta) + q_1(\theta) - \rho q_2(\theta) - \theta) - t(\theta) \\ &\geq \quad p_1(\widetilde{\theta}) q_1(\widetilde{\theta}) - \Psi(p_1(\widetilde{\theta}) + q_1(\widetilde{\theta}) - \rho q_2(\theta) - \theta) - t(\widetilde{\theta}). \end{aligned}$$

The high-demand agent's IC can be written as:

$$\begin{aligned} IC(\overline{\theta}) \quad &: \quad p_1(\overline{\theta}) q_1(\overline{\theta}) - \Psi(p_1(\overline{\theta}) + q_1(\overline{\theta}) - \rho q_2(\overline{\theta}) - \overline{\theta}) - t(\overline{\theta}) \\ &\geq \quad p_1(\underline{\theta}) q_1(\underline{\theta}) - \Psi(p_1(\underline{\theta}) + q_1(\underline{\theta}) - \rho q_2(\overline{\theta}) - \overline{\theta}) - t(\underline{\theta}), \end{aligned}$$

or

$$U^R(\overline{\theta}) \geq U^R(\underline{\theta}) + \Psi(e(\underline{\theta})) - \Psi(e(\underline{\theta}) - (\Delta\theta + \rho\Delta q_2(\theta)). \tag{30}$$

Similarly, the low-demand agent's IC constraint is:

$$U^R(\underline{\theta}) \geq U^R(\overline{\theta}) + \Psi\left(e(\overline{\theta})\right) - \Psi(e(\overline{\theta}) + (\Delta\theta + \rho\Delta q_2(\theta)) \tag{31}$$

Appendix D: Derivation of the principal's program with QF contracts Using (5) and considering the two possible realizations of demand, the principal's constrained optimization program is

$$\begin{aligned} P_1^Q \quad : \quad & \max_{q_1(\cdot)} \frac{1}{2}[(\overline{\theta} + e(\overline{\theta}) - q_1(\overline{\theta}) + \rho q_2(\overline{\theta}))\, q_1(\overline{\theta}) - \Psi\left(e(\overline{\theta})\right) - U(\overline{\theta})] + \\ & \frac{1}{2}[(\underline{\theta} + e(\underline{\theta}) - q_1(\underline{\theta}) + \rho q_2(\underline{\theta})) q_1(\underline{\theta}) - \Psi(e(\underline{\theta})) - U(\underline{\theta})] \\ & s.t.\ PC(\overline{\theta}), PC(\underline{\theta}), IC(\overline{\theta}), IC(\underline{\theta}). \end{aligned}$$

The auxiliary program under standard distortion (14) is obtained by inserting the high-demand agent's informational rent (28) and assuming that the low-demand agent receives a null rent. Specularly, the auxiliary program under CI (21) is obtained by using the low-demand type's informational rent (29) - with $U^Q(\overline{\theta}) \geq U_0$ - and letting the high-demand agent have a null rent.

Appendix E: Derivation of the principal's program with RPM contracts Using (10), the principal's program is given by:

$$\begin{aligned} P_1^R \quad : \quad & \max_{q_1(\cdot),e(\cdot)} \frac{1}{2}[(\overline{\theta} + e\left(\overline{\theta}\right) - q_1\left(\overline{\theta}\right) + \rho q_2\left(\overline{\theta}\right))\, q_1\left(\overline{\theta}\right) - \Psi\left(e\left(\overline{\theta}\right)\right) - U\left(\overline{\theta}\right)] + \\ & \frac{1}{2}[(\underline{\theta} + e\left(\underline{\theta}\right) - q_1\left(\underline{\theta}\right) + \rho q_2\left(\underline{\theta}\right))\, q_1\left(\underline{\theta}\right) - \Psi\left(e\left(\underline{\theta}\right)\right) - U\left(\underline{\theta}\right)] \\ & s.t.\ PC\left(\overline{\theta}\right), PC\left(\underline{\theta}\right), IC\left(\overline{\theta}\right), IC\left(\underline{\theta}\right). \end{aligned}$$

Substituting (30) into this generic formulation program and assuming away the informational rent of the low-demand agent, one obtains the principal's program in the case of standard distortion (17), while the analogous under CI (24) is obtained using (31) and assuming that the the high-demand agent's rent is represented by his reservation utility ($U_0 > 0$).

