# Selling Information to Competitive Firms*

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**Abstract**

Internal agency conflicts distort firms' choices and reduce social welfare. To limit these distortions, principals dealing with privately informed agents often acquire information from specialized intermediaries, such as auditing and certification companies, that are able to ascertain, and credibly disclose, agents' private information. We study how the structures of both the information provision and the final good markets affect information accuracy. A monopolistic information provider may supply imprecise information to perfectly competitive firms, even if the precision of this information can be increased at no cost. This is due to a price effect of information: while more accurate information reduces agency costs and allows firms to increase production, it also results in a lower price in the final good market, which reduces principals' willingness to pay for information. The result hinges on the assumption that firms are competitive and it exacerbates when principals can coordinate *vis-à-vis* the information provider. In an imperfectly competitive information market, providers may restrict information by not selling to some of the principals.

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# 1 Introduction

Firms' internal conflicts affect industry performance, even in perfectly competitive markets (Legros and Newman, 2013). When 'neoclassical black-box' firms are replaced by vertical organizations whose members have diverging objectives, information asymmetries between principals and agents generate distortions that reduce profits and social welfare. Since the severity of these distortions depends on the verifiable information possessed by principals, in order to implement proper incentives in their organizations principals often acquire information from specialized providers, such as auditors or certification companies, that are able to discover, and credibly disclose, agents' private information.[1] The quality of this information affects firms' production choices and, through the market mechanism, impacts equilibrium prices and, hence, industry performance. In this paper, we analyze the interplay between firms' incentives to acquire information, endogenous information quality, and the structure of the markets in which information is supplied and used.

Information acquisition and information disclosure are two aspects of the information management problem that, in recent years, has become central to the mechanism design literature (see the survey by Bergemann and Välimäki, 2006). The emergence of endogenous information structures provides both theoretical insights for mechanism design, and policy implications for market design and regulation. Little is known, however, about the role of information providers in competitive environments, and about the effect of market competition on the quality of the information that they supply.

We show that, although more accurate information enhances efficiency by reducing agency costs and improving production, it also affects firms' profits and welfare indirectly, through its impact on equilibrium market prices and quantities. Our key insight is that, when buyers of information compete in a product market, their production choices generate a (general equilibrium) *price effect* that influences a provider's choice of the aggregate amount of information to supply.

How much are then competitive firms willing to pay for information? How much information do providers supply? What is the difference between firms' individual and collective incentives to acquire information? Do firms in competitive markets acquire too much or too little information? To address these questions, we begin by analyzing an environment in which a monopolistic information provider sells an informative experiment to a large number of perfectly competitive firms,[2] each composed by a principal and an

[1] Alternatively, providers may supply information technology that makes information processing less costly and facilitates decentralized decision making (Argyres, 1999).

[2] Considering a monopolistic information provider provides a useful benchmark. A concentrated market structure in the certification industry often arises due to economies of scale or specialization — see, e.g., Lizzeri (1999) and Bergemann *et al.* (2015) who also considers a monopolistic market for information.

exclusive agent who is privately informed about his cost of production.[3] Principals take the market clearing price as given, simultaneously choose whether to acquire information and offer incentive compatible mechanisms to agents. The information provider designs the accuracy of the experiment (which is the same for all firms) that produces an informative signal (which is specific to each firm) about the agent's cost. This signal allows the principal to better screen the agent, thus reducing agency costs and distortions.

Our main result is that, even if information is costless for the provider (and even if the provider has the same information as the principal ex ante), the optimal experiment is not fully informative and does not maximize social welfare when aggregate demand is inelastic — i.e., in industries that face low competition from other markets where substitute products are sold — and agents are likely to have high costs — i.e., in industries far from the technological frontier. In this context, the provider supplies less precise information in order to reduce competition in the product market.

A key role in the analysis is played by a firm's *incremental value* of acquiring information. This represents the price that a principal is willing to pay for the experiment, and is equal to the difference between the profit of a firm that acquires information, and his outside option — i.e., the profit of a firm that does not acquire information, when all other firms do. Increasing the experiment's accuracy has two effects on the incremental value of information. First, a more informative experiment increases principals' willingness to pay because, holding the market price constant, it reduces agents' information rent and increases production and profits: an *incentive effect* of information. Second, since a more informative experiment increases the aggregate quantity produced, it also reduces the market clearing price, which (ceteris paribus) reduces both principals' equilibrium profit and their outside option: a *price effect* of information.

If the price effect is negative and dominates the incentive effect of information, the provider prefers to offer an experiment that does not fully reveal agents' cost. This happens when aggregate demand is relatively price inelastic because, in this case, increasing the experiment's accuracy greatly reduces the market price and, hence, principals' willingness to pay for information. Moreover, the price effect is stronger when the agent is likely to have a high cost because, in this case, the informativeness of the experiment has a large impact on aggregate supply and, hence, on the market price.

Our analysis suggests the existence of a positive relationship between competition, transparency and efficiency. In very competitive markets (where aggregate demand is very responsive to prices), firms purchase accurate information, minimize agency conflicts and produce on the first-best frontier. By contrast, in industries that face relatively low

[3] The production cost may be interpreted as a measure of the manager's efficiency or of the extent to which his preferences are aligned to those of the firm's owner.

competition from other markets (where aggregate demand is less responsive to prices), less accurate information is produced, which results in higher information rents that distort production and increase prices, thus harming final consumers.

Although our main model analyzes a monopolist selling information to competitive firms, we also consider alternative market structures both in the product market and in the information market. When firms explicitly collude or coordinate production decisions and act as a monopoly in the product market, the optimal experiment is fully informative. Similarly, perfect competition between information providers (with each firm independently choosing its provider) induces them to offer the fully informative experiment.[4] In imperfectly competitive information markets, however, information providers may still restrict the total amount of information disclosed, by exploiting their market power to exclude some firms from the market, in order to increase profits. Finally, if firms can jointly commit to acquire information from a single provider (i.e., they form a monopsony in the information market) but lack market power in the product market, the equilibrium experiment is less informative than with a monopolistic provider. Hence, a monopsony in the information market may be worse than a monopoly for final consumers.

A natural interpretation of our theoretical framework is auditing. Like our information provider, in addition to performing standard certification activities, auditing companies advise firms by providing so-called 'assessments', which are evaluations of firms' organizational and technological characteristics, like financial conditions, production efficiency and business risk (see, e.g., Gray and Manson, 2011). Indeed, the purpose of an assessment is to analyze whether the processes of a business are managed effectively, in order to highlight inefficiencies and to provide recommendations for fixing problems.[5] For example, an assessment that results in a specific production recommendation can be interpreted as an experiment that induces the principal to adjust production depending on the signal that he observes on the efficiency of his agent. Similarly, our model captures relevant features of 'internal auditing'.[6]

The existence of a positive relationship between variables reflecting the intensity of agency costs and auditors' quality is a well documented phenomenon. For example, Chow (1982) shows that prior to the legislation making auditing mandatory in the United States, demand for auditing services depended on indicators directly related to the degree of con-

[4] See Lizzeri (1999) for a similar result.

[5] More generally, the information provider can represent a business consultant that produces detailed information on a firm, which are used to advice managers on how to optimize the firm's activities.

[6] According to the Institute of Internal Auditors' definition, internal auditing is "an independent, objective assurance and consulting activity designed to add value and improve an organization's operations. It [...] is a catalyst for improving an organization's governance, risk management and management controls by providing insight and recommendations based on analyses and assessments of data and business processes."

flict between management and shareholders. Moreover, the auditing market features high barriers to entry, often attributed to large specialization costs. There are, in fact, four large international service networks in the auditing market (the Big 4) that are highly specialized in offering their services to specific industries. Craswell *et al.* (1995), among many others, argue that auditees voluntarily contract with expensive industry specialists that offer quality-differentiated audits, even though any licensed auditor can legally perform audits (see also Eichenseher and Danos, 1981). An important component of audit pricing is an industry-specific premium that provides positive returns to investment in industry specialization. This is consistent with our model's implication that information providers have an incentive to monopolize an industry and suggests that antitrust authorities should worry about industry-specific auditors that may reduce welfare. A policy implication of our analysis is that, even in the absence of litigation issues (see, e.g., Dye 1993), the enforcement of binding auditing standards may increase the amount of information provided and hence welfare.

More generally, our analysis offers an example of information as "a source of productivity" (Arrow, 1994). Information in our model is costly and valuable, like a standard commodity, because it reduces agency costs and allows a more efficient use of managerial inputs. Of course, information may also be a technical input in firms' production functions, which reduces costs by allowing firms to achieve a more efficient combination of labor and capital, for example (Arrow, 1987). In this perspective, the scope of our contribution goes beyond the specific agency framework that we focus on, because our analysis suggests that the quality of any type of productive information obtained by firm may not be socially optimal, whenever this information imposes a price externality in the final good market.

Moreover, while we cast our model as an analysis of the quality of information supplied to a firm that suffers from inefficiencies due to an agency relationship, other interpretations are also possible, and our insights apply to any market for cost reducing technologies or innovations. For example, Katz and Shapiro (1985, 1986) analyze innovation development and licensing, and show that an innovator that has access to a cost-reducing technology of a given quality may want to restrict the number of licenses he sells to direct competitors, thus reducing welfare, so as not to erode the value of the license and/or to soften competition. One may interpret our model as endogenizing the quality of such innovation: even if a regulator requires mandatory licensing, the innovator may still have an incentive to distort quality. Therefore, regulating access to licenses may not be sufficient to maximize welfare.

The rest of the paper is organized as follows. After discussing the related literature, we describe the model in Section 2. Section 3 characterizes the equilibrium and presents the main results. We analyze extensions and how our results depend on the market structure in Section 4. Section 5 concludes. All proofs are in the Appendix.

**Related Literature** Our paper contributes to the literature on selling information. The closest paper is Bergemann *et al.* (2015), that analyzes a monopolist selling informative experiments to buyers facing a decision problem, who have different prior information and, hence, willingness to pay for the experiment. When the monopolist offers a menu of experiments to screen buyers' types, a rent-extraction/efficiency trade off may lead to a distortion in the experiment's accuracy and require flat or discriminatory pricing. Our analysis complements Bergemann *et al.* (2015) because it focuses on competing firms and shows that a monopolist may undersupply information even when buyers have no private information.

In the auction literature, Milgrom and Weber (1982) consider the incentives of an auctioneer to disclose public information about the characteristics of the object on sale and show that transparency increases the seller's revenue when signals are affiliated (the *linkage principle*).[7] In a price discrimination environment, Ottaviani and Prat (2001) show that a monopolist wants to acquire and commit to reveal information affiliated with the buyer's information. Similar results are obtained by Johnson and Myatt (2006), Esö and Szentes (2007), Bergemann and Pesendorfer (2007), and Li and Shi (2013) in models where the seller commits (simultaneously or sequentially) to disclosure and pricing policies. We extend this literature by: (i) highlighting the effect of information disclosure on the market clearing price (which is typically neglected in mechanism design); (ii) considering an endogenous information structure, as in Bergemann *et al.* (2015), while in other papers the information provider only chooses whether to disclose his exogenous information.

As in our analysis, the effect of accuracy on market prices also plays an important role in Admati and Pfleiderer (1986, 1990), who analyze the sale of information to traders in financial markets. They show that the seller may prefer to supply noisier information, in order to reduce the information revealed to competing traders by prices. In our model, this dilution problem is absent since agents' costs are independent, so that principals cannot infer them from prices. Moreover, our model highlights how agency conflicts alone may induce a seller to offer an experiment that is not fully informative to soften competition (see Remark 1 below).

Lizzeri (1999) shows that a monopolistic certification intermediary can benefit from manipulating information about the quality of a seller's product and extracts all the information surplus by only revealing whether quality is above a minimal standard. Again,

[7] See also Abraham *et al.* (2014) who study vertical information disclosure in auctions.

while Lizzeri (1999) considers a single buyer of information, in our model principals (i.e., firms organized as vertical hierarchies) compete in the product market so that their production choices create negative externalities through the price mechanism.

More recent papers, among which Balestrieri and Izmalkov (2014), Celik (2014), Koessler and Skreta (2014), Mylovanov and Tröger (2014), and Piccolo *et al.* (2015) take an informed-principal perspective: privately informed sellers choose the amount of information on the product's quality to disclose to buyers. By contrast, in our model principals and the information provider are different players. A similar approach is developed in the growing literature on Bayesian persuasion — e.g., Rayo and Segal (2010) and Kamenica and Gentzkow (2011) — where, however, there are no monetary transfers. In all these models buyers in the information market do not compete in the product market.

By highlighting the link between firms' internal conflicts and information acquisition, our model also contributes to the literature studying how firms' organization design affects the efficiency of competitive markets. In particular, while Legros and Newman (2013) examine the trade off between private and social costs of coordination, we analyze the related trade off between private and social benefits of information provision.

Finally, the idea that people may choose to obtain imprecise information echoes the Diamond paradox in the search literature. In particular, buyers may choose not to search for products' prices because they do not internalize the 'search externality' that would intensify competition among sellers. Relatedly, Eliaz and Spiegler (2011) show that an information intermediary that selects the pool of sellers among which buyers search may find it optimal to degrade the quality of the pool in order to reduce competition among sellers and charge them higher fees.

# 2 The Model

**Market and Players.** A perfectly competitive market has a continuum of unit mass of risk-neutral firms that produce a homogeneous good.[8] There is a representative consumer with a smooth quasi-linear utility function

$$u(x) - px,$$

where $x \geq 0$ represents the quantity consumed and $p$ the market price, with $u'(\cdot) > 0$ and $u''(\cdot) \leq 0$ (see, e.g., Legros and Newman, 2013). Since consumers take the price $p$ as given, the first order condition for utility maximization, $u'(x) = p$, yields a standard differentiable downward-sloping demand function $D(p) = u'^{-1}(p)$.

[8] In Section 4.1, we consider a monopolistic market.

Firms also take the (correctly anticipated) market price $p$ as given when choosing how much to produce. Each firm owner (principal) relies on a self-interested and risk-neutral manager (agent) to run the firm. A firm's production technology depends on the agent's (private) marginal cost of production $\theta_i \in \Theta \equiv \left\{\underline{\theta}, \overline{\theta}\right\}$, with $\overline{\theta} > \underline{\theta}$ and $\Pr\left[\theta_i = \underline{\theta}\right] = \nu$. In Appendix A.4, through an example, we show that our main qualitative results also hold with more than two types. Agents are privately informed about their cost of production, and are protected by limited liability.[9]

For tractability, we assume that each firm either produces 1 unit of the good, or it does not produce at all — i.e., a firm's supply is $y_i \in \{0, 1\}$. A binary production technology can be interpreted as an approximation of symmetric firms' production decisions in a perfectly competitive market, since firms are price takers and can either produce zero or a fixed share of the total quantity demanded.[10] Hence, aggregate supply is $\int_0^1 y_i di$ and the market clearing condition requires that

$$p = u'\left(\int_0^1 y_i di\right).$$

If a firm produces, given a price $p$ and a transfer $t_i$ paid by the principal to the agent, the principal obtains Bernoulli utility equal to $p - t_i$ and the agent obtains Bernoulli utility equal to $t_i - \theta_i$.

**Information Acquisition.** A principal can acquire information on his agent's cost from a monopolistic information provider.[11] We assume that the information provider commits to an anonymous disclosure policy $\{E, \rho_E\}$, which specifies an experiment $E$ and its price $\rho_E$ — see, e.g., Bergemann *et al.* (2015).[12] Hence, the provider offers the same disclosure policy to all firms, and all principals acquire the experiment if this is profitable. In Appendix A.3, we show that all our results hold even when the information provider uses

[9] For related models of vertical contracting with downstream competition, but exogenous information, see, e.g., Boyer and Laffont (2003), Caillaud *et al.* (1999), Gal-Or (1991, 1999), Hart (1983), Hermalin (1992), Martimort (1996), Martin (1993), Pagnozzi *et al.* (2015), and Raith (2003), among many others.

