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INCOMPLETE CONTRACTS AS A SCREENING DEVICE IN COMPETING VERTICAL INTRA-FIRM RELATIONSHIPS

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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 misreporting incentives for both unobservable types.

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

JEL Classification: D82; D86

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1 Introduction

The recent literature in the field of applied contract theory 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 the context of the classical agency theory, it has been 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).

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 information asymmetries. 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 largely neglected in the contracting literature[1]. This lack of interest might be due to the standard tenet that a (sufficiently) complete contract, which provides the principal with several instruments to control the other party, 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 complete arrangements does not offer an efficient solution to the problems arising from the asymmetric

[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.

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 that, once the relationship in place ends, *bad* agents are precluded from participating into future profitable relationships. Under sufficiently large expected gains from future cooperation, the provision of better contractual terms may outweigh the loss from misreporting in the current relationship, and hence provide an incentive

[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.

to false revelation for the *bad* type[3]. Hence, both agents can in principle gain from falsely revealing their private information to the principal. In accordance with the two-type nature of the basic model, we label this situation as the *binary misreporting incentives* case. As a main result, we will show that, while QF contracts always induce truthful revelation, irrespective of the presence of binary misreporting 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 possibility that both the unobservable agent's types may face an incentive to misreport. 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[4]. 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 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. In this regard, our paper abstracts entirely from the analysis

[3]This view applies, a fortiori, when the original agreement can be renogotiated.

[4]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.

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). 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 uninformative 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[5].

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

[5]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 for the principal in the vertical hierarchy.

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[6].

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[7] 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.

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

[6] In fact, the reaction function of the competitor is independent of alternative assumptions about the distribution of information within the hierarchy, as the integrated structure does not face any agency problem.

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

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[8], 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 structure solves the program:

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

[8] 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.

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

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

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 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:

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

while the seller's PC is given by:

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

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

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

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

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

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

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

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[9].

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[10]:

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

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:

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

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

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)[11].

Proposition 1. *Let the superscript j denote the QF (j=Q) or the RPM (j=R) contractual regime,*

[9] See Appendix A.

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

[11] See Appendix A.

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 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:

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

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

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

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:

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

where $U(\widetilde{\theta})$ indicates the agent's utility from entering the contract and falsely reporting his (demand) type[12]. 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.

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)).

Using the agent's informational rent to pin down the level of the transfer and the IC constraint of

[12] 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.

the high-demand type, the principal's contractual problem is:[13]:

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

The reaction functions are:

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

and

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

While the optimal level of effort is unaltered with respect to the complete information scenario, the principal is forced to introduce a downward distortion in the production program of 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 of this distortion depends 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-type agent[14].

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 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[15].

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

For any θ, first order conditions with respect to effort and quantity are:

$$
q_1\left(\theta\right) = \frac{\theta + e\left(\theta\right) + \rho q_2\left(\theta\right)}{2} \qquad (18)
$$

[13]See Appendix D.
[14]The equilibrium allocation with QF contracts is reported in Appendix F.
[15]See Appendix E.

and

$$e\left(\overline{\theta}\right)=\frac{q_{1}\left(\overline{\theta}\right)}{\psi},\tag{19}$$

$$e\left(\underline{\theta}\right)=\frac{q_{1}\left(\underline{\theta}\right)}{\psi}-\frac{\left(\Delta+\rho q_{2}\left(\Delta\theta\right)\right)}{\psi}.\tag{20}$$

In order to extract the informational rent, the principal induces a downward distortion in the level of effort - and not in the quantity to be produced - of the agent who faces a low state of demand. In equilibrium, however, this distortion will generate a bias in the low-demand type's quantity, whereas the optimal effort exerted by the high-demand type as well as the quantity produced by the latter will attain their first best levels[16]. 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, underproduction for the low-demand type occurs in equilibrium under either type of contract.*

6 Asymmetric information and binary misreporting incentives

This section studies the incidence of binary misreporting incentives (BMI) on the revelation strategies of agents and hence on the optimal design of contractual arrangements. To this end, we consider an immaterial setting in which, once the relationship in place ends, (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 upstream producer[17]. 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 the informational rent - which would result in the current relationship from misreporting - 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 type's PC and the low-demand one's IC constraint[18].

[16] Again, the actual degree of 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. The equilibrium allocation with RPM contracts is presented in Appendix G.

[17] The opportunity of misreporting is not restricted to future participation. In fact, when the reservation utility of the high-demand type agent is high enough, to ensure participation in the 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.

[18] In fact, as we consider the case of constant (zero) reservation utility for th high-demand type, it is intuitive to assume that the low-demand agent's participation constraint is not satisfied in this first part of the game.

We show that the actual effects of binary misreporting 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 BMI. 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 BMI 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 BMI, the principal can exploit contractual incompleteness as a screening device, we assume that the relevant constraints in the contractual problem are represented by the PC of the high-demand type and the IC constraint of the low-demand type, and demonstrate ex post, using the resulting allocation, that only QF contracts are able to ensure always - i.e., under any parameterizations of the models - that all 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]:

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

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

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

and

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

Unlike the standard case, the low-demand type agent is required the first best production quantity while an upward distortion in the quantity for the high-demand type emerges, which depends on the degree of uncertainty on the realization of demand and the gap between the quantities produced and sold by the competitor under the two possible states of nature. This distortion involves an

[19] See Appendix D.