Appendix F: Equilibrium with QF contracts and standard distortion The second best allocation, expressed as a function of the first best one, is obtained using the reaction functions of the integrated structure (13) and those of the hierarchical relationship (15) and (16), as well as the first order condition with respect to effort (6)[27]

$$q_1^{SB}\left(\overline{\theta}\right) = q_1^{FB}\left(\overline{\theta}\right), \tag{32}$$

$$q_1^{SB}\left(\underline{\theta}\right) = q_1^{FB}\left(\underline{\theta}\right) - \frac{2\Delta(2+\rho)(1-2\psi)\psi}{(4\psi - \psi\rho^2 - \rho\sigma - 2)(\rho\sigma - 2\psi + \psi\rho^2 + 1)}, \tag{33}$$

$$e^{SB}\left(\overline{\theta}\right) = e^{FB}\left(\overline{\theta}\right), \tag{34}$$

$$e^{SB}\left(\underline{\theta}\right) = e^{FB}\left(\underline{\theta}\right) - \frac{2\Delta(2+\rho)(1-2\psi)}{(4\psi - \psi\rho^2 - \rho\sigma - 2)(\rho\sigma - 2\psi + \psi\rho^2 + 1)}, \tag{35}$$

$$q_2^{SB}\left(\overline{\theta}\right) = q_2^{FB}\left(\overline{\theta}\right), \tag{36}$$

$$q_2^{SB}\left(\underline{\theta}\right) = q_2^{FB}\left(\underline{\theta}\right) - \frac{\Delta(\sigma + \psi\rho)(2+\rho)(1-2\psi)}{(4\psi - \psi\rho^2 - \rho\sigma - 2)(\rho\sigma - 2\psi + \psi\rho^2 + 1)}. \tag{37}$$

[27] To isolate the effects of the asymmetric distribution of information, the possible realizations of θ are expressed in terms of the gap $\Delta = \Delta\theta/2$ by setting $\overline{\theta} = 1 + \Delta$ and $\underline{\theta} = 1 - \Delta$.

Notice that:

$$(\Delta\theta + \rho\Delta q_2(\theta)) = \frac{(2\psi-1)(\rho+2)\,\Delta}{(2\psi-\sigma\rho-\psi\rho^2-1)} > 0 \quad \Leftrightarrow \quad \big(2\psi-\sigma\rho-\psi\rho^2-1\big) > 0,$$

and

$$q_1(\overline{\theta}) - q_1(\underline{\theta}) = \frac{2(\rho+2)\,\Delta\psi}{(2\psi-\sigma\rho-\psi\rho^2-1)} > 0 \quad \Leftrightarrow \quad \big(2\psi-\sigma\rho-\psi\rho^2-1\big) > 0.$$

This proves Lemma 1 in the main text.

Appendix G: Equilibrium with RPM contracts and standard distortion Equilibrium effort and quantity with RPM contracts, obtained using (13) and (18)-(20), are given by:

$$q_1^{SB}\left(\overline{\theta}\right) = q_1^{FB}\left(\overline{\theta}\right), \tag{38}$$

$$q_1^{SB}\left(\underline{\theta}\right) = q_1^{FB}\left(\underline{\theta}\right) - \frac{2\Delta(2+\rho\sigma)(2+\rho)(1-2\psi)}{(4\psi-\psi\rho^2-\rho\sigma-2)(3\sigma\rho-4\psi+\rho^2+\psi\rho^2+2)}, \tag{39}$$

$$e^{SB}\left(\overline{\theta}\right) = e^{FB}\left(\overline{\theta}\right), \tag{40}$$

$$e^{SB}\left(\underline{\theta}\right) = e^{FB}\left(\underline{\theta}\right) - \frac{2\Delta(1-2\psi)(2+\rho)^2(2-\rho)}{(4\psi-\psi\rho^2-\rho\sigma-2)(3\sigma\rho-4\psi+\rho^2+\psi\rho^2+2)}, \tag{41}$$

$$q_2^{SB}\left(\overline{\theta}\right) = q_2^{FB}\left(\overline{\theta}\right), \tag{42}$$

$$q_2^{SB}\left(\underline{\theta}\right) = q_2^{FB}\left(\underline{\theta}\right) - \frac{2\Delta(1-2\psi)(2\sigma+\rho)(2+\rho)}{(4\psi-\psi\rho^2-\rho\sigma-2)(3\sigma\rho-4\psi+\rho^2+\psi\rho^2+2)}. \tag{43}$$