[10] Since firms may be ex post asymmetric and have different marginal cost of production, binary production implies that firms are capacity constrained, so that no firm can supply the whole market. This may reflect un-modelled technological constraints that prevent firms from arbitrarily increasing the quantity produced (as, for example, in the shipping and transportation industries, and in electricity markets). Otherwise, a low-cost firm would always be able to reduce the market price up to the point where production is unprofitable for a high-cost firm.

[11] In Section 4.2, we consider competitive information providers.

[12] With full commitment and public offers, the information provider has no incentive to offer more than one policy: since firms are ex ante symmetric and price takers, all principals purchase the same policy in equilibrium. Moreover, full commitment eliminates the "opportunism problem" that arises when a principal contracts with multiple competing agents, whose solution depends on off-equilibrium beliefs (see, e.g., Dequiedt and Martimort, 2015, Hart and Tirole, 1990, O'Brien and Shaffer, 1992, McAfee and Schwartz, 1994, and Segal and Whinston, 2003). Even without full commitment, an anonymous policy may arguably arise because firms are ex ante identical and, hence, discrimination may be legally impossible.

stochastic rationing and does not sell the experiment to all principals.

An experiment $E \equiv \{S_E, f_E\}$ is an information structure consisting of a set of signals $S_E \subseteq \mathbb{R}$, with generic element $s_i$, and a likelihood function $f_E : \Theta \to \Delta(S_E)$ mapping states into signals. Signals are independent conditional on the agent's cost. Slightly abusing notation, we denote by $F_E(s_i|\theta_i)$ the cumulative distribution function indicating the probability that experiment $E$ yields a signal lower than $s_i$ when the agent's cost is $\theta_i$, with corresponding density $f_E(s_i|\theta_i)$. As a convention, $s_i = \varnothing$ indicates that principal $i$ has not acquired information.

The provider can produce any information structure at no cost. Essentially, the provider does not know the agent's cost, but he can improve upon each principal's original information with arbitrarily precise and costless signals.

**Contracts.** Agents need to be induced by principals to truthfully reveal their information. Their outside options are normalized to zero without loss of generality. For simplicity, we assume that the outcome of an experiment purchased by a principal is observed by his agent,[13] but not by other players.

Principals offer a direct revelation mechanism

$$\{q_i(m_i, s_i), t_i(m_i, s_i)\}_{m_i \in \Theta, s_i \in S_E \cup \{\varnothing\}},$$

which specifies the probability of production

$$q_i(\cdot, \cdot) : \Theta \times S_E \cup \{\varnothing\} \to [0, 1]$$

and the transfer paid to the agent

$$t_i(\cdot, \cdot) : \Theta \times S_E \cup \{\varnothing\} \to \mathbb{R},$$

both contingent on the agent's report about his cost $(m_i)$ and on the signal produced by the information provider $(s_i)$.[14]

Contracts between principals and agents are secret. This is a standard assumption in the literature because public contracts are typically not robust to secret renegotiations.

**Timing.** The timing of the game is the following:

- Agents learn their marginal costs.

[13]However, all our results hold even if agents do not observe the signal produced by the information provider, since an agent's choice only depends on the actual menu of quantities and transfers offered by the principal contingent on his report.

[14]We assume that principals have the bargaining power to offer a mechanism to the agent. This is consistent, for example, with a situation in which there is a continuum of competing identical agents of mass greater than the mass of principals.

- The information provider announces an information disclosure policy.
- Principals decide whether to acquire the experiment from the information provider and then offer contracts to agents.
- Each firm that has acquired the experiment observes a signal and then agents choose whether to accept contracts.
- Firms produce, transfers are paid, and goods are traded.

Our results are robust to alternative timings — see the discussion at the end of Section 3.3 and Section 4.4.

**Equilibrium.** A (symmetric) Perfect Bayesian equilibrium in which agents truthfully report their costs and the product market clears specifies a disclosure policy $\{E^e, \rho_E^e\}$ that is acquired by principals and maximizes the information provider's expected profit; an individual supply function $y^e(\theta_i, s_i) \in \{0,1\}$ that maximizes principals' expected profit and depends on the individual draw $(\theta_i, s_i) \in \Theta \times S_{E^e} \cup \{\varnothing\}$; an aggregate supply function that (because of the continuum of firms and the law of large numbers) is almost surely equal to

$$y(E^e) \equiv \sum_{\theta_i \in \Theta} \Pr[\theta_i] \int_{s_i \in S_{E^e} \cup \{\varnothing\}} y^e(\theta_i, s_i)\, dF_{E^e}(s_i|\theta_i),$$

and an equilibrium price $p^e = u'(y(E^e))$ that equalizes demand and aggregate supply. As in Legros and Newman (2013), the aggregate supply $y(\cdot)$ should be interpreted as a "short run" supply curve, when there is no entry of new firms in the market.

**Assumptions.** Following the adverse selection literature, we assume that with complete information — i.e., if the experiment fully reveals the agents' costs — it is always profitable for principals to produce, even when the cost is high.

**Assumption 1** *$u'(1) > \overline{\theta}$.*

We also assume that the information provider's maximization problem is strictly concave.

**Assumption 2** *The function $\Phi(x) = xu''(\nu + (1-\nu)x) + 2u'(\nu + (1-\nu)x)$ is decreasing in $x$.*

We denote by $P \equiv [u'(1), u'(\nu)]$ the set of admissible equilibrium prices.[15]

[15] The lowest possible quantity produced is $\nu$ since by Assumption 1 firms always produce in equilibrium when the cost is low.

# 3 Equilibrium Analysis

Consider a symmetric equilibrium in which all principals acquire information. Given an experiment $E$ offered by the information provider, for any expected market price $p$, let $V_E(p)$ be a principal's equilibrium indirect profit function when he acquires the experiment, and let $V_\varnothing(p)$ be his indirect profit function when he does not acquire the experiment and all other principals do, ceteris paribus.

Given the equilibrium market price $p(E)$ induced by experiment $E$, (when all principals acquire $E$) the highest price that the information provider can charge a principal reflects the *incremental value* of acquiring information and is equal to

$$\rho(E) \equiv V_E(p(E)) - V_\varnothing(p(E)).$$

Since this price makes each principal indifferent between acquiring $E$ and not,[16] the information provider offers the experiment that maximizes $\rho(E)$. The functions $V_E(p(E))$ and $V_\varnothing(p(E))$ determine the impact of the experiment's informativeness on the provider's profit. In the next two sections, we are going to separately analyze these two functions.

## 3.1 Uninformed Principal

Consider a principal who does not acquire experiment $E$, while all other principals do. Agent $i$'s expected utility is

$$U_\varnothing(\theta_i) \equiv q_i(\theta_i, \varnothing)(t_i(\theta_i, \varnothing) - \theta_i).$$

It is straightforward to show that the relevant incentive compatibility constraint for agent $i$ is

$$U_\varnothing(\underline{\theta}) \geq U_\varnothing(\overline{\theta}) + q_i(\overline{\theta}, \varnothing)\Delta\theta,$$

where $q_i(\overline{\theta}, \varnothing)\Delta\theta$ is the information rent of a low-cost agent; while the relevant participation constraint is $U_\varnothing(\overline{\theta}) \geq 0$, by limited liability.

Since it is optimal to choose $U_\varnothing(\overline{\theta}) = 0$, for any expected equilibrium price $p \in P$, by a standard change of variable a principal who does not acquire information solves

$$\max_{q_i(\cdot,\varnothing)\in[0,1]} \left\{ \sum_{\theta_i\in\Theta} \Pr[\theta_i]\, q_i(\theta_i, \varnothing)(p - \theta_i) - \nu q_i(\overline{\theta}, \varnothing)\Delta\theta \right\}. \tag{1}$$

[16] Notice that, with a continuum of firms, the production choice of a single principal does not affect the market price. Hence, if a principal unilaterally deviates from a candidate equilibrium with price $p(E)$, the market price remains $p(E)$.

Differentiating this objective function with respect to $q_i(\overline{\theta}, \varnothing)$ and re-arranging yields the principal's virtual surplus when his agent has high cost

$$\Gamma_{\varnothing}(p) \equiv p - \overline{\theta} - \frac{\nu}{1-\nu}\Delta\theta.$$

This is positive if and only if

$$\nu \leq \underline{\nu}(p) \equiv \frac{p - \overline{\theta}}{p - \underline{\theta}} < 1.$$

Hence, if a principal expects his agent to have low cost with a sufficiently low probability, he induces a high-cost agent to produce; otherwise, he shuts down production of a high-cost agent.

The following result characterizes the solution to problem (1).

**Proposition 1** *For any expected market price $p \in P$, the optimal contract offered by a principal who does not acquire information features $q_i(\underline{\theta}, \varnothing) = 1$ and*

$$q_i\left(\overline{\theta}, \varnothing\right) = \begin{cases} 1 \text{ if } \nu \leq \underline{\nu}(p), \\ 0 \text{ if } \nu > \underline{\nu}(p). \end{cases}$$

A principal who does not acquire information always produces when his agent has low cost (the "no distortion at the top" property); while he induces a high-cost agent not to produce if the expected rent that he has to pay to a low-cost agent in order to induce him to reveal his information (when the high-cost agent produces), $\nu\Delta\theta$, is large relative to the expected price-cost margin when the agent has high cost, $(1-\nu)\left(p - \overline{\theta}\right)$. In this case, the profit obtained by producing with high cost is so low that the principal prefers to reduce the information rent of a low-cost agent to zero by inducing a high-cost agent not to produce. Hence, the principal's profit is $\nu(p - \underline{\theta})$ when the high-cost agent does not produce, and $p - \overline{\theta}$ otherwise.

Therefore, the principal's expected profit if he does not acquire experiment $E$ when all other principals do is

$$V_{\varnothing}(p(E)) \equiv \nu(p(E) - \underline{\theta}) + (1-\nu)\max\{0; \Gamma_{\varnothing}(p(E))\}, \tag{2}$$

where $p(E)$ is the equilibrium market price when all principals acquire information.

### 3.2 Informed Principal

Suppose now that all principals acquire experiment $E$. In Appendix A.1, we show that we can restrict attention to binary experiments without loss of generality.[17] Binary experiments consist of two signals only, $\overline{s}$ and $\underline{s}$, and can be represented as

| | $\overline{s}$ | $\underline{s}$ |
|---|---|---|
| $\overline{\theta}$ | $\alpha$ | $1-\alpha$ |
| $\underline{\theta}$ | $1-\beta$ | $\beta$ |

where, slightly abusing notation, the precision parameters $\alpha = \Pr\left[\overline{s}|\overline{\theta}\right]$ and $\beta = \Pr\left[\underline{s}|\underline{\theta}\right]$ measure the informativeness, or accuracy, of the experiment. As a convention (and without loss of generality), we assume that $\alpha+\beta \geq 1$.[18] An experiment with $\alpha = \beta = 1$ is fully informative.

Similarly to the case of an uninformed principal: $(i)$ by limited liability the high-cost agent obtains no utility, regardless of the signal produced by the experiment, and $(ii)$ the relevant incentive-compatibility constraint is the one of the low-cost agent, which has to hold for any signal.[19]

Using a standard change of variable, given a binary experiments offered by the information provider and an expected market price $p$, a principal who acquires information solves

$$\max_{q_i(\cdot,\cdot)\in[0,1]} \left\{ \sum_{\theta_i\in\Theta} \Pr\left[\theta_i\right] \sum_{s_i\in\{\underline{s},\overline{s}\}} \Pr\left[s_i|\theta_i\right] q_i\left(\theta_i,s_i\right)\left(p-\theta_i\right) - \nu\Delta\theta \sum_{s_i\in\{\underline{s},\overline{s}\}} \Pr\left[s_i|\underline{\theta}\right] q_i(\overline{\theta},s_i) \right\}.$$

Differentiating and rearranging yields the principal's virtual surplus when his agent has a high cost and he observes signal $s_i$

$$\begin{aligned} \Gamma_{\alpha,\beta}\left(s_i,p\right) &\equiv p-\overline{\theta}-\frac{\Pr\left[\underline{\theta}|s_i\right]}{\Pr\left[\overline{\theta}|s_i\right]}\Delta\theta \\ &= \begin{cases} p-\overline{\theta}-\frac{\nu}{1-\nu}\frac{\beta}{1-\alpha}\Delta\theta & \text{if } s_i=\underline{s} \\ p-\overline{\theta}-\frac{\nu}{1-\nu}\frac{1-\beta}{\alpha}\Delta\theta & \text{if } s_i=\overline{s}, \end{cases} \end{aligned}$$

where $\frac{\beta}{1-\alpha} > \frac{1-\beta}{\alpha}$ and, hence, $\Gamma_{\alpha,\beta}\left(\overline{s},p\right) \geq \Gamma_{\alpha,\beta}\left(\underline{s},p\right)$.

[17] Notice that, even if production is a binary choice, it is not obvious that restricting to binary experiments is without loss of generality. The reason is that the contract offered by a principal specifies a probability of production, which is not a binary choice, and depends on the agent's report about his type.

[18] This is just a labelling of signals that ensures that $\Pr\left[\overline{s}|\overline{\theta}\right] > \Pr\left[\overline{s}|\underline{\theta}\right]$ and $\Pr\left[\overline{s}|\underline{\theta}\right] > \Pr\left[\underline{s}|\overline{\theta}\right]$: upon observing signal $\overline{s}$ (resp. $\underline{s}$), the principal assigns higher probability to the agent having high (resp. low) cost.

[19] See the Appendix for details.

As in the case of an uninformed principal, whether a principal who acquires information chooses to shut down production of a high cost-agent depends on the ratio between his posterior beliefs about the agent's cost, given the signal produced by the experiment — i.e., $\Pr\left[\underline{\theta}|s_i\right] / \Pr\left[\overline{\theta}|s_i\right]$. If this ratio is large, the principal assigns a relatively high probability to state $\underline{\theta}$ (rather than $\overline{\theta}$) when he observes signal $s_i$. In this case, $\Gamma_{\alpha,\beta}(s_i, p) < 0$ and the principal prefers to induce a high-cost agent not to produce in order to eliminate the information rent of a low-cost agent, because he expects to pay this rent with a relatively high probability. By contrast, if the ratio is small relative to the price-cost margin when the agent has high cost, then $\Gamma_{\alpha,\beta}(s_i, p) \geq 0$ and the principal prefers to induce a high-cost agent to produce and pay the information rent.

The principal's virtual surplus is decreasing in $\alpha$ and $\beta$ when $s_i = \underline{s}$: with a more informative (precise) experiment, a principal who observes signal $\underline{s}$ assigns a higher probability to the agent having low cost and, hence, increases production distortion in the high-cost state to reduce the information rent. By contrast, the virtual surplus is increasing in $\alpha$ and $\beta$ when $s_i = \overline{s}$, because in this case a more informative experiment induces a principal who observes signal $\overline{s}$ to reduce production distortion in the high-cost state. Clearly, when the experiment is fully informative, in the high cost-state a principal always observes $\overline{s}$ and always produces (by Assumption 1).

**Proposition 2** *For any expected market price $p \in P$, the optimal contract offered by a principal who acquires a binary experiment features $q_i(\underline{\theta}, \underline{s}) = q_i(\underline{\theta}, \overline{s}) = 1$ and*

$$\begin{cases} q_i\left(\overline{\theta}, \overline{s}\right) = q_i\left(\overline{\theta}, \underline{s}\right) = 1 & \text{if } \frac{\beta}{1-\alpha} \leq \frac{1-\nu}{\nu}\frac{p-\overline{\theta}}{\Delta\theta} \\ q_i\left(\overline{\theta}, \overline{s}\right) = 1 \text{ and } q_i\left(\overline{\theta}, \underline{s}\right) = 0 & \text{if } \frac{1-\beta}{\alpha} < \frac{1-\nu}{\nu}\frac{p-\overline{\theta}}{\Delta\theta} < \frac{\beta}{1-\alpha} \\ q_i\left(\overline{\theta}, \overline{s}\right) = q_i\left(\overline{\theta}, \underline{s}\right) = 0 & \text{if } \frac{1-\nu}{\nu}\frac{p-\overline{\theta}}{\Delta\theta} \leq \frac{1-\beta}{\alpha} \end{cases}$$

Hence, a principal always produces when his agent has low cost, and produces if and only if his virtual surplus is positive when his agent has high cost. Distorting production of an inefficient agent when the principal observes signal $\underline{s}$ is optimal if $\alpha$ is high so that the experiment is informative, holding $\beta$ constant. In this case, the principal prefers to eliminate the information rent of an efficient agent, since he expects the agent to have low cost with a high probability. By contrast, distorting production of an inefficient agent when the principal observes signal $\overline{s}$ is optimal if $\alpha$ is low, holding $\beta$ constant, because in this case the signal is not informative enough about the agent's cost. Of course, since $q_i\left(\overline{\theta}, \overline{s}\right) \geq q_i\left(\overline{\theta}, \underline{s}\right)$, the principal is "more likely" to distort production of an inefficient agent after observing signal $\underline{s}$.[20]

[20] More precisely, if the principal distorts production of an inefficient agent when he observes signal $\overline{s}$, then he also distorts production of an inefficient agent when he observes signal $\underline{s}$, but not vice versa, because observing signal $\overline{s}$ indicates that the agent is relatively more likely to be inefficient.