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 funtion (see 9), and hence remains identical to that derived in the full information case, as do the agent's expected utility and first order conditions (10) and (11). The auxiliary program of the principal is then[21]:

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

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

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

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

and

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

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 BMI induces an upward 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, overproduction for the high-demand type occurs in equilibrium under either type of contract.*

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

[20]The equilibrium allocation with QF contracts in the presence of BMI is reported in Appendix H.
[21]See Appendix E.
[22]The equilibrium allocation with RPM contracts in the presence of BMI is reported in Appendix I.

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. *Under standard distorsion, $U(\underline{\theta}) \geq U(\widetilde{\theta})$, 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 by the underproduction equilibrium requirement 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. *Under BMI, $U(\overline{\theta}) > U(\widetilde{\theta})$ 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, given the quantity required in the contract. In this case, the upward distortion in the equilibrium quantity of high-demand retailers 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 increases, the informational rent enjoyed by the agent under false revelation is scaled down. 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 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.

[23]See Appendix L for a formal proof of Propositions 2 and 3.

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 e Besanko, 1987; Laffont e 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 greater level of effort exerted in the first one and, hence, untruthful disclosure can still configure a dominant strategy[25].

Corollary 3. *When $\frac{1}{2} < \psi < \frac{\rho - 4\sigma\rho - 2\rho^2 + 2}{2(2+\rho)}$, no separating equilibrium exists with RPM contracts*[26].

If both agents have an incentive not to disclose truthfully their private information, the principal offers a menu of contracts of the form $\{q_1^P, p_1^P, t_1^P\}$ where the quantity, the price and the transfer are exogenously fixed, and do not depend on the nature of the contractual relationship. More specifically, he solves:

$$\begin{aligned} P_1 &: \max t^P \\ s.t.\ PC &: U(\theta) \geq 0, \end{aligned}$$

or:

$$P_1 : \max_{q_1^P, e_1^P} \left(\underline{\theta} + e^P - q_1^P + \rho q_2(\underline{\theta})\right) q_1^P - \Psi\left(e^P\right),$$

whereas the first order conditions for the optimal level of effort and quantity are given by:

$$e^P = \frac{q_1^P}{\psi} \tag{28}$$

and

$$q_1^P = \frac{\underline{\theta} + e^P + \rho q_2(\underline{\theta})}{2}. \tag{29}$$

In the pooling equilibrium, the quantity produced in the hierarchy is affected by the demand state of nature, the level of effort exerted and the quantity produced by the competitor in the event of low realization of demand. Equilibrium quantity and effort are type-independent.

[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, optimal contracts may still be of the incomplete type under some circumstances.

[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 $\sigma > 1/2$.

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 market. It has been 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 informational 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.:

$$U_1^Q(\overline{\theta}) \geq U^Q(\underline{\theta}) + (\Delta\theta + \rho q_2(\Delta\theta))\, q_1(\underline{\theta}). \tag{30}$$

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

$$U^Q(\underline{\theta}) \geq U^Q\left(\overline{\theta}\right) - (\Delta\theta + \rho q_2(\Delta\theta))\, q_1\left(\overline{\theta}\right). \tag{31}$$

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

$$
U^R\left(\overline{\theta}\right) \geq U^R(\underline{\theta}) + \Psi(e(\underline{\theta})) - \Psi(e(\underline{\theta}) - (\Delta\theta + \rho q_2(\Delta\theta))). \tag{32}
$$

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

$$
U^R(\underline{\theta}) \geq U^R\left(\overline{\theta}\right) + \Psi\left(e\left(\overline{\theta}\right)\right) - \Psi(e\left(\overline{\theta}\right) + (\Delta\theta + \rho q_2(\Delta\theta))) \tag{33}
$$

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

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

The auxiliary program under standard distortion (14) is obtained by inserting the high-demand agent's informational rent (30) and assuming that the low-demand agent receives a null rent. Specularly, the auxiliary program under BMI (21) is obtained by using the low-demand type's informational rent (31) 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:

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

Substituting (32) 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 BMI (24) is obtained using (33) and assuming a zero rent for the high-demand agent.