Appendix H: Equilibrium with QF contracts and CI Equilibrium effort and quantity are obtained by using the reaction functions of the two competitors (13), (22) and (23) and the first order condition with respect to effort (6):

$$q_1^{CI}\left(\overline{\theta}\right) = q_1^{FB}\left(\overline{\theta}\right) + \frac{2\Delta(2+\rho)(1-2\psi)\psi}{(4\psi-\psi\rho^2-\rho\sigma-2)(\sigma\rho-2\psi+\psi\rho^2+1)}, \tag{44}$$

$$q_1^{CI}\left(\underline{\theta}\right) = q_1^{FB}\left(\underline{\theta}\right), \tag{45}$$

$$e^{CI}\left(\overline{\theta}\right) = e^{FB}\left(\overline{\theta}\right) + \frac{2\Delta(2+\rho)(1-2\psi)}{(4\psi-\psi\rho^2-\rho\sigma-2)(\sigma\rho-2\psi+\psi\rho^2+1)}, \tag{46}$$

$$e^{CI}\left(\underline{\theta}\right) = e^{FB}\left(\underline{\theta}\right), \tag{47}$$

$$q_2^{CI}\left(\overline{\theta}\right) = q_2^{FB}\left(\overline{\theta}\right) + \frac{\Delta(\sigma+\psi\rho)(2+\rho)(1-2\psi)}{(4\psi-\psi\rho^2-\rho\sigma-2)(\sigma\rho-2\psi+\psi\rho^2+1)}, \tag{48}$$

$$q_2^{CI}\left(\underline{\theta}\right) = q_2^{FB}\left(\underline{\theta}\right). \tag{49}$$

Appendix I: Equilibrium with RPM contracts and CI The equilibrium allocation is derived from the reaction functions of the two competitors (13), (25) -(27):

$$q_1^{CI}\left(\overline{\theta}\right) = q_1^{FB}\left(\overline{\theta}\right) + \frac{2\Delta(2\sigma\rho - \rho - 4\psi + 2\psi\rho + 2\psi\rho^2 + 2)(2 + \rho\sigma)}{(4\psi - \psi\rho^2 - \rho\sigma - 2)(\psi\rho^2 - \sigma\rho - \rho^2 - 4\psi + 2)}, \tag{50}$$

$$q_1^{CI}\left(\underline{\theta}\right) = q_1^{FB}\left(\underline{\theta}\right), \tag{51}$$

$$e^{CI}\left(\overline{\theta}\right) = e^{FB}\left(\overline{\theta}\right) + \frac{2\Delta(2\sigma\rho - \rho - 4\psi + 2\psi\rho + 2\psi\rho^2 + 2)(2 + \rho)(2 - \rho)}{(4\psi - \psi\rho^2 - \rho\sigma - 2)(\psi\rho^2 - \sigma\rho - \rho^2 - 4\psi + 2)}, \tag{52}$$

$$e^{CI}\left(\underline{\theta}\right) = e^{FB}\left(\underline{\theta}\right), \tag{53}$$

$$q_2^{CI}\left(\overline{\theta}\right) = q_2^{FB}\left(\overline{\theta}\right) + \frac{2\Delta(2\sigma\rho - \rho - 4\psi + 2\psi\rho + 2\psi\rho^2 + 2)(2\sigma + \rho)}{(4\psi - \psi\rho^2 - \rho\sigma - 2)(\psi\rho^2 - \sigma\rho - \rho^2 - 4\psi + 2)}, \tag{54}$$

$$q_2^{CI}\left(\underline{\theta}\right) = q_2^{FB}\left(\underline{\theta}\right). \tag{55}$$

Appendix L: Proof of Propositions 2 and 3 Under standard distortion, the principal takes into account the high-demand agent's IC constraint when designing the contract and verifies ex post that the low-demand agent's IC constraint is not violated. The latter is given by:

$$q_1\left(\underline{\theta}\right)\left(\Delta\theta + \rho\Delta q_2(\theta)\right) - q_1\left(\overline{\theta}\right)\left(\Delta\theta + \rho\Delta q_2(\theta)\right) \leq 0.$$

which is always satisfied given the assertion of Lemma 1.