If all principals acquire a binary experiment with precision $\alpha$ and $\beta$, by Proposition 2 aggregate supply is

$$y(\alpha) \equiv \begin{cases} 1 & \text{if } \Gamma_{\alpha,\beta}(\underline{s}, p(\alpha)) \geq 0, \\ \nu + (1-\nu)\alpha & \text{if } \Gamma_{\alpha,\beta}(\overline{s}, p(\alpha)) \geq 0 > \Gamma_{\alpha,\beta}(\underline{s}, p(\alpha)), \\ \nu & \text{if } \Gamma_{\alpha,\beta}(\overline{s}, p(\alpha)) < 0, \end{cases}$$

where $p(\alpha) \equiv u'(y(\alpha))$ is the market clearing price. Hence, a principal's expected profit is

$$V_{\alpha,\beta}(p(\alpha)) \equiv \nu(p(\alpha) - \underline{\theta}) + (1-\nu) \sum_{s_i \in \{\underline{s}, \overline{s}\}} \Pr\left[s_i | \overline{\theta}\right] \max\{0, \Gamma_{\alpha,\beta}(s_i, p(\alpha))\}. \tag{3}$$

Notice that aggregate supply and the market clearing price only depend on $\alpha$, and not on $\beta$, because principals always produce in the low-cost state. In particular, when $\alpha$ increases — i.e., the experiments becomes more accurate — expected production increases and, as a consequence, the equilibrium price decreases.

### 3.3 Optimal Experiment

If the information provider offers a binary experiment, the price that each principal is willing to pay for the experiment is the difference between a principal's expected profits with and without information acquisition, if all other principals acquire information. Hence, using (2) and (3), the information provider chooses the experiment's precision $\alpha$ and $\beta$ to maximize

$$\begin{aligned} \rho(\alpha, \beta) &\equiv V_{\alpha,\beta}(p(\alpha)) - V_{\varnothing}(p(\alpha)) \\ &= (1-\nu)\left[\sum_{s_i \in \{\underline{s}, \overline{s}\}} \Pr\left[s_i | \overline{\theta}\right] \max\{0, \Gamma_{\alpha,\beta}(s_i, p(\alpha))\} - \max\{0, \Gamma_{\varnothing}(p(\alpha))\}\right]. \end{aligned}$$

This objective function does not depend on the principal's surplus in the low-cost state, because the principal always produces when the agent has a low cost, regardless of whether he acquires the experiment or not.

Through its effect on the market price $p(\alpha)$, the experiment's precision affects both the equilibrium profit with information acquisition and the deviation profit of a principal who does not acquire information. Moreover, the experiment's precision also directly affects the principal's virtual surplus when his agent has high cost $\Gamma_{\alpha,\beta}(\cdot, \cdot)$, and hence his production choice.

In order to characterize the solution to the provider's problem, it is useful to establish the following facts. First, it is never optimal for the information provider to always induce shut down of the high-cost agent because, in this case, $\rho(\alpha,\beta) \leq 0$. Second, it is never optimal to offer an experiment that never induces shut down but is not fully informative. The reason is that a fully informative experiment yields[21]

$$\begin{aligned}\rho(1,1) &= (1-\nu)\left[p(1)-\overline{\theta}-\max\left\{0,p(1)-\overline{\theta}-\frac{\nu}{1-\nu}\Delta\theta\right\}\right] \\ &= \min\left\{\nu\Delta\theta,(1-\nu)\left(u'(1)-\overline{\theta}\right)\right\} > 0,\end{aligned}$$

while an experiment that never induces shut down (but is not fully informative) yields $\rho(\alpha,\beta) = 0$ because a principal obtains the same profit $p - \overline{\theta}$ regardless of whether he acquires information or not.[22] Therefore, by Proposition 2, the optimal experiment for the information provider is either the fully informative one, or the best experiment that induces shut down only with signal $\underline{s}$.

Let $\tilde{\alpha}$ be such that

$$\Gamma_{\varnothing}(p(\tilde{\alpha})) = 0 \quad \Leftrightarrow \quad \underbrace{u'(\nu+(1-\nu)\tilde{\alpha})}_{p(\tilde{\alpha})} = \overline{\theta}+\frac{\nu}{1-\nu}\Delta\theta. \tag{4}$$

Since the price function is decreasing in $\alpha$, if $\alpha > \tilde{\alpha}$ then $\Gamma_{\varnothing}(p(\alpha)) < 0$ and the profit of a principal when his agent has high cost and he does not acquire information (given that his competitors do) is equal to zero.

**Lemma 1** *An experiment that is not fully informative and induces shut down only with signal* $\underline{s}$ *yields*

$$\rho(\alpha,\beta) = \begin{cases} (1-\nu)\alpha\left[u'(\nu+(1-\nu)\alpha)-\overline{\theta}\right]-\nu(1-\beta)\Delta\theta & \text{if } \alpha \geq \tilde{\alpha} \\ \beta\nu\Delta\theta-(1-\alpha)(1-\nu)\left[u'(\nu+(1-\nu)\alpha)-\overline{\theta}\right] & \text{if } \alpha < \tilde{\alpha}. \end{cases} \tag{5}$$

When $\alpha > \tilde{\alpha}$, the incremental value of information in Lemma 1 is equal to the expected profit when the agent has high cost and the signal is $\overline{s}$ (since in this case information induces the principal to produce),

$$(1-\nu)\alpha\left[u'(\nu+(1-\nu)\alpha)-\overline{\theta}\right],$$

minus the rent of a low-cost agent, $\nu(1-\beta)\Delta\theta$. By contrast, when $\alpha < \tilde{\alpha}$, the incremental value of information is equal to the rent saved by the experiment when the signal is $\underline{s}$,

[21] If the experiment has $\alpha = \beta = 1$, agents obtain no information rents and firms always produce, so that the market price is $p(1) = u'(1)$.

[22] It is straightforward to show that $\Gamma_{\alpha,\beta}(\underline{s},p(\alpha)) > 0$ implies $\Gamma_{\varnothing}(p(\alpha)) > 0$.

$\beta\nu\Delta\theta$, minus the loss due to shut down of production,

$$(1-\alpha)(1-\nu)\left[u'(\nu+(1-\nu)\alpha)-\overline{\theta}\right].$$

The next result characterizes the experiment that maximizes the information provider's profit, by comparing the experiment that maximizes (5) with the fully informative one. We let $\varepsilon(1) \equiv \frac{u'(1)}{|u''(1)|}$ denote the elasticity of demand with respect to price at $q = 1$, which is the inverse of the elasticity of price with respect to quantity.

**Proposition 3** *For any pair $(\nu, \overline{\theta})$ and any utility function $u(\cdot)$, there exists a threshold $\overline{\varepsilon}(\nu, \overline{\theta})$ such that the optimal experiment features $\alpha^* < 1$ if and only if $\varepsilon(1) \leq \overline{\varepsilon}(\nu, \overline{\theta})$, and $\beta^* = 1$. The threshold $\overline{\varepsilon}(\nu, \overline{\theta})$ is decreasing in $\nu$ and increasing in $\overline{\theta}$.*

The optimal experiment features $\beta^* = 1$ because, holding $\alpha$ constant, a higher $\beta$ increases the informativeness of signal $\underline{s}$ and allows principals to reduce information rents (see (5)). Hence, the optimal experiment always produces a "low cost" signal $\underline{s}$ when the agent's cost is indeed low or, equivalently, it fully reveals when the agent's cost is high through the signal $\overline{s}$. The intuition is that leading the principal to believe that the agent may be inefficient when in fact he has a low cost does not affect the actual quantity produced, but it increases the information rent of a low-cost agent, because it induces the principal to reduce the distortion in the quantity of an inefficient agent, which is never optimal.

By contrast, the optimal experiment may feature $\alpha^* < 1$, so that observing a signal $\underline{s}$ does not fully reveal that the agent's cost is low, because an increase in the informativeness of signal $\overline{s}$ has two contrasting effects on the value of information. First, a higher $\alpha$ increases principals' willingness to pay for information because, holding the market price constant, it increases expected production (since it increases the probability of signal $\overline{s}$ when the cost is high): an incentive effect of information. Second, however, by increasing production a higher $\alpha$ also reduces the market price which, ceteris paribus, reduces both the principals' equilibrium profits and their deviation profit: a price effect of information. This has an ambiguous effect on principals' willingness to pay for information.

The price effect is negative and dominates the incentive effect of information when price is elastic with respect to quantity (or, equivalently, when demand is inelastic with respect to price), which is typically the case for markets that face weak competition from other industries where substitute products are sold. In this case, a higher $\alpha$ induces a large reduction in the market price which reduces principals' willingness to pay for information.

The price effect is stronger when $\nu$, the probability of the agent having a low cost, is low because, in this case, the informativeness of the experiment has a large impact on aggregate supply and, hence, on the market price. Similarly, an increase in $\overline{\theta}$, the agent's highest possible cost, reduces principals' profit and induces the information provider to offer a less informative experiment, because a higher market price is required (other things being equal) in order to induce the agent to produce when his agent has high cost.

Let $\hat{\alpha}$ be the accuracy of the experiment that maximizes principals' (expected) profit in the high-cost state — i.e., the solution of the first-order condition

$$u'\left(\nu+(1-\nu)\,\hat{\alpha}\right)-\overline{\theta}+\hat{\alpha}\,(1-\nu)\,u''\left(\nu+(1-\nu)\,\hat{\alpha}\right)=0, \tag{6}$$

which is unique by Assumption 2. The next proposition analyzes the factors that affect the informativeness of the optimal experiment when it is not fully informative.

**Proposition 4** *If $\varepsilon(1)\leq\overline{\varepsilon}(\nu,\overline{\theta})$, the optimal experiment features $\alpha^{*}=\max\{\tilde{\alpha},\hat{\alpha}\}$. Moreover, there exists a threshold $\underline{\Delta\theta}$ such that $\alpha^{*}=\hat{\alpha}$ if and only if $\Delta\theta\geq\underline{\Delta\theta}$.*

To maximize principals' willingness to pay for information $\rho(\alpha,1)$, the information provider would like to offer an experiment that: (i) induces an uninformed principal to shut down production by a high-cost agent, because this reduces the principal's deviation profit, and (ii) maximizes the profit of a principal who acquires information in the high-cost state — i.e., that solves condition (6). When $\hat{\alpha}$ is higher than $\tilde{\alpha}$, the experiment that solves (6) also induces an uninformed principal to shut down production by a high-cost agent, because a high $\hat{\alpha}$ results in a low market price $p(\hat{\alpha})\equiv u'(\nu+(1-\nu)\,\hat{\alpha})$. By contrast, when $\hat{\alpha}$ is lower than $\tilde{\alpha}$, the experiment that solves (6) does not induce an uninformed principal to shut down production by a high-cost agent. In this case, the information provider prefers to offer an experiment with accuracy $\tilde{\alpha}$ to minimize the difference between production with and without information acquisition (as explained in the discussion following Lemma 1). Finally, ceteris paribus, $\tilde{\alpha}$ is low and the information provider chooses $\hat{\alpha}$ when the adverse selection problem is particularly severe — i.e., when $\Delta\theta$ is relatively large (see (4)) and it is thus expensive to screen agents.

**Remark 1.** Our analysis is based on the assumption that agents are privately informed about their costs. How crucial is the presence of asymmetric information and the resulting agency costs for our results? Consider a model without agents, where firms can acquire information about their own marginal cost (which they do not know) from an information provider. In this case, in our framework (by Assumption 1) firms always produce regardless of their marginal cost and, hence, their willingness to pay for information is equal to zero. Therefore, without agency costs, an information provider plays no role in our environment.

Moreover, even with alternative assumptions about marginal costs, the presence of asymmetric information crucially affects the scope for information provision. To see why, consider an environment where costs may be so high that firms do not produce if they do not acquire information, regardless of the choice of their competitors.[23] In this case, when there are privately informed agents (as in our model), principals never produce when their agent has a high cost to avoid obtaining negative profit (since $u'(0) < \overline{\theta}$). Hence, with asymmetric information, agents obtain no information rent and principals have no incentive to acquire information from an information provider.

By contrast, in a model without agents, firms do have an incentive to acquire information from a provider in order to avoid producing when the cost is high. The information provider does not distort information when the marginal cost is $\overline{\theta}$: offering an experiment with $\alpha < 1$ reduces firms' willingness to pay for information because production is never profitable when the cost is $\overline{\theta}$. The information provider may only distort information when the marginal cost is $\underline{\theta}$ to restrict firms' aggregate production and increase the market price. Therefore, although the rationale for not offering a fully informative experiment is similar to our model, information distortion may arise in exactly the opposite state of the world than in our model.

**Remark 2.** We focus on disclosure policies that do not discriminate principals. In Appendix A.3, we show that the optimal policy of an information provider who offers the fully informative experiment to some, but not necessarily all, principals is equivalent to the optimal policy described in Proposition 3. The reason is that the provider's profit depends on aggregate production in the market, and the provider is indifferent between achieving the optimal level of production through providing "imperfect" information to all principals or "perfect" information to some principals only. In our model, however, total demand for information is fixed (because the number of firms is fixed and they are ex ante identical). Therefore, preventing some principals from acquiring the experiment requires stochastic rationing, which is difficult to implement, and randomization devices, which are hardly verifiable in practice.

**Remark 3.** Our qualitative results also hold with more than two costs. Specifically, in Appendix A.4 we develop an example showing that the information provider may have an incentive to offer an experiment that is not fully informative even when the agent has three different possible types, under a condition that is similar to the one in Proposition 3. Exactly as in our main analysis, restricting principals' information reduces the market price and allows the provider to obtain higher profit.

**Remark 4.** If agents learn their costs after accepting the contract and are not protected by limited liability, by standard results the principal can completely solve the adverse

[23] Formally, this requires that $u'(0) < \mathbb{E}[\theta]$. Moreover, $\underline{\theta} < u'(1)$ so that firms always produce if they have a low marginal cost.

selection problem without acquiring information from the provider. However, if agents are protected by limited liability, they obtain information rents even if costs are observed after accepting the contract (see, e.g., Laffont and Martimort, 2002). Therefore, principals are still willing to acquire information from the provider and the optimal experiment is identical to the one characterized in Proposition 3.

## 3.4 Welfare

Consider, without loss of generality, a binary experiment with precision $\alpha$ and $\beta$. Given an optimal contract offered by the principal, social welfare is equal to the difference between consumers' gross utility and total production costs (since all other payments are simply transfers among players) — i.e., by the law of large numbers,

$$\mathcal{W}(\alpha,\beta) \equiv u(y(\alpha,\beta)) - \nu\underline{\theta} - (1-\nu)\left[\alpha q_i\left(\overline{\theta},\overline{s}\right) + (1-\alpha)\, q_i\left(\overline{\theta},\underline{s}\right)\right]\overline{\theta},$$

where $q_i\left(\overline{\theta}, s_i\right)$ is the production of a representative firm with cost $\overline{\theta}$ and signal $s_i$.

**Proposition 5** *Social welfare is maximized by the fully informative experiment.*

Therefore, a social planner always chooses an experiment with $\alpha = \beta = 1$ in order to maximize the total quantity produced. In contrast to Lizzeri (1999) and Bergemann *et al.* (2015), full efficiency requires a fully informative experiment in our environment, and social welfare is not maximized when the optimal experiment offered by the information provider features $\alpha^* < 1$.