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]

$$q_1^{SB}\left(\overline{\theta}\right)=q_1^{FB}\left(\overline{\theta}\right), \tag{34}$$

$$q_1^{SB}\left(\underline{\theta}\right)=q_1^{FB}\left(\underline{\theta}\right)-\frac{2\Delta(2+\rho)(1-2\psi)\psi}{(4\psi-\psi\rho^2-\rho\sigma-2)(\rho\sigma-2\psi+\psi\rho^2+1)}, \tag{35}$$

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

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

$$q_2^{SB}\left(\overline{\theta}\right)=q_2^{FB}\left(\overline{\theta}\right), \tag{38}$$

$$q_2^{SB}\left(\underline{\theta}\right)=q_2^{FB}\left(\underline{\theta}\right)-\frac{\Delta(\sigma+\psi\rho)(2+\rho)(1-2\psi)}{(4\psi-\psi\rho^2-\rho\sigma-2)(\rho\sigma-2\psi+\psi\rho^2+1)}. \tag{39}$$

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:

$$q_1^{SB}\left(\overline{\theta}\right)=q_1^{FB}\left(\overline{\theta}\right), \tag{40}$$

[27] To isolate the effects of the asymmetric distribution of information, the possible realizations of θ are expressed in terms of the gap Δ. In particular, we set $\overline{\theta}=1+\Delta$ and $\underline{\theta}=1-\Delta$.

$$q_1^{SB}\left(\underline{\theta}\right)=q_1^{FB}\left(\underline{\theta}\right)-\frac{2\Delta(2+\rho\sigma)(2+\rho)(1-2\psi)}{(4\psi-\psi\rho^2-\rho\sigma-2)(3\sigma\rho-4\psi+\rho^2+\psi\rho^2+2)}, \tag{41}$$

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

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

$$q_2^{SB}\left(\overline{\theta}\right)=q_2^{FB}\left(\overline{\theta}\right), \tag{44}$$

$$q_2^{SB}\left(\underline{\theta}\right)=q_2^{FB}\left(\underline{\theta}\right)-\frac{2\Delta(1-2\psi)(2\sigma+\rho)(2+\rho)}{(4\psi-\psi\rho^2-\rho\sigma-2)(3\sigma\rho-4\psi+\rho^2+\psi\rho^2+2)}. \tag{45}$$

Appendix H: Equilibrium with QF contracts and BMI 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):

$$q_1^{CI}\left(\overline{\theta}\right)=q_1^{FB}\left(\overline{\theta}\right)+\frac{2\Delta(2+\rho)(1-2\psi)\psi}{(4\psi-\psi\rho^2-\rho\sigma-2)(\sigma\rho-2\psi+\psi\rho^2+1)}, \tag{46}$$

$$q_1^{CI}\left(\underline{\theta}\right)=q_1^{FB}\left(\underline{\theta}\right), \tag{47}$$

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

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

$$q_2^{CI}\left(\overline{\theta}\right)=q_2^{FB}\left(\overline{\theta}\right)+\frac{\Delta(\sigma+\psi\rho)(2+\rho)(1-2\psi)}{(4\psi-\psi\rho^2-\rho\sigma-2)(\sigma\rho-2\psi+\psi\rho^2+1)}, \tag{50}$$

$$q_2^{CI}\left(\underline{\theta}\right)=q_2^{FB}\left(\underline{\theta}\right). \tag{51}$$

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

$$q_1^{CI}\left(\overline{\theta}\right)=q_1^{FB}\left(\overline{\theta}\right)+\frac{2\Delta(2\sigma\rho-\rho-4\psi+2\psi\rho+2\psi\rho^2+2)(2+\rho\sigma)}{(4\psi-\psi\rho^2-\rho\sigma-2)(\psi\rho^2-\sigma\rho-\rho^2-4\psi+2)}, \tag{52}$$

$$q_1^{CI}\left(\underline{\theta}\right)=q_1^{FB}\left(\underline{\theta}\right), \tag{53}$$

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

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

$$q_2^{CI}\left(\overline{\theta}\right) = q_2^{FB}\left(\overline{\theta}\right) + \frac{2\Delta(2\sigma\rho - \rho - 4\psi + 2\psi\rho + 2\psi\rho^2 + 2)(2\sigma + \rho)}{(4\psi - \psi\rho^2 - \rho\sigma - 2)(\psi\rho^2 - \sigma\rho - \rho^2 - 4\psi + 2)}, \tag{56}$$

$$q_2^{CI}\left(\underline{\theta}\right) = q_2^{FB}\left(\underline{\theta}\right). \tag{57}$$

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:

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

Using the equilibrium quantities produced by the competitors (34), (35), (38), (39), the low-demand agent's IC constraint can be rewritten as:

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

which is always satisfied given the second order condition on effort (7).

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

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

or equivalently, using the equilibrium level of effort and quantity for the vertically integrated structure, (42) and (45):

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

The latter is always satisfied given (7).

In the case of BMI, 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:

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

and using the equilibrium quantities (46), (47), (50) and (51):

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

which always holds true given (7).

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

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

and using the equilibrium level of effort and quantity for the vertically integrated structure, (54) and (57), 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:

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

Note that $\frac{\rho-4\sigma\rho-2\rho^2+2}{2(2+\rho)}$ is larger than $\frac{\rho-2\sigma\rho-2}{2+\rho}$; hence, the first condition holds true if $\psi>\max\{\frac{1}{2},\frac{\rho-4\sigma\rho-2\rho^2+2}{2(2+\rho)}\}$, while the second one is fulfilled if $\frac{1}{2}<\psi<\frac{\rho-2\sigma\rho-2}{2+\rho}$. However, since $\frac{\rho-2\sigma\rho-2}{2+\rho}<\frac{1}{2}$, 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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