With RPM contracts, the IC constraint for the low-demand agent is:

$$\Psi\left(e\left(\underline{\theta}\right)\right) - \Psi\left(e\left(\underline{\theta}\right) - \left(\Delta\theta + \rho\Delta q_2(\theta)\right)\right) + \Psi\left(e\left(\overline{\theta}\right)\right) - \Psi\left(e\left(\overline{\theta}\right) + \left(\Delta\theta + \rho\Delta q_2(\theta)\right)\right) \leq 0,$$

or equivalently, using the equilibrium level of effort and quantity for the vertically integrated structure, (40) and (43):

$$\frac{8\psi\left(2\psi - 1\right)\left(\psi + 1\right)\left(\rho + 2\right)^2\Delta^2}{\left(3\sigma\rho - 4\psi + \rho^2 + \psi\rho^2 + 2\right)^2} \geq 0.$$

The latter is always satisfied given (7).

In the case of CI, the principal takes into account the low-demand agent's IC constraint when designing the contract and verifies ex post that the high-demand agent's IC constraint is not violated.

With QF contracts, the latter is given by:

$$q_1\left(\underline{\theta}\right)\left(\Delta\theta+\rho\Delta q_2(\theta)\right)-q_1\left(\overline{\theta}\right)\left(\Delta\theta+\rho\Delta q_2(\theta)\right)\leq 0,$$

and using the equilibrium quantities (44), (45), (48) and (49):

$$\frac{2\psi\left(2\psi-1\right)\left(\rho+2\right)^2\Delta^2}{\left(\sigma\rho-2\psi+\psi\rho^2+1\right)^2}\geq 0,$$

which always holds true given (7).

With RPM contracts, the high-demand type's IC constraints is:

$$\Psi\left(e\left(\overline{\theta}\right)\right)-\Psi(e\left(\overline{\theta}\right)+\left(\Delta\theta+\rho\Delta q_2(\theta)\right))+\Psi\left(e\left(\underline{\theta}\right)\right)-\Psi(e\left(\underline{\theta}\right)-\left(\Delta\theta+\rho\Delta q_2(\theta)\right))\leq 0,$$

and using the equilibrium level of effort and quantity for the vertically integrated structure, (52) and (55), it can be written as:

$$\frac{8\psi\left(4\psi-\rho+4\sigma\rho+2\psi\rho+2\rho^2-2\right)\left(2\psi-\rho+2\sigma\rho+\psi\rho+2\right)\Delta^2}{\left(4\psi+\sigma\rho+\rho^2-\psi\rho^2-2\right)^2}\geq 0,$$

the latter being satisfied if:

$$\psi>\max\{\frac{1}{2},\frac{\rho-4\rho\sigma-2\rho^2+2}{2\left(2+\rho\right)},\frac{\rho-2\rho\sigma-2}{2+\rho}\},$$

or if:

$$\frac{1}{2}<\psi<\min\{\frac{\rho-4\sigma\rho-2\rho^2+2}{2\left(2+\rho\right)},\frac{\rho-2\sigma\rho-2}{2+\rho}\}.$$

Since $\frac{\rho-4\sigma\rho-2\rho^2+2}{2(2+\rho)}>\frac{\rho-2\sigma\rho-2}{2+\rho}$ and $\frac{\rho-2\sigma\rho-2}{2+\rho}<\frac{1}{2}$ for any $|\rho|\leq 1$ and $|\sigma|\leq 1$, the high-demand agent's IC constraint is not violated if and only if:

$$\psi>\max\left\{\frac{1}{2},\frac{\rho-4\sigma\rho-2\rho^2+2}{2\left(2+\rho\right)}\right\}.$$

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