Notice that a regulation that forces the information provider to offer the fully informative experiment would not restore full efficiency, since the provider would respond to this policy by not selling the experiment to all principals (see Remark 2).

## 3.5 Example

To gain further insights on the optimal policy, consider a linear example that allows to obtain closed form solutions. Let $\underline{\theta} = 0$, $\overline{\theta} = 1$, and let the utility function be

$$u(x) = 2x - b\frac{x^2}{2},$$

so that $\varepsilon(1) = \frac{2}{b} - 1$ is decreasing in $b$.[24] By equation (4),

$$\tilde{\alpha} \equiv \frac{1-\nu\left(2+b(1-\nu)\right)}{b(1-\nu)^2},$$

[24] Assumption 1 requires $b < 1$ while Assumption 2 is always satisfied.

which is decreasing in $\nu$ and $b$ (when it is positive).

First, if $b \leq \frac{1-2\nu}{1-\nu}$, then $\tilde{\alpha} > 1$ and

$$\rho(\alpha, 1) = \nu - (1-\alpha)(1-\nu)[1 - b(\nu + (1-\nu)\alpha)] \quad \forall \alpha \in [0,1].$$

Since this function is increasing in $\alpha$, the optimal experiment is fully informative in this case.

Second, if $b > \frac{1-2\nu}{\nu(1-\nu)}$, then $\tilde{\alpha} \leq 0$ and

$$\rho(\alpha, 1) = (1-\nu)\alpha[1 - b(\nu + (1-\nu)\alpha)] \quad \forall \alpha \in [0,1].$$

This function is maximized at

$$\hat{\alpha} \equiv \min\left\{1, \frac{1-b\nu}{2b(1-\nu)}\right\},$$

which is (weakly) increasing in $\nu$ and decreasing in $b$. Hence,

$$\hat{\alpha} < 1 \quad \Leftrightarrow \quad b > b^*(\nu) \equiv \frac{1}{2-\nu}.$$

Third, if $\frac{1-2\nu}{1-\nu} < b < \frac{1-2\nu}{\nu(1-\nu)}$, then $\tilde{\alpha} \in (0,1)$ and the optimal experiment features

$$\alpha^* = \begin{cases} \max\{\hat{\alpha}, \tilde{\alpha}\} & \text{if } \hat{\alpha} < 1 \\ 1 & \text{if } \hat{\alpha} = 1. \end{cases}$$

Moreover,

$$\hat{\alpha} - \tilde{\alpha} = \frac{b\nu(1-\nu) + 3\nu - 1}{2b(1-\nu)^2} \geq 0 \quad \Leftrightarrow \quad b \geq \frac{1-3\nu}{\nu(1-\nu)}.$$

Finally: if $\nu > 1 - \frac{1}{\sqrt{2}}$, then $b^*(\nu) > \frac{1-2\nu}{1-\nu}$ and $b^*(\nu) > \frac{1-3\nu}{\nu(1-\nu)}$; if $\nu \leq 1 - \frac{1}{\sqrt{2}}$, then $b^*(\nu) \leq \frac{1-3\nu}{\nu(1-\nu)}$.

Summing up, if $\nu \leq 1 - \frac{1}{\sqrt{2}}$, then the optimal experiment features

$$\alpha^* = \begin{cases} 1 & \text{if } b \leq \frac{1-2\nu}{\nu(1-\nu)} \\ \tilde{\alpha} & \text{if } \frac{1-2\nu}{\nu(1-\nu)} < b \leq \frac{1-3\nu}{\nu(1-\nu)} \\ \hat{\alpha} & \text{if } b > \frac{1-3\nu}{\nu(1-\nu)}; \end{cases}$$

while if $\nu > 1 - \frac{1}{\sqrt{2}}$, then the optimal experiment features

$$\alpha^* = \begin{cases} 1 & \text{if } b \leq b^*(\nu) \\ \hat{\alpha} & \text{if } b > b^*(\nu). \end{cases}$$

Hence, when demand is relatively unresponsive to price, the information provider offers an experiment that does not fully reveal the agent's cost in order to increase the market price. The optimal informativeness of the experiment $\alpha^*$ is decreasing in $b$, while it is decreasing (resp. increasing) in $\nu$ for intermediate (resp. large) values of $b$.

# 4 Extensions

In this section we consider various extensions and show how the results of Section 3 change under alternative assumptions on the degree of competition in the product market and in the information market.

## 4.1 Downstream Monopoly

The result of Proposition 3 on underprovision of information hinges on the assumption that there is competition in the product market. In fact, when there is a single information buyer that produces in a monopolistic downstream market, he internalizes the price externality of its production decisions, exactly like a monopolist operating in multiple locations that compete with each other. Hence, the information provider has no incentive to offer an experiment that is not fully informative to a monopolist, or to principals acting as a cartel in the product market.

**Proposition 6** *The information provider offers a fully informative experiment to a monopolist.*

A less informative experiment reduces the monopolist willingness to pay for two reasons. First, an imperfectly informative experiment reduces production efficiency due to the standard trade-off between rents and efficiency. Second, when the monopolist is uncertain about the agent's cost, he must provide a rent to induce truthful information revelation. Both of these effects reduce the surplus that the information provider can be extracted from the monopolist.

Note, however, that the main trade-off described in Proposition 3 does not necessarily require the product market to be perfectly competitive, since it would still arise with imperfect competition. Essentially, as long as more accurate information allows principals to reduce information rents but also increases the market price, there is a tension between the price effect and the incentive effects described in Section 3.[25]

[25] An important caveat is that Lemma 3 may not hold when firms' production choice is a continuous variable — e.g., when firms choose quantities or prices (Cournot or Bertrand or differentiated products) — because the optimal experiment may require more than two signals.

## 4.2 Competing Information Providers

Consider now the case in which both the product and the information markets are competitive — for example, a market with multiple competing rating agencies or auditing companies.

In order to capture the effect of competition in the information market on the amount of information supplied, we consider the 'linear city' model of Hotelling (1929). Principals are uniformly distributed with density 1 over the interval $[0,1]$. There are two identical information providers located at the extremes of interval: provider $A$ is located at 0 and provider $B$ at 1. Principals pay a quadratic transportation cost to reach an information provider. Specifically, a principal located at $x \in [0,1]$ pays $cx^2$ to buy from $A$ and $c(1-x)^2$ to buy from $B$, where $c > 0$ is a measure of the cost of transportation.

Each information provider $j \in \{A, B\}$ simultaneously announces an anonymous information policy $\{E_j, \rho_j\}$ that consists in an experiment $E_j$ with precision $\alpha_j$ and $\beta_j$ and a price $\rho_j$.[26] Principals observe the offers and decide whether and from which provider to buy information. Principals cannot coordinate their decisions — i.e., they cannot commit to buy from the same information provider.

For simplicity, we impose the following assumption which implies that, when no information is provided, only low-cost agents produce.

**Assumption 3** $u'(\nu) < \frac{\nu}{1-\nu}\Delta\theta$.

We first consider symmetric equilibria with full coverage, in which all principals acquire information and information providers offers the same policy $\{(\alpha^*, \beta^*), \rho^*\}$. The principal that is indifferent between buying from $A$ or $B$ is such that

$$V_A(\boldsymbol{\alpha}, \boldsymbol{\beta}) - \rho_A - cx^2 = V_B(\boldsymbol{\alpha}, \boldsymbol{\beta}) - \rho_B - c(1-x)^2$$
$$\Leftrightarrow \quad x^*(\boldsymbol{\rho}, \boldsymbol{\alpha}, \boldsymbol{\beta}) \equiv \frac{1}{2} + \frac{\rho_B - \rho_A}{2c} + \frac{V_A(\boldsymbol{\alpha}, \boldsymbol{\beta}) - V_B(\boldsymbol{\alpha}, \boldsymbol{\beta})}{2c},$$

where $\boldsymbol{\rho} = (\rho_A, \rho_B)$, $\boldsymbol{\alpha} = (\alpha_A, \alpha_B)$, $\boldsymbol{\beta} = (\beta_A, \beta_B)$ and

$$V_j(\boldsymbol{\alpha}, \boldsymbol{\beta}) \equiv \nu\left(p(\boldsymbol{\alpha}, \boldsymbol{\beta}) - \underline{\theta}\right) + (1-\nu) \sum_{s_j \in \{\underline{s}, \overline{s}\}} \Pr\left[s_j | \overline{\theta}\right] \max\left\{0, \Gamma^j_{\alpha_j, \beta_j}\left(s_j, p(\boldsymbol{\alpha}, \boldsymbol{\beta})\right)\right\}.$$

When $\alpha_B = \alpha^*$ and $\beta_B = \beta^*$,

$$p(\alpha_A, \beta_A, \alpha^*, \beta^*) = u'\left(\nu + (1-\nu)\left(x^*(\cdot)\,\alpha_A + (1 - x^*(\cdot))\,\alpha^*\right)\right),$$

[26] It can be shown using the arguments developed above that we can restrict attention (without loss of generality) to binary experiments. In fact, holding constant the policy offered by his competitor, each information provider weakly prefers to offer a binary experiment rather than a more complex one.

where, if it exists, the cut-off $x^* (\cdot)$ is implicitly defined by

$$x^* (\alpha_A, \beta_A, \rho_A, \rho^*, \alpha^*, \beta^*) \equiv \frac{1}{2} + \frac{\rho^* - \rho_A}{2c} + \underbrace{\frac{V_A (\alpha_A, \beta_A, \alpha^*, \beta^*) - V_B (\alpha^*, \beta^*, \alpha_A, \beta_A)}{2c}}_{\text{Vertical differentiation}}.$$

Hence, when $B$ behaves according to equilibrium, $A$'s expected profit is

$$\pi_A (\rho_A, \alpha_A, \beta_A, \rho^*, \alpha^*, \beta^*) = x^* (\cdot) \rho_A.$$

Notice that, compared to a standard Hotelling game, our model also involves a form of (endogenous) vertical differentiation between information providers, which derives from the accuracy of the experiments offered. Clearly, other things being equal, principals are willing to pay a higher price to acquire a more informative experiment. Hence, apart from competing in prices, information providers also compete through the accuracy of their experiments. However, competing along this dimension might not be in their individual and joint interest because the equilibrium market price is decreasing in the amount of information provided, and so does the surplus that providers can extract from inframarginal principals.

Does the equilibrium features underprovision of information? Will providers exploit both dimensions of differentiation to attract principals?

**Proposition 7** *There cannot exist a symmetric equilibrium with full market coverage and imperfect information provision. An equilibrium with full market coverage and full information provision exists if and only if $c$ is sufficiently low. In this equilibrium, the price charged by the information providers is $\rho^* = c$.*

If the market is fully covered in a symmetric equilibrium, it is always profitable for a provider to offer a slightly more informative experiment in order to attract marginal principals from the rival, without changing the price of the experiment. This is because, holding the experiment offered by the rival constant, a provider gains by selling to an additional principal, whose production choice does not affect the market price.[27] Hence, to avoid this free-riding problem, in a symmetric equilibrium with full market coverage providers never offer an experiment that is not fully informative.

When transportation costs are sufficiently small, there is an equilibrium in which both providers offer the fully informative experiment at price $\rho^* = c$, following the standard 'Hotelling' rule. In this case, competition between providers bites both horizontally and

[27] Of course, the change in the informativeness of the experiment must be arbitrarily small to have a negligible effect on the market price — i.e., a second order effect on provider's profit compared to the effect of an increase in the number of principals served.

vertically. To understand why, consider the case of perfect competition in the information market — i.e., $c = 0$. A straightforward undercutting logic implies that information providers charge a price equal to zero, $\rho^* = 0$, and make no profit in equilibrium, regardless of the experiment they offer. Moreover, if a provider offers the fully informative experiment at price zero, it is clear that his competitor cannot gain by offering a different experiment and/or a different price (because, when there is no transportation cost, by doing so he cannot attract any principal). A similar logic applies to the case of small $c$.

Hence, when competition in the information market is relatively strong, full information is provided in equilibrium to all principals. When $c$ is large, however, are there equilibria in which providers limit the amount of information?

By Proposition 7, if full information is not provided to all principals in a symmetric equilibrium, this must be because the market is not fully covered — i.e., each provider sells to a mass of principals smaller than $\frac{1}{2}$. In this case, some principals acquire no information and shut down production in state $\underline{s}$. In the next proposition we show that, indeed, when $c$ is relatively large there exists an equilibrium in which providers offer the fully informative experiment, but price some principals out of the market.

**Proposition 8** *If $c$ is is sufficiently high, there exists a symmetric equilibrium in which each provider offers the fully informative experiment and sells to a mass of principals $\frac{1}{2} - k^*$, with $k^* \in \left(0, \frac{1}{2}\right)$ such that*

$$\frac{c}{4}\left[1-2k^*\right]^2 = (1-\nu)\left[u'\left(1-2\left(1-\nu\right)k^*\right)-\overline{\theta}\right] + \frac{1-2k^*}{2}\left(1-\nu\right)^2 u''\left(1-2\left(1-\nu\right)k^*\right). \tag{7}$$

*In this equilibrium, the price charged by the information providers is $\rho^* > c$. Moreover, $k^*$ is increasing in $c$.*

When competition in the information market is not too strong — i.e., when products are sufficiently differentiated — competition between providers along the 'horizontal dimension' becomes less intense: providers still offer the fully informative experiment (to undercut each other along the 'vertical dimension'), but they charge a price higher than $c$ in order to exclude some principals from the information market, thereby increasing market price and profits.[28] This may be interpreted as a situation where some firms cannot find a rating agency that understands their business well enough to provide a reliable rating.

[28] Of course, in addition to the symmetric equilibrium characterized in Proposition 8, with competing providers there may also be asymmetric equilibria in which only one provider offers an experiment that is not fully informative (which also benefits the competitor). Characterizing the full set equilibria is outside the scope of the paper, however, since our purpose is simply to show the robustness of the results obtained in the monopoly case.

Therefore, our qualitative result that the maximal degree of information may not be provided, even if information is costless, holds both in a monopolistic and in an imperfectly competitive information market.

Notice that, with competing providers, information may be limited for two reasons. First, as in the case of a monopolistic information provider, supplying less information increases the market price because it reduces the total quantity produced (see the right-hand side of condition (7)). Second, each provider exploits its monopoly power with respect to firms which are close to its location by increasing the price of the experiment and reducing the number of firms to which it sells information (see the left-hand side of condition (7)).[29] As intuition suggests, this effect becomes stronger when transportation costs increase, implying that information underprovision becomes more severe as competition in the information market weakens.

Of course, in addition to the symmetric equilibria characterized in Propositions 7 and 8, with imperfect competition there may also be asymmetric equilibria in which only one provider offers an experiment that is not fully informative and/or exclude some principals (which also benefits the competitor).[30] This potential multiplicity of equilibria echoes Lizzeri (1994), who in a different context shows that competition between information intermediaries may generate different types of equilibria, with and without full information disclosure. Characterizing the full set equilibria is outside the scope of our analysis, however, since our purpose is simply to show the robustness of the results obtained in the monopoly case.

## 4.3 Monopsony in the Information Market

In the previous sections, we have assumed that principals do not coordinate their information acquisition decisions — i.e., each principal buys the experiment that maximizes his own profit. Suppose now that principals behave as a single buyer and can commit to purchase information from the same provider, although they are still price takers in the product market. What is the experiment that principals jointly offer to the information provider(s)? Will they acquire more or less information than in the baseline model?

By the same logic of Lemma 3, we can consider binary experiments without loss of generality. If principals commit to deal exclusively with one information provider,

[29] As discussed at the end of Section 3.3, a monopolistic provider may also want to sell to fewer firms and increase the price of the experiment but, in our model with fixed demand for information, he can only do this by stochastic rationing.

[30] For example, asymmetric equilibria may arise for intermediate values of $t$, when there is no symmetric equilibrium with full coverage (because a relatively high transportation cost induces providers to ration principals to exploit their monopoly power), and no symmetric equilibrium without full market coverage (because a relatively low transportation cost induces providers to compete aggressively by either reducing the price of the experiment or increasing its accuracy).

they choose the experiment that maximizes their expected profits — i.e., $V_{\alpha,\beta}(p(\alpha))$ in equation (3) — rather than the incremental value of information. The reason is that the willingness to pay for information only depends on firms' equilibrium profit, and not on the outside option. As before, it is easy to show that: $(i)$ it is never optimal to offer an experiment that always induces shut down of the high-cost agent; $(ii)$ if the experiment distorts production with only one signal, then this must be $\underline{s}$; $(iii)$ it is optimal to set $\beta$ equal to 1; $(iv)$ for any $\alpha < 1$ such that $\Gamma_{\alpha,1}(\underline{s}, p) > 0$,

$$V_{\alpha,1}(p(\alpha)) = p(1) - \mathbb{E}[\theta] - \nu\Delta\theta < p(1) - \mathbb{E}[\theta] = V_{1,1}(p(1)).$$

Hence, as in our main model, if it is optimal to offer an experiment that is not fully informative, then it must be

$$\Gamma_{\alpha,1}(\overline{s}, p) \geq 0 > \Gamma_{\alpha,1}(\underline{s}, p).$$

In this case, principals' objective function is

$$V_{\alpha,1}(p(\alpha)) \equiv \nu\left[u'(\nu + (1-\nu)\alpha) - \underline{\theta}\right] + (1-\nu)\alpha\left[u'(\nu + (1-\nu)\alpha) - \overline{\theta}\right],$$

whose derivative with respect to $\alpha$ is

$$\underbrace{u'(\nu + (1-\nu)\alpha) - \overline{\theta}}_{>0} + \underbrace{(\nu + (1-\nu)\alpha)\, u''(\nu + (1-\nu)\alpha)}_{<0}. \tag{8}$$

The first term represents the incentive effect, which is identical to the one in our main model, while the second represents a modified (stronger) price effect, which also takes into account the effect of information when the agent has a low cost (since this affects principals' expected profit but not the incremental value of information).

**Proposition 9** *Suppose that principals act as a single buyer in the information market. There exists a threshold $\overline{\varepsilon}(\overline{\theta}) : \mathbb{R}^+ \to \mathbb{R}^+$ such that the optimal experiment features $\alpha^{**} < 1$ if and only if $\varepsilon(1) \leq \overline{\varepsilon}(\overline{\theta})$, and $\beta^* = 1$. Moreover, $\alpha^{**} \leq \alpha^*$ and $\overline{\varepsilon}(\overline{\theta}) \geq \overline{\varepsilon}(\nu, \overline{\theta})$, with equality at $\nu = 0$.*

Hence, a coalition of principals acquires less accurate information than each principal does because the experiment that maximizes their expected profit does not depend on the outside option, which strengthens the price effect of information. As a result, contrary to what may be expected, a monopsony in the information market reduces the equilibrium level of information provided.

## 4.4 Selling Information Ex Post

In our model, principals acquire information before contracting with agents, which is in line with the literature on ex ante information gathering — see, e.g., Crémer and Khalil (1992) and Crémer, Khalil and Rochet (1998).

By contrast, the literature on costly state verification considers principals who may acquire information after the agent has reported his type, and information providers that can verify whether the agent's report is truthful ex post — see, e.g., Townsend (1979) and Border and Sobel (1987). This verification relaxes incentive constraints and reduces agency costs when principals can commit to punish untruthful reports. Because (with two types) the Revelation Principle still guarantees that agents truthfully report their costs in equilibrium, ex post verification perfectly solves the adverse selection problem if verification can be provided at no cost and the provider cannot ration principals, as in our model, and ensures that principals always produce, yielding an equilibrium market price equal to $u'(1)$.[31]

Therefore, the ex post information supplied by a provider has no effect on the market price. The highest profit of the information provider in this case is

$$\min\left\{\nu\Delta\theta, (1-\nu)\left(u'(1)-\overline{\theta}\right)\right\},$$

because principals' willingness to pay for information is equal to their willingness to pay for a fully informative experiment in our model — i.e., $\rho(1,1)$.

However, since this profit is lower than the information provider's profit when he sells an experiment ex ante as in our model (see Proposition 3), the provider always has an incentive to commit to provide information ex ante rather than verification ex post. Of course, if the information provider can commit ex ante to an ex post verification rule — e.g., to discover an untruthful report only with some probability lower than one — he has the same incentive to restrict information as in our model.

# 5 Conclusions

Building on the recent literature on selling information, we have examined the decision problem of a monopolist who sells an informative experiment to a large number of perfectly competitive firms in which principals contract with privately informed agents. We have shown that, even if information is costless for the provider, the optimal experiment is not fully informative when demand is inelastic to price and agents are likely to be

[31] See, e.g., Laffont and Martimort (2002, Section 3.7) for a model with two types that can be easily adapted to our perfectly competitive framework.

inefficient. In this case, the provider obtains a higher profit by limiting the amount of information supplied to principal, due to the negative price effect generated by information when firms compete in the product market. This result hinges on the assumption that firms are competitive and exacerbates when principals can coordinate vis-à-vis the information provider. In an imperfectly competitive information market, underprovision of information may still occur through the exclusion of some principals from the information market.

The analysis suggests a positive relationship between competition, transparency and efficiency. In very competitive markets where demand is very responsive to prices, firms purchase accurate information in order to solve agency problems and produce on the first-best frontier: the equilibrium experiment is fully informative about the agents' cost. By contrast, in industries where demand is not very responsive to prices, firms do not obtain full information. This lack of transparency generates information rents that further reduce production and increase prices, at the expense of final consumers.

Following Arrow's idea that information should be considered a standard commodity whose market may be subject to regulatory intervention, our results offer testable predictions on the relation between agency costs, market structures, and auditing quality.

# A Appendix

## A.1 Binary Experiments

We show that we can restrict attention to binary experiments without loss of generality. Given an experiment $E$ offered by the information provider and an expected market price $p$, the expected profit of a principal who acquires information is

$$\sum_{\theta_i \in \Theta} \Pr[\theta_i] \int_{s_i \in S_E} q_i(\theta_i, s_i)[p - t_i(\theta_i, s_i)]\, dF(s_i|\theta_i).$$

For any signal $s_i$, incentive compatibility for the agent requires

$$U_E(\theta_i, s_i) \equiv q_i(\theta_i, s_i)\, t_i(\theta_i, s_i) - q_i(\theta_i, s_i)\,\theta_i \geq q_i(\theta_i', s_i)\, t_i(\theta_i', s_i) - q_i(\theta_i', s_i)\,\theta_i \quad \forall \theta_i' \neq \theta_i.$$

Hence, the agent's relevant incentive compatibility constraint is

$$U_E(\underline{\theta}, s_i) \geq U_E\left(\overline{\theta}, s_i\right) + q_i(\overline{\theta}, s_i)\Delta\theta,$$

where $q_i(\overline{\theta}, s_i)\Delta\theta$ is the information rent of a low-cost agent. Moreover, $U_E\left(\overline{\theta}, s_i\right) = 0$ for every $s_i$ due to limited liability.

Substituting into the principal's objective function yields

$$\begin{aligned} & \sum_{\theta_i \in \Theta} \Pr[\theta_i] \int_{s_i \in S_E} [q_i(\theta_i, s_i)(p - \theta_i) - U_E(\theta_i, s_i)]\, dF(s_i|\theta_i) \\ = & \sum_{\theta_i \in \Theta} \Pr[\theta_i] \int_{s_i \in S_E} q_i(\theta_i, s_i)(p - \theta_i)\, dF_E(s_i|\theta_i) - \nu U_E(\underline{\theta}), \end{aligned}$$

where

$$U_E(\underline{\theta}) \equiv \Delta\theta \int_{s_i \in S_E} q_i(\overline{\theta}, s_i) dF_E(s_i|\underline{\theta})$$

is the expected information rent of a low-cost agent.

Maximizing the principal's objective function with respect to $q(\cdot,\cdot)$ yields: $(i)$ $q_i(\underline{\theta}, s_i) = 1$ since $p > \underline{\theta}$ for any $p \in P$ by Assumption 1; and $(ii)$ $q_i\left(\overline{\theta}, s_i\right) = 1$ if and only if the principal's virtual surplus when his agent has high cost and he observes signal $s_i$ is positive — i.e.,

$$\Gamma_E(s_i, p) \equiv p - \overline{\theta} - \underbrace{\frac{\nu}{1-\nu} \frac{f_E(s_i|\underline{\theta})}{f_E\left(s_i|\overline{\theta}\right)}}_{= \frac{\Pr[\underline{\theta}|s_i]}{\Pr[\overline{\theta}|s_i]}} \Delta\theta \geq 0.$$

Hence, we have the following result.

**Lemma 2** *Let $\tilde{S}_E(p) \equiv \{s_i \in S_E : \Gamma_E(s_i, p) \geq 0\}$. For any expected market price $p \in P$, the optimal contract offered by a principal who acquires information features $q_i(\underline{\theta}, s_i) =$*

$1 \quad \forall s_i$, *and*

$$q_i\left(\overline{\theta}, s_i\right) = \begin{cases} 1 \text{ if } s_i \in \tilde{S}_E(p), \\ 0 \text{ if } s_i \notin \tilde{S}_E(p). \end{cases}$$

If all principals acquire information, then by the law of large numbers aggregate supply is

$$y(E) = \nu + (1-\nu)\Pr\left[s_i \in \tilde{S}_E(p_E)\right],$$

where the equilibrium market price is $p_E = u'(y(E))$, and the principal's expected profit is

$$V_E(p_E) \equiv \nu\left(p_E - \underline{\theta}\right) + (1-\nu)\int_{s_i \in \tilde{S}_E(p_E)} \Gamma_E(s_i, p_E)\, dF_E\left(s_i|\overline{\theta}\right).$$

Since experiment $E$ only affects the equilibrium price and the principals' expected profit through $\tilde{S}_E(p_E)$, the subset of signals that do not induce shut down of a high-cost agent, we can simplify the analysis through the following result, which echoes the findings of Calzolari and Pavan (2006) and Bergemann *et al.* (2015).

**Lemma 3** *The optimal experiment offered by the information provider consists of only two signals.*

**Proof of Lemma 3.** Let $E$ be a generic experiment with $S_E \subseteq \mathbb{R}$. Denote by $p_E$ the equilibrium price induced by that experiment. Recall that $\tilde{S}_E(p)$ is the subset of signals that induce a principal to produce when the agent's cost is high and that Assumption 1 guarantees that production always occurs when the cost is low.

Suppose first that $\tilde{S}_E(p_E) \neq \varnothing$ and that $S_E \backslash \tilde{S}_E(p_E) \neq \varnothing$. Then

$$\rho(E) = (1-\nu)\left[\int_{s_i \in \tilde{S}_E(p_E)} \left[p_E - \overline{\theta} - \frac{\nu}{1-\nu}\frac{f_E(s_i|\underline{\theta})}{f_E(s_i|\overline{\theta})}\Delta\theta\right] dF\left(s_i|\overline{\theta}\right) - \max\{0, \Gamma_{\varnothing}(p_E)\}\right].$$

Notice that

$$\rho(E) < (1-\nu)\left[\int_{s_i \in \tilde{S}_E(p_E)} \left[p_E - \overline{\theta} - \frac{\nu}{1-\nu}\min_{s_i \in \tilde{S}_E(p_E)}\frac{f_E(s_i|\underline{\theta})}{f_E(s_i|\overline{\theta})}\Delta\theta\right] dF\left(s_i|\overline{\theta}\right) - \max\{0, \Gamma_{\varnothing}(p_E)\}\right].$$

Next, consider a new experiment $E'$, with $S_{E'} \subset S_E$, such that

$$S_{E'} = S_E \backslash \tilde{S}_E(p_E) \cup \arg\min_{s_i \in \tilde{S}_E(p_E)} \frac{f_E(s_i|\underline{\theta})}{f_E(s_i|\overline{\theta})},$$

and

$$f_{E'}(s_i|\theta) = \begin{cases} f_E(s_i|\theta) & \Leftrightarrow s_i \in S_E \backslash \tilde{S}_E(p_E), \\ \int_{s_i \in \tilde{S}_E(p_E)} f_E(s_i|\theta)\, ds & \Leftrightarrow s_i \in \arg\min\limits_{s_i \in \tilde{S}_E(p_E)} \frac{f_E(s_i|\underline{\theta})}{f_E(s_i|\overline{\theta})}, \\ 0 & \text{otherwise.} \end{cases}$$

Note that $p_E = p_{E'}$ because $y(E) = y(E')$ by the law of large numbers. Hence, $\rho(E) < \rho(E')$. Using the same logic we can show that for any $E$ such that $\tilde{S}_E(p_E) = S_E$ or

$\tilde{S}_E(p_E) = \varnothing$ the information provider cannot be worse off by offering a simpler experiment that implements the same price. The result then follows immediately. ■

Given a generic experiment $E$, since the market price when all principals acquire information only depends on the probability of production in the high-cost state, the information provider can offer a simpler experiment $E'$ that assigns probability $\Pr\left[s_i \in \tilde{S}_E(p_E)\right]$ only to the signal that minimizes the agent's information rent. In other words, the provider can always group all signals leading to production by the high-cost agent as one signal, and group all signals leading to no production by the high-cost agent as another signal, in a way that minimizes agency costs. Principals strictly prefer experiment $E'$ to experiment $E$, since $E'$ increases principals' profits and results in the same production decision and market price.

## A.2 Proofs

**Proof of Proposition 1.** Using standard techniques, it can be shown that the maximization problem of a principal who does not acquire information and expects a market price $p \in P$ is

$$\max_{q_i(\cdot,\varnothing)\in[0,1]} \left\{ \sum_{\theta_i\in\Theta} \Pr[\theta_i]\, q_i(\theta_i,\varnothing)(p-\theta_i) - \nu q_i\left(\overline{\theta},\varnothing\right)\Delta\theta \right\}.$$

Differentiating with respect to $q_i(\underline{\theta},\varnothing)$ it follows that $\nu(p-\underline{\theta}) > 0$ for any $p \in P$. Hence, $q_i(\underline{\theta},\varnothing) = 1$. Differentiating with respect to $q_i\left(\overline{\theta},\varnothing\right)$, it follows that $q_i\left(\overline{\theta},\varnothing\right) = 1$ if and only if $p - \overline{\theta} - \frac{\nu}{1-\nu}\Delta\theta \geq 0$ — i.e., $\nu \leq \underline{\nu}(p)$. ■

**Proof of Proposition 2.** By Lemma 2,

$$q_i\left(\overline{\theta},\underline{s}\right) = \begin{cases} 1 & \text{if } \frac{\beta}{1-\alpha} \leq \frac{1-\nu}{\nu}\frac{p-\overline{\theta}}{\Delta\theta} \\ 0 & \text{otherwise} \end{cases}$$
$$q_i\left(\overline{\theta},\overline{s}\right) = \begin{cases} 1 & \text{if } \frac{1-\beta}{\alpha} \leq \frac{1-\nu}{\nu}\frac{p-\overline{\theta}}{\Delta\theta} \\ 0 & \text{otherwise.} \end{cases}$$

The result follows immediately. ■

**Proof of Lemma 1.** Consider an experiment such that

$$\Gamma_{\alpha,\beta}(\overline{s}, p(\alpha)) \geq 0 > \Gamma_{\alpha,\beta}(\underline{s}, p(\alpha)).$$

Then, by definition,

$$\rho(\alpha,\beta) = (1-\nu)\,\alpha\left[p(\alpha) - \overline{\theta}\right] - \nu(1-\beta)\Delta\theta - (1-\nu)\max\{0, \Gamma_{\varnothing}(p(\alpha))\},$$

where $p(\alpha)$ is the market clearing price when all principals acquire information. By concavity of $u(\cdot)$, there exists a unique $\tilde{\alpha}$ that solves

$$u'(\nu+(1-\nu)\alpha)=\overline{\theta}+\frac{\nu}{1-\nu}\Delta\theta,$$

such that

$$\max\left\{0,u'(\nu+(1-\nu)\alpha)-\overline{\theta}-\frac{\nu}{1-\nu}\Delta\theta\right\}>0\quad\Leftrightarrow\quad\alpha\leq\tilde{\alpha}.$$

This yields equation (5). ■

**Proof of Proposition 3.** By Lemma 1**,** it immediately follows that for any experiment such that

$$\Gamma_{\alpha,\beta}(\underline{s},p(\alpha))<0\leq\Gamma_{\alpha,\beta}(\overline{s},p(\alpha)),$$

it is optimal for the information provider to set $\beta=1$. Hence,

$$\rho(\alpha,1)=\begin{cases}(1-\nu)\alpha\left[u'(\nu+(1-\nu)\alpha)-\overline{\theta}\right] & \text{if }\alpha\geq\tilde{\alpha},\\ \nu\Delta\theta-(1-\nu)(1-\alpha)\left[u'(\nu+(1-\nu)\alpha)-\overline{\theta}\right] & \text{if }\alpha<\tilde{\alpha}.\end{cases}$$

In order to characterize the precision $\alpha$ that maximizes $\rho(\alpha,1)$ three cases must be considered.

First, if $\frac{\nu}{1-\nu}\Delta\theta<u'(1)-\overline{\theta}$, then $\tilde{\alpha}>1$ and

$$\rho(\alpha,1)=\nu\Delta\theta-(1-\alpha)(1-\nu)\left[u'(\nu+(1-\nu)\alpha)-\overline{\theta}\right]<\rho(1,1)=\nu\Delta\theta.$$

Hence, in this case the information provider chooses $\alpha^*=\beta^*=1$.

Second, if $\frac{\nu}{1-\nu}\Delta\theta\geq u'(\nu)-\overline{\theta}$, then concavity of $u(\cdot)$ implies $\frac{\nu}{1-\nu}\Delta\theta>u'(1)-\overline{\theta}$. Hence,

$$\rho(\alpha,1)=(1-\nu)\alpha\left[u'(\nu+(1-\nu)\alpha)-\overline{\theta}\right].$$

This function is single peaked by Assumption 1 and is maximized at $\alpha\in(0,1)$ such that

$$u'(\nu+(1-\nu)\alpha)-\overline{\theta}+\alpha u''(\nu+(1-\nu)\alpha)(1-\nu)=0,$$

if and only if

$$u'(1)-\overline{\theta}+u''(1)(1-\nu)<0\quad\Leftrightarrow\quad\varepsilon(1)\equiv\frac{u'(1)}{|u''(1)|}<\overline{\varepsilon}\left(\overline{\theta},\nu\right)\equiv\frac{\overline{\theta}}{|u''(1)|}+1-\nu.$$

Otherwise, $\rho(\alpha,1)$ is maximized at $\alpha=1$. Since $\rho(1,1)=(1-\nu)\left(u'(1)-\overline{\theta}\right)$, the result follows immediately.

Third, if $u'(1) - \overline{\theta} < \frac{\nu}{1-\nu}\Delta\theta < u'(\nu) - \overline{\theta}$, then $\tilde{\alpha} \in (0,1)$ and

$$\rho(\alpha, 1) = \begin{cases} (1-\nu)\,\alpha\left[u'(\nu + (1-\nu)\,\alpha) - \overline{\theta}\right] & \text{if } \alpha \geq \tilde{\alpha}, \\ \nu\Delta\theta - (1-\nu)(1-\alpha)\left[u'(\nu + (1-\nu)\,\alpha) - \overline{\theta}\right] & \text{if } \alpha < \tilde{\alpha}. \end{cases}$$

Note that

$$\frac{\partial \rho(\alpha, 1)}{\partial \alpha} = (1-\nu)\left[u'(\nu + (1-\nu)\,\alpha) - \overline{\theta}\right] + (1-\nu)^2 (1-\alpha)\, u''(\nu + (1-\nu)\,\alpha) > 0 \quad \forall \alpha \leq \tilde{\alpha},$$

which means that $\max_{\alpha \leq \tilde{\alpha}} \rho(\alpha, 1) = \tilde{\alpha}\nu\Delta\theta$. Suppose that

$$\left.\frac{\partial}{\partial \alpha}\alpha\left(u'(\nu + (1-\nu)\,\alpha) - \overline{\theta}\right)\right|_{\alpha = \tilde{\alpha}} \geq 0.$$

Assumption 2 implies that $\rho(\alpha, 1)$ is maximized at $\alpha^*$. Hence, as before, $\rho(\alpha^*, 1) > \rho(1, 1)$ as long as $\varepsilon(1) < \overline{\varepsilon}\left(\overline{\theta}, \nu\right)$. By contrast, if

$$\left.\frac{\partial}{\partial \alpha}\alpha\left(u'(\nu + (1-\nu)\,\alpha) - \overline{\theta}\right)\right|_{\alpha = \tilde{\alpha}} < 0,$$

then Assumption 2 implies that $\rho(\alpha, 1)$ is maximized at $\tilde{\alpha}$. But, by definition,

$$\tilde{\alpha}\left(u'(\nu + (1-\nu)\,\tilde{\alpha}) - \overline{\theta}\right) = \frac{\nu}{1-\nu}\Delta\theta - (1-\tilde{\alpha})\left(u'(\nu + (1-\nu)\,\tilde{\alpha}) - \overline{\theta}\right).$$

Hence, $\rho(\tilde{\alpha}, 1) > \rho(1, 1)$ as long as $\varepsilon(1) < \overline{\varepsilon}\left(\overline{\theta}, \nu\right)$. In this case, Assumption 2 implies that the optimal experiment features $\beta^* = 1$ and $\alpha^* < 1$. ■

**Proof of Proposition 4.** Suppose that $\varepsilon(1) < \overline{\varepsilon}\left(\overline{\theta}, \nu\right)$. The fact that $\alpha^* = \max\{\hat{\alpha}, \tilde{\alpha}\}$ follows immediately from the proof of Proposition 3. Moreover, by concavity of $u(\cdot)$, $\tilde{\alpha}$ is decreasing in $\Delta\theta$ and $\tilde{\alpha} \to 0$ as $\Delta\theta$ becomes large enough; while (other things being constant) $\tilde{\alpha}$ does not vary with $\Delta\theta$ (see condition 6). Hence, by continuity of $u(\cdot)$ there exists a threshold $\underline{\Delta\theta}$ such that $\hat{\alpha} \geq \tilde{\alpha}$ if and only if $\Delta\theta \geq \underline{\Delta\theta}$. ■

**Proof of Proposition 5.** Recall that aggregate supply is

$$y(\alpha, \beta) = \nu + \underbrace{(1-\nu)\left[\alpha q_i\left(\overline{\theta}, \overline{s}\right) + (1-\alpha)\, q_i\left(\overline{\theta}, \underline{s}\right)\right]}_{\equiv \overline{y}}.$$

Suppose that $\alpha$ and $\beta$ are such that $y(\alpha, \beta) < 1$ and consider an alternative experiment with precision $\alpha'$ and $\beta'$ that increases aggregate supply to $y(\alpha', \beta') = \nu + \overline{y}\varepsilon \leq 1$, where $\varepsilon \geq 1$. Then

$$\begin{aligned} \mathcal{W}(\alpha', \beta') - \mathcal{W}(\alpha, \beta) &= u(y(\alpha', \beta')) - u(y(\alpha, \beta)) - \overline{y}\varepsilon\overline{\theta} + \overline{y}\overline{\theta} \\ &= u(\nu + \overline{y}\varepsilon) - u(\nu + \overline{y}) - \overline{y}\overline{\theta}(\varepsilon - 1). \end{aligned}$$

This function is equal to 0 at $\varepsilon = 1$ and

$$\frac{\partial}{\partial \varepsilon}\left[\mathcal{W}\left(\alpha', \beta'\right) - \mathcal{W}\left(\alpha, \beta\right)\right] = \overline{y}\left(u'\left(\nu + \overline{y}\varepsilon\right) - \overline{\theta}\right),$$

which is strictly positive by Assumption 1. Hence, choosing an experiment that increases aggregate supply always increases social welfare. Since the experiment that maximizes aggregate supply is the fully informative one, this experiment also maximizes social welfare. ■

**Proof of Proposition 6.** Consider a fully informative experiment. The agent obtains no rent and, in every state $\theta_i$, the monopolist produces the output $q^M\left(\theta_i\right)$ that solves

$$u'\left(q^M\left(\theta_i\right)\right) + q^M\left(\theta_i\right)u''\left(q^M\left(\theta_i\right)\right) = \theta_i.$$

Denote the full information profit

$$V^* \equiv \sum_{\theta_i \in \Theta} \Pr\left[\theta_i\right] q^M\left(\theta_i\right)\left[u'\left(q^M\left(\theta_i\right)\right) - \theta_i\right].$$

Consider now an experiment $E$ that is not fully informative. Let $q\left(\theta_i, s_i\right)$ be the monopolist's production in the state $\left(\theta_i, s_i\right) \in \Theta \times S_E$. For any information policy, the monopolist's maximization problem is

$$\max_{q(\cdot)\in[0,1]}\left\{\sum_{\theta_i\in\Theta}\Pr\left[\theta_i\right]\int_{s_i\in S}\left[q\left(\theta_i, s_i\right)\left(u'\left(q\left(\theta_i, s_i\right)\right) - \theta_i\right)\right]dF_E\left(s_i|\theta_i\right) - \nu\Delta\theta\int_{s_i\in S} q(\overline{\theta}, s_i)dF_E\left(s_i|\underline{\theta}\right)\right\}. \tag{9}$$

The first-order conditions imply $q^E\left(\underline{\theta}, s_i\right) = q^M\left(\underline{\theta}\right)$ for every $s_i \in S_E$ and

$$u'(q^E(\overline{\theta}, s_i)) + q^E(\overline{\theta}, s_i)u''(q^E(\overline{\theta}, s_i)) = \overline{\theta} + \frac{\nu}{1-\nu}\frac{f_E(s_i|\underline{\theta})}{f_E(s_i|\overline{\theta})}\Delta\theta,$$

with $q^E\left(\overline{\theta}, s_i\right) \leq q^M\left(\overline{\theta}\right)$ for every $s_i \in S_E$. By Assumption 2, the value function associated to the maximization problem (9) is

$$\begin{aligned}
V^M\left(E\right) &< \sum_{\theta_i\in\Theta}\Pr\left[\theta_i\right]\int_{s_i\in S} q^E\left(\theta_i, s_i\right)\left[u'\left(q^E\left(\theta_i, s_i\right)\right) - \theta_i\right]dF_E\left(s_i|\theta_i\right) \\
&< \sum_{\theta_i\in\Theta}\Pr\left[\theta_i\right] q^M\left(\theta_i\right)\left[u'\left(q^M\left(\theta_i\right)\right) - \theta_i\right] = V^*.
\end{aligned}$$

Hence, the result follows. ■

**Proof of Proposition 7.** Consider a symmetric equilibrium, in which the information providers share the market equally (i.e., each sells to a mass $\frac{1}{2}$ of principals) and offer an experiment $\left(\alpha^*, \beta^*\right)$ that is not fully informative $\left(\alpha^* + \beta^* < 2\right)$ and induces principals to shut down production only in state $\underline{s}$. (Since $\alpha + \beta > 1$, if there is shut down in state $\overline{s}$, there must be shut down also in state $\underline{s}$.) If provider $B$ behaves according to equilibrium,

$$x^*(\cdot) \equiv \frac{1}{2} + \frac{\rho^* - \rho_A}{2c} + \frac{V_A(\alpha_A, \beta_A, \alpha^*, \beta^*) - V_B(\alpha^*, \beta^*, \alpha_A, \beta_A)}{2c},$$

where

$$\begin{aligned} V_A(\cdot) - V_B(\cdot) \equiv (1-\nu) & \sum_{s_A \in \{\underline{s}, \overline{s}\}} \Pr\left[s_A | \overline{\theta}\right] \max\left\{0, \Gamma^A_{\alpha_A, \beta_A}(s_A, p(\alpha_A, \alpha^*, \beta_A, \beta^*))\right\} \\ & - (1-\nu) \sum_{s_B \in \{\underline{s}, \overline{s}\}} \Pr\left[s_B | \overline{\theta}\right] \max\left\{0, \Gamma^B_{\alpha^*, \beta^*}(s_B, p(\alpha_A, \alpha^*, \beta_A, \beta^*))\right\}, \end{aligned}$$

and

$$p(\alpha_A, \alpha^*, \beta_A, \beta^*) = u'(\nu + (1-\nu)(x^*(\cdot)\alpha_A + (1 - x^*(\cdot))\alpha^*)).$$

Since $\pi_A(\cdot) = x^*(\cdot)\rho_A$, the equilibrium experiment is

$$(\alpha^*, \beta^*) \in \arg\max_{(\alpha_A, \beta_A)} \{V_A(\alpha_A, \beta_A, \alpha^*, \beta^*) - V_B(\alpha^*, \beta^*, \alpha_A, \beta_A)\}.$$

First the equilibrium features $\beta^* = 1$. Indeed, if $\beta^* < 1$, then a provider, say $A$, can strictly increase his profit by choosing $\beta_A = \beta^* + \varepsilon$ ($\varepsilon > 0$), since

$$V_A(\alpha^*, \beta^* + \varepsilon, \alpha^*, \beta^*) - V_B(\alpha^*, \beta^*, \alpha^*, \beta^* + \varepsilon) = (1-\nu)\varepsilon\Delta\theta > 0.$$

Second, following the same logic of the monopoly case, if $\alpha^* < 1$ then principals cannot always produce in equilibrium.

Third, it is not possible that $\alpha^* < 1$ and $\beta^* = 1$. The reason is that, in this case, a deviation $\alpha_A = \alpha^* + \varepsilon$, with $\varepsilon$ arbitrarily small, is profitable if

$$V_A(\alpha^* + \varepsilon, 1, \alpha^*, 1) - V_B(\alpha^*, 1, \alpha^* + \varepsilon, 1) > 0.$$

Differentiating with respect to $\varepsilon$,

$$\left.\frac{\partial [V_A(\cdot) - V_B(\cdot)]}{\partial \varepsilon}\right|_{\varepsilon=0} = (1-\nu)\left\{\max\left\{0, \Gamma^A_{\alpha^*,1}(\overline{s}, p(\cdot))\right\} + \alpha^* \underbrace{\left[\frac{\partial}{\partial \alpha_A} p(\cdot) - \frac{\partial}{\partial \alpha_A} p(\cdot)\right]}_{=0}\right\},$$

which is strictly positive since $\max\left\{0, \Gamma^A_{\alpha^*,1}(\overline{s}, p(\cdot))\right\} > 0$ in equilibrium.

Fourth, a deviation by a provider, say $A$, with $x^*(\cdot) > \frac{1}{2}$ is not profitable. In fact, since $A$ cannot charge a price higher than $\rho^*$, this deviation can be profitable only if

$$x^*(\alpha^*, \beta^*, \rho^*) = \tfrac{1}{2} > \tfrac{1}{2} + V_A(\alpha_A, 1, 1, 1) - V_B(1, 1, \alpha_A, 1),$$

where, by definition,

$$V_A(\alpha_A, 1, 1, 1) - V_B(1, 1, \alpha_A, 1) \equiv$$
$$(1-\nu)\left\{\sum_{s_A \in \{\underline{s}, \overline{s}\}} \Pr\left[s_A|\overline{\theta}\right] \max\left\{0, \Gamma^A_{\alpha_A,1}(s_A, p(\cdot))\right\} - \left[p(\cdot) - \overline{\theta}\right]\right\}.$$

However:

- If $\alpha_A$ induces shut down in both states,

$$\sum_{s_A \in \{\underline{s}, \overline{s}\}} \Pr\left[s_A|\overline{\theta}\right] \max\left\{0, \Gamma^A_{\alpha_A,1}(s_A, p(\cdot))\right\} = 0,$$

  implying that $V_A(\cdot) < V_B(\cdot)$.

- If $\alpha_A < 1$ never induces shut down,

$$\sum_{s_A \in \{\underline{s}, \overline{s}\}} \Pr\left[s_A|\overline{\theta}\right] \max\left\{0, \Gamma^A_{\alpha_A,1}(s_A, p(\cdot))\right\} = p(\cdot) - \overline{\theta} - \frac{\nu}{1-\nu}\Delta\theta < p(\cdot) - \overline{\theta},$$

  implying that $V_A(\cdot) < V_B(\cdot)$.

- If $\alpha_A < 1$ induces shut down only is state $\underline{s}$,

$$V_A(\cdot) - V_B(\cdot) \equiv (1-\nu)\left\{\alpha_A\left[p(\cdot) - \overline{\theta}\right] - p(\cdot) - \overline{\theta}\right\} < 0.$$

Hence, in a symmetric equilibrium with full market coverage, both providers offer the fully informative experiment — i.e., $\alpha^* = \beta^* = 1$ — and $\rho^* = c$: the standard Hotelling's pricing rule (which follows from differentiation of a provider's expected profit and symmetry).

By Assumption 3, such an equilibrium requires that, for every $x \leq 1/2$,

$$\nu\left(u'(1) - \underline{\theta}\right) + (1-\nu)\left(u'(1) - \overline{\theta}\right) - cx^2 - \rho^* \geq \nu\left(u'(1) - \underline{\theta}\right).$$

Substituting $\rho^* = c$ yields

$$(1-\nu)\left(u'(1) - \overline{\theta}\right) \geq \max_{x \leq \frac{1}{2}} c\left(1 + x^2\right) \quad \Leftrightarrow \quad c \leq \underline{c} \equiv \frac{4(1-\nu)\left(u'(1) - \overline{\theta}\right)}{5}.$$

■

**Proof of Proposition 8.** In Proposition 7 we have shown that for $c > \underline{c}$ there is no symmetric equilibrium with full market coverage. Hence, if a symmetric equilibrium exists in this case, it must be such that some principals do not buy information. Accordingly, we now characterize sufficient conditions for an equilibrium without full market coverage

— i.e., such that, for some $k^* \in \left(0, \frac{1}{2}\right)$: $(i)$ principals in the interval $\left[0, \frac{1}{2} - k^*\right]$ buy from $A$; $(ii)$ principals in the interval $\left[\frac{1}{2} + k^*, 1\right]$ buy from $B$; $(iii)$ principals in the interval $\left[\frac{1}{2} - k^*, \frac{1}{2} + k^*\right]$ do not buy information. Following the logic of the proof of Proposition 7, it can be shown that there is no loss of generality in considering equilibria such that $\beta^* = 1$.

We first show, by contradiction, that such equilibrium cannot feature $k^* \in \left(0, \frac{1}{2}\right)$, $\alpha^* < 1$ and informed principals shutting down production only in state $\underline{s}$. To characterize $A$'s best response when $B$ behaves according to equilibrium notice that, if $A$ offers $(\alpha_A, \rho_A)$ and a mass $\frac{1}{2} - k_A < \frac{1}{2}$ of principals acquires the experiment from him, then it must be

$$V_A\left(\alpha_A, \alpha^*, k_A, k^*\right) - c\left(\tfrac{1}{2} - k_A\right)^2 - \rho_A = V_\varnothing\left(p\left(\alpha_A, \alpha^*, k_A, k^*\right)\right),$$

where

$$p\left(\alpha_A, \alpha^*, k_A, k^*\right) \equiv u'\left(\left(\tfrac{1}{2} - k_A\right)\left(\nu + (1-\nu)\,\alpha_A\right) + \left(\tfrac{1}{2} - k^*\right)\left(\nu + \alpha^*(1-\nu)\right) + \nu\left(\varepsilon_A + \varepsilon^*\right)\right),$$

and $V_A\left(\alpha_A, \alpha^*, k_A, k^*\right)$ is the gross profit of a principal who buys from $A$ (which depends on $k_A$ and $k^*$ through their effect on the market price). For any $k_A$ that provider $A$ wants to implement, he must charge

$$\rho_A\left(\alpha_A, \alpha^*, k^*, k_A\right) \equiv \underbrace{\Delta V_A\left(\alpha_A, \alpha^*, k_A, k^*\right)}_{V_A\left(\alpha_A, \alpha^*, k_A, k^*\right) - V_\varnothing\left(p\left(\alpha_A, \alpha^*, k_A, k^*\right)\right)} - c\left(\tfrac{1}{2} - k_A\right)^2,$$

where, by Assumption 3,

$$\Delta V_A\left(\alpha_A, \alpha^*, k_A, k^*\right) \equiv (1-\nu) \sum_{s_A \in \{\underline{s}, \overline{s}\}} \Pr\left[s_A | \overline{\theta}\right] \max\left\{0, \Gamma_{\alpha_A,1}\left(s_A, p\left(\alpha_A, \alpha^*, k_A, k^*\right)\right)\right\}.$$

Note that $\Delta V_A(\cdot)$ is increasing in $k_A$ because $u''(\cdot) < 0$. Hence, for any $\alpha_A$, $\rho_A(\cdot)$ is a monotone function of $k_A$. This implies that we can analyze (without loss of generality) an equivalent game in which information providers choose the fraction of principals they wish to serve rather than prices (which are determined to make the marginal principal indifferent between buying information and not). Note that this change of variables does not affect the nature of the strategic interaction among players because in the equilibrium that we consider information providers do not compete directly and hence, as monopolists, they can either choose prices or quantity, if demand is well behaved.

Therefore, provider $A$'s problem can be written as

$$\max_{k_A, \alpha_A} \rho_A\left(\alpha_A, \alpha^*, k_A, k^*\right) \tfrac{1-2k_A}{2}.$$

The first-order conditions are (imposing symmetry)

$$-\alpha^*\left[u'\left(\nu+\left(1-2k^*\right)\left(1-\nu\right)\alpha^*\right)-\overline{\theta}\right]+\tfrac{3c}{4}\left(1-2k^*\right)^2$$
$$=\tfrac{1}{2}\left(1-2k^*\right)\alpha^{*2}\left(1-\nu\right)u''\left(\nu+\left(1-2k^*\right)\left(1-\nu\right)\alpha^*\right).$$

and

$$u'\left(\nu+\left(1-2k^*\right)\left(1-\nu\right)\alpha^*\right)-\overline{\theta}=-\tfrac{1}{2}\left(1-\nu\right)\left(1-2k^*\right)\alpha^*u''\left(\nu+\left(1-2k^*\right)\left(1-\nu\right)\alpha^*\right).$$

Substituting the second condition in the first and rearranging yields

$$\tfrac{3c}{4}\left(1-2k^*\right)^2=0,$$

which cannot be true if $k^*<\frac{1}{2}$: a contradiction.

Moreover, since a symmetric equilibrium cannot feature $k^*=0$, then it must be $\alpha^*=1$. We now characterize sufficient conditions for this outcome to be an equilibrium. When $\alpha_A=1$, $A$'s problem is

$$\max_{k_A\in\left(0,\frac{1}{2}\right)}\rho_A\left(k_A,k^*\right)\tfrac{1-2k_A}{2},$$

where

$$\begin{aligned}\rho_A\left(k_A,k^*\right)&\equiv\left(1-\nu\right)\left[p\left(k_A,k^*\right)-\overline{\theta}\right]-\tfrac{c}{4}\left(1-2k_A\right)^2\\&=\left(1-\nu\right)\left[u'\left(1-\left(1-\nu\right)\left(k_A+k^*\right)\right)-\overline{\theta}\right]-\tfrac{c}{4}\left(1-2k_A\right)^2.\end{aligned}$$

Differentiating $A$'s profit with respect to $k_A$

$$-\left(1-\nu\right)\left[u'\left(1-\left(1-\nu\right)\left(k_A+k^*\right)\right)-\overline{\theta}\right]+\tfrac{c}{4}\left(1-2k_A\right)^2$$
$$+\tfrac{1-2k_A}{2}\left[c\left(1-2k_A\right)-\left(1-\nu\right)^2u''\left(1-\left(1-\nu\right)\left(k_A+k^*\right)\right)\right]=0.$$

In equilibrium,

$$\tfrac{c}{4}\left(1-2k^*\right)^2=\left(1-\nu\right)\left[u'\left(1-2\left(1-\nu\right)k^*\right)-\overline{\theta}\right]+\tfrac{1-2k_A}{2}\left(1-\nu\right)^2u''\left(1-2\left(1-\nu\right)k^*\right).\tag{10}$$

If the solution of this equation exists, it pins down the candidate equilibrium. Let

$$\Phi\left(x\right)\equiv-\left(1-\nu\right)\left[u'\left(1-2\left(1-\nu\right)x\right)-\overline{\theta}\right]+\tfrac{c}{4}\left(1-2x\right)^2-\tfrac{1-2x}{2}\left(1-\nu\right)^2u''\left(1-2\left(1-\nu\right)x\right).$$

Note that $\Phi\left(0.5\right)=-\left(1-\nu\right)\left(u'\left(\nu\right)-\overline{\theta}\right)<0$ by Assumption 1 and

$$\Phi\left(0\right)=-\left(1-\nu\right)\left(u'\left(1\right)-\overline{\theta}\right)+\tfrac{c}{4}-\tfrac{1}{2}\left(1-\nu\right)^2u''\left(1\right),$$

which is positive if and only if

$$c \geq \bar{c} \equiv 2(1-\nu)\left[2\left(u'(1)-\overline{\theta}\right)+(1-\nu)u''(1)\right].$$

Moreover, at an optimum $k_A = k^*$, $A$'s profit is concave — i.e.,

$$2\left[(1-\nu)^2 u''(1-(1-\nu)(k_A+k^*)) - c(1-2k_A)\right] \\ + \tfrac{1-2k_A}{2}\left[(1-\nu)^3 u'''(1-(1-\nu)(k_A+k^*)) - 2c\right] < 0,$$

which is always true if $u'''(x) < \eta$ for every $x \in [0,1]$, with $\eta > 0$ and small enough. Hence, if a symmetric equilibrium in which the market is not fully covered exists, then $k^*$ must solve (10).

To complete the proof we show that $A$ cannot profitably deviate from this candidate equilibrium because $A$'s best deviation features $\alpha_A = 1$ and, hence, his profit is maximized by $k_A = k^*$, as shown above. This is done in the following three steps.

**Step 1.** For any $k_A$, a conceivable deviation in $\alpha_A$ such that $\alpha_A < 1$ must induce principals who buy from $A$ to shut down production in state $\underline{s}$ only. In fact, as argued before, $A$ has no incentive to offer $\alpha_A < 1$ if principals who buy the experiment produce in both states.

**Step 2.** Provider $A$'s optimal deviation cannot feature both $\alpha_A < 1$ and $k_A \in \left(-\frac{1}{2}, \frac{1}{2}\right)$. To see this, note that if the optimal deviation is such that $\alpha_A < 1$, then principals buying from $A$ must shut down production in state $\underline{s}$ only. Otherwise $A$ strictly gain by setting $\alpha_A = 1$, a contradiction. Hence, provider $A$'s maximization problem is

$$\max_{k_A \in \left(-\frac{1}{2}, \frac{1}{2}\right), \alpha_A < 1} \rho_A(\alpha_A, k_A, )\, \tfrac{1-2k_A}{2},$$

where

$$\rho_A(\alpha_A, k_A) \equiv \\ (1-\nu)\alpha_A\left[u'\left(\left(\tfrac{1}{2}-k_A\right)(\nu+(1-\nu)\alpha_A)+\left(\tfrac{1}{2}-k^*\right)+\nu(k_A+k^*)\right)-\overline{\theta}\right] - \tfrac{c}{4}(1-2k_A)^2.$$

The first-order conditions for an interior solution are

$$-(1-\nu)\alpha_A\left[u'\left(\left(\tfrac{1}{2}-k_A\right)(\nu+(1-\nu)\alpha_A)+\left(\tfrac{1}{2}-k^*\right)+\nu(k_A+k^*)\right)-\overline{\theta}\right] + \tfrac{3c}{4}(1-2k_A)^2 \\ - \tfrac{1-2k_A}{2}(1-\nu)^2\alpha_A^2 u''\left(\left(\tfrac{1}{2}-k_A\right)(\nu+(1-\nu)\alpha_A)+\left(\tfrac{1}{2}-k^*\right)+\nu(k_A+k^*)\right) = 0.$$

and

$$u'\left(\left(\tfrac{1}{2}-k_A\right)(\nu+(1-\nu)\alpha_A)+\left(\tfrac{1}{2}-k^*\right)+\nu(k_A+k^*)\right)-\overline{\theta} \\ + \tfrac{1-2k_A}{2}(1-\nu)\alpha_A u''\left(\left(\tfrac{1}{2}-k_A\right)(\nu+(1-\nu)\alpha_A)+\left(\tfrac{1}{2}-k^*\right)+\nu(k_A+k^*)\right) = 0.$$

Substituting the second condition in the first and rearranging yields a contradiction:

$$\tfrac{c}{4}\left(1-2k_A\right)^2=0 \quad \Leftrightarrow \quad k_A=\tfrac{1}{2}.$$

**Step 3.** A deviation with $k_A=-\frac{1}{2}$ and $\alpha_A<1$ is not optimal if $c$ is large. To see why, recall that $A$'s objective function is concave in $\alpha_A$ if $u'''(\cdot)$ is small. At $k_A=-\frac{1}{2}$, the derivative of this function with respect to $\alpha_A$ is

$$u'\left(\nu+\left(1-\nu\right)\alpha_A\right)-\overline{\theta}+\left(1-\nu\right)\alpha_A u''\left(\nu+\left(1-\nu\right)\alpha_A\right)=0, \tag{11}$$

while the derivative with respect to $k_A$ is

$$-\left(1-\nu\right)\hat{\alpha}_A\left[u'\left(\nu+\left(1-\nu\right)\alpha_A\right)-\overline{\theta}\right]+\tfrac{3}{2}c-\tfrac{(1-\nu)^2}{2}\hat{\alpha}_A^2u''\left(\left(\nu+\left(1-\nu\right)\alpha_A\right)\right). \tag{12}$$

Substituting (11) in (12),

$$\tfrac{(1-\nu)^2}{2}\hat{\alpha}_A^2u''\left(\nu+\left(1-\nu\right)\hat{\alpha}_A\right)+\tfrac{3}{2}c,$$

which is positive if

$$c>\tfrac{2}{3}\sup_{x\in[0,1]}\left|u''\left(x\right)\right|.$$

Since by steps 1, 2 and 3 $A$'s best deviation features $\alpha_A=1$ and $k_A\in\left(0,\frac{1}{2}\right)$ and yields at the most the equilibrium profit, the result follows.

Finally, it is easy to show that

$$\rho^*=\tfrac{1-2k^*}{2}\left(1-\nu\right)^2\left|u''\left(1-2\left(1-\nu\right)k^*\right)\right|.$$

$\rho^*>c$ follows from the fact that in the equilibrium with full market coverage the fully informative experiment has price $c$. In addition, the first-order condition (10) and concavity of providers' objective function imply that $k^*$ is increasing in $c$. ■

**Proof of Proposition 9.** A coalition formed by principals maximizes

$$V_{\alpha,1}\left(p\left(\alpha\right)\right)\equiv\left(\nu+\left(1-\nu\right)\alpha\right)u'\left(\nu+\left(1-\nu\right)\alpha\right)-\nu\underline{\theta}-\left(1-\nu\right)\alpha\overline{\theta}.$$

Differentiating with respect to $\alpha$ yields

$$u'\left(\nu+\left(1-\nu\right)\alpha\right)-\overline{\theta}+\left(\nu+\left(1-\nu\right)\alpha\right)u''\left(\nu+\left(1-\nu\right)\alpha\right).$$

Since

$$\tfrac{\partial V_{1,1}(p(1))}{\partial\alpha}=u'\left(1\right)-\overline{\theta}+u''\left(1\right)<0 \quad \Leftrightarrow \quad \varepsilon\left(1\right)<\frac{\overline{\theta}}{\left|u''\left(1\right)\right|}\equiv\overline{\varepsilon}(\overline{\theta}),$$

the optimal experiment features $\alpha^{**} < 1$ if $\varepsilon(1) < \overline{\varepsilon}(\overline{\theta})$. Finally, since $\overline{\varepsilon}(\nu, \overline{\theta}) \leq \varepsilon(1)$, $\alpha^{*} < 1$ implies that $\alpha^{**} < 1$. ■

## A.3 Stochastic Rationing

Consider an information provider who sells the fully informative experiment to a mass $x < 1$ of principals, through a stochastic rationing rule. What is the optimal choice of $x$ for the provider?

Suppose, for simplicity, that a principal who does not acquire information shuts down production in the high cost state — i.e., $u'(v) < \frac{\nu}{1-\nu}\Delta\theta$. Since a principal who acquires information always produces by Assumption 1, in equilibrium aggregate supply is

$$y(x) = x + (1-x)\nu = \nu + (1-\nu)x,$$

so that the equilibrium market price is

$$p = u'(\nu + (1-\nu)x).$$

Therefore, a principal's willingness to pay for information is

$$\rho(x) \equiv (1-\nu)\left[u'(\nu + (1-\nu)x) - \overline{\theta}\right],$$

and the information provider's profit is

$$x\rho(x) = (1-\nu)x\left[u'(\nu + (1-\nu)x) - \overline{\theta}\right].$$

This is equivalent to the provider's profit in our model when $\alpha = x$ (see equation (5) when $\beta = 1$).

Maximizing this function with respect to $x$ yields

$$u'(\nu + (1-\nu)x) - \overline{\theta} + x(1-\nu)u''(\nu + (1-\nu)x) = 0,$$

which is identical to condition (6) that characterizes the optimal choice of $\alpha$ when the provider cannot discriminate principals. Hence, compared to our main model, when the provider can discriminate principals the optimal choice of $x$ is identical to the optimal choice of $\alpha$ (so that the provider has the same incentive to restrict the information provided to principals in order to reduce aggregate supply) and the provider obtains the same profit.

A similar result can be obtained when $u'(v) > \frac{\nu}{1-\nu}\Delta\theta$ and when the provider offers an experiment that is not fully informative to some of the principals only (because principals always produce when agents have low cost).

## A.4 Three or More Types

In order to show that our main results do not hinge on the assumption of two types, we analyze an example with more than two types in which the information provider still finds it profitable to restrict information in order to increase the market price. Suppose that $\theta \in \left\{\underline{\theta}, \hat{\theta}, \overline{\theta}\right\}$, with $\Pr\left[\theta = \overline{\theta}\right] = \Pr\left[\theta = \hat{\theta}\right] = \Pr\left[\theta = \underline{\theta}\right] = \frac{1}{3}$ and $\overline{\theta} - \hat{\theta} = \hat{\theta} - \underline{\theta} = \Delta\theta > 0$, for simplicity. Note that the monotone hazard rate property is satisfied — i.e.,

$$\frac{\Pr\left[\theta < \hat{\theta}\right]}{\Pr\left[\theta = \hat{\theta}\right]} = 1 < \frac{\Pr\left[\theta < \overline{\theta}\right]}{\Pr\left[\theta = \overline{\theta}\right]} = 2.$$

Hence, for a given market price $p$, the optimal contract offered by an uninformed principal is such that only local incentive constraints bind — i.e., $q_i(\underline{\theta}, \varnothing) = 1$ and

$$q_i(\hat{\theta}, \varnothing) = 1 \quad \Leftrightarrow \quad \Gamma(\hat{\theta}, p) = p - \hat{\theta} - \Delta\theta \geq 0,$$

$$q_i(\overline{\theta}, \varnothing) = 1 \quad \Leftrightarrow \quad \Gamma(\overline{\theta}, p) = p - \overline{\theta} - 2\Delta\theta \geq 0,$$

so that $q_i(\underline{\theta}, \varnothing) \geq q_i(\hat{\theta}, \varnothing) \geq q_i(\overline{\theta}, \varnothing)$ as required by the monotonicity condition (see, e.g., Laffont and Martimort, 2002, Ch. 3).

Without loss of generality, consider the fully informative experiment with $S_E = \{\underline{s}, \hat{s}, \overline{s}\}$ and associated probabilities

| | $\overline{s}$ | $\hat{s}$ | $\underline{s}$ |
|---|---|---|---|
| $\overline{\theta}$ | 1 | 0 | 0 |
| $\hat{\theta}$ | 0 | 1 | 0 |
| $\underline{\theta}$ | 0 | 0 | 1 |

Assuming that principals buy the experiment in equilibrium, the provider's profit is

$$\rho^{FI} = \frac{p - \sum_{\theta=\overline{\theta},\hat{\theta}} \theta - \sum_{\theta=\overline{\theta},\hat{\theta}} \max\left\{0, \Gamma(\theta, p)\right\}}{3}.$$

Now consider an experiment $E'$ with the same signals and probabilities

| | $\overline{s}$ | $\hat{s}$ | $\underline{s}$ |
|---|---|---|---|
| $\overline{\theta}$ | $\alpha$ | $\frac{1-\alpha}{2}$ | $\frac{1-\alpha}{2}$ |
| $\hat{\theta}$ | $\frac{1-\beta}{2}$ | $\beta$ | $\frac{1-\beta}{2}$ |
| $\underline{\theta}$ | 0 | 0 | 1 |

Similarly to the binary case, without loss of generality, assume as convention that $2\alpha > 1 - \beta$ and $2\beta > 1 - \alpha$.

A principal's willingness to pay for experiment $E'$ is

$$\rho(\alpha, \beta) = \sum_{\theta=\overline{\theta},\hat{\theta}} \Pr\left[\theta\right] \left\{ \sum_{s=\underline{s},\hat{s},\overline{s}} \Pr\left[s|\theta\right] \max\left\{0, \Gamma_{\alpha,\beta}(\theta, s, p)\right\} - \max\left\{0, \Gamma(\theta, p)\right\} \right\},$$

where, if only local incentive constraints bind, virtual surpluses are

$$\Gamma_{\alpha,\beta}(\hat{\theta},s,p)=p-\hat{\theta}-\frac{\Pr\left[s|\underline{\theta}\right]}{\Pr[s|\hat{\theta}]}\Delta\theta=\begin{cases} p-\hat{\theta} & \text{if } s=\overline{s},\hat{s} \\ p-\hat{\theta}-\frac{2}{1-\beta}\Delta\theta & \text{if } s=\underline{s} \end{cases}$$

$$\Gamma_{\alpha,\beta}(\overline{\theta},s,p)=p-\overline{\theta}-\frac{\Pr\left[s|\underline{\theta}\right]+\Pr[s|\hat{\theta}]}{\Pr\left[s|\overline{\theta}\right]}\Delta\theta=\begin{cases} p-\overline{\theta}-\frac{3-\beta}{1-\alpha}\Delta\theta & \text{if } s=\underline{s} \\ p-\overline{\theta}-\frac{2\beta}{1-\alpha}\Delta\theta & \text{if } s=\hat{s} \\ p-\overline{\theta}-\frac{1-\beta}{2\alpha}\Delta\theta & \text{if } s=\overline{s} \end{cases}$$

When $2\alpha>1-\beta$ and $2\beta>1-\alpha$,

$$\frac{\Pr\left[s|\underline{\theta}\right]}{\Pr[s|\hat{\theta}]}<\frac{\Pr\left[s|\underline{\theta}\right]+\Pr[s|\hat{\theta}]}{\Pr\left[s|\overline{\theta}\right]}\quad\forall s,$$

monotonicity is preserved, and $q(\hat{\theta},s)\geq q(\overline{\theta},s)$ for every $s$.

Suppose, only for simplicity, that an agent produces only in the low-cost state when the principal does not acquire information — i.e.,

$$u'\left(\frac{1}{3}\right)<\hat{\theta}+\Delta\theta<\overline{\theta}+2\Delta\theta\quad\Rightarrow\quad\max\left\{0,\Gamma(\hat{\theta},p)\right\}=\max\left\{0,\Gamma(\overline{\theta},p)\right\}=0.$$

Restricting attention to $\beta=1$, which may be suboptimal, the provider's profit is

$$\rho\left(\alpha,1\right)=\frac{p-\hat{\theta}}{3}+\frac{1-\alpha}{3}\max\left\{0,p-\overline{\theta}-\frac{2}{1-\alpha}\Delta\theta\right\}+\frac{\alpha\left(p-\overline{\theta}\right)}{3}.$$

If $\alpha=1$, the experiment is fully informative and $\rho\left(1,1\right)=\rho^{FI}$. If $\alpha<1$, aggregate supply is

$$y\left(\alpha\right)=\begin{cases} \frac{2}{3}+\frac{\alpha}{3} & \text{if } p-\overline{\theta}<\frac{2}{1-\alpha}\Delta\theta, \\ 1 & \text{if } p-\overline{\theta}\geq\frac{2}{1-\alpha}\Delta\theta. \end{cases}$$

Therefore, if $p-\overline{\theta}<\frac{2}{1-\alpha}\Delta\theta$, the equilibrium market price is

$$p^{*}(\alpha)=u'\left(\frac{2+\alpha}{3}\right),$$

and the provider solves

$$\max_{\alpha\in(\overline{\alpha},1]}\rho\left(\alpha,1\right)=\max_{\alpha\in(\overline{\alpha},1]}\left\{\left(1+\alpha\right)u'\left(\frac{2+\alpha}{3}\right)-\hat{\theta}-\alpha\overline{\theta}\right\}.$$

where $\overline{\alpha}$ is uniquely determined by

$$u'\left(\frac{2+\overline{\alpha}}{3}\right)-\overline{\theta}=\frac{2}{1-\overline{\alpha}}\Delta\theta.$$

Neglecting the constraint $\alpha > \overline{\alpha}$, the first-order condition for an interior solution $\alpha^*$ is

$$u'\left(\frac{2+\alpha^*}{3}\right) - \overline{\theta} + \frac{1+\alpha^*}{3}u''\left(\frac{2+\alpha^*}{3}\right) = 0.$$

This solution is lower than 1 if and only if

$$u'(1) - \overline{\theta} + \frac{2}{3}u''(1) < 0 \quad \Leftrightarrow \quad \varepsilon(1) \leq \overline{\varepsilon}(\overline{\theta}) \equiv \frac{2}{3} + \frac{\overline{\theta}}{|u''(1)|}.$$

This condition, whose interpretation is similar to the one in Proposition 3, guarantees that the provider never chooses the fully informative experiment since there always exists an $\alpha < 1$ that yields a profit higher than $\rho(1,1)$.

It can be shown that a similar argument extends to the case with a finite number of types.

# References


[1] Abraham, I., S. Athey, M. Babaioff and M. Grubb (2014), "Peaches, Lemons, and Cookies: Designing Auction Markets with Dispersed Information." Mimeo, Stanford and Boston College.

[2] Admati, A., and P. Pfleiderer (1986), "A Monopolistic Market for Information." *Journal of Economic Theory*, 39(2), 400-438.

[3] Admati, A., and P. Pfleiderer (1990), "Direct and Indirect Sale of Information." *Econometrica*, 58(4), 901-928.

[4] Argyres, N. (1999), "The Impact of Information Technology on Coordination: Evidence from the B-2 'Stealth' Bomber." *Organization Science*, 10(2), 162-180.

[5] Arrow, K. (1987), "Technical Information, Returns to Scale, and the Existence of Competitive Equilibrium." In *Information, Incentives, and Economics Mechanisms*, edited by T. Groves, R. Radner and S. Reiter. University of Minnesota Press.

[6] Arrow, K. (1994), "Information and the Organization of Industry." *Rivista Internazionale di Scienze Sociali*, 102(2), 111-123.

[7] Balestrieri, F., and S. Izmalkov (2014), "Informed Seller in a Hotelling Market." Mimeo, New Economic School.

[8] Bergemann, D., A. Bonatti and A. Smolin (2015), "Selling Experiments." Mimeo, MIT and Yale.

[9] Bergemann, D., and M. Pesendorfer (2007), "Information Structures in Optimal Auctions." *Journal of Economic Theory*, 137, 580-609.

[10] Bergemann, D., and J. Välimäki (2006), "Information in Mechanism Design." In *Proceedings of the 9th World Congress of the Econometric Society*, edited by R. Blundell, W. Newey and T. Persson. Cambridge: Cambridge University Press.

[11] Border, K., and J. Sobel (1987), "Samurai Accountant: A Theory of Auditing and Plunder." *Review of Economic Studies*, 54(4), 525-540.

[12] Boyer, M., and J.J. Laffont (2003), "Competition and the Reform of Incentive Schemes in the Regulated Sector." *Journal of Public Economics* 87, 2367-2395.

[13] Calzolari, G., and A. Pavan (2006), "On the Optimality of Privacy in Sequential Contracting." *Journal Economic Theory*, 130(1), 168-204.

[14] Celik, L. (2014), "Information Unraveling Revisited: Disclosure of Horizontal Attributes." *Journal of Industrial Economics*, 62(1), 113-136.

[15] Caillaud, B., B. Jullien and P. Picard (1995), "Competing Vertical Structures: Precommitment and Renegotiation." *Econometrica*, 63, 621-646.

[16] Chow, C. W. (1982), "The Demand for External Auditing: Size, Debt and Ownership Influences." *The Accounting Review*, 272-291.

[17] Craswell, A., J. Francis and L. Taylora (1995), "Auditor Brand Name Reputations and Industry Specialization." *Journal of Accounting and Economics*, 20, 297-322.

[18] Crémer, J., and F. Khalil (1992), "Gathering Information before Signing a Contract." *American Economic Review,* 82, 566-578.

[19] Crémer, J., F. Khalil and J.-C. Rochet (1998), "Strategic Information Gathering before a Contract Is Offered." *Journal of Economic Theory,* 81, 163-200.

[20] Dequiedt, V., and D. Martimort (2015), "Vertical Contracting with Informational Opportunism" *American Economic Review,* 105(7), 2141-82.

[21] Dye, R. (1993), "Auditing Standards, Legal Liability, and Auditor Wealth." *Journal of Political Economy*, 101(5), 887-914.

[22] Eichenseher, J., and P. Danos (1981), "The Analysis of Industry-Specific Auditor Concentration: Towards an Explanatory Model." *The Accounting Review,* 56, 79-492.

[23] Eso, P., and B. Szentes (2007), "The Price of Advice." *RAND Journal of Economics*, 38(4), 863-880.

[24] Eliaz, K., and R. Spiegler (2011), "A Simple Model of Search Engine Pricing." *Economic Journal*, 121, F329–F339.

[25] Gal-Or, E. (1991), "Vertical Restraints with Incomplete Information." *Journal of Industrial Economics*, 39, 503-516.

[26] Gal-Or, E. (1999), "Vertical Integration or Separation of the Sales Functions as Implied by Competitive Forces." *International Journal of Industrial Organization,* 17(5), 641-662.

[27] Gray, L. and S. Manson (2011), "The Audit Process. Principles, Practice and Cases." Cengage Learning EMEA.

[28] Hart, O. (1983). "The Market as an Incentive Scheme." *Bell Journal of Economics,* 14, 366-382.

[29] Hart, O., and J. Tirole (1990), "Vertical Integration and Market Foreclosure." *Brookings Papers on Economic Activity: Microeconomics*, 205-276.

[30] Hermalin, B. (1992). "The Effects of Competition on Executive Behavior." *RAND Journal of Economics*, 23, 350-365.

[31] Hörner, J., and A. Skrzypacz (2014), "Selling Information." *Journal of Political Economy*, forthcoming.

[32] Johnson, J., and D. Myatt (2006), "On the Simple Economics of Advertising, Marketing, and Product Design." *American Economic Review*, 96(3), 756-784.

[33] Katz, M., and C. Shapiro (1985), "On the Licensing of Innovations." *RAND Journal of Economics*, 16, 504-520.

[34] Katz, M., and C. Shapiro (1986), "How to License Intangible Property." *Quarterly Journal of Economics*, 101, 567-590.

[35] Kamenica, E., and M. Gentzkow (2011), "Bayesian Persuasion." *American Economic Review,* 101(6), 2590-2615.

[36] Koessler, F., and V. Skreta (2014), "Sales Talk." Mimeo, PSE and UCL.

[37] Laffont, J.J., and D. Martimort (2002), *The Theory of Incentives: The Principal-Agent Model.* Princeton University Press, Princeton, NJ, U.S.A.

[38] Legros, P., and A. Newman (2013), "A Price Theory of Vertical and Lateral Integration." *Quarterly Journal of Economics*, 128 (2), 725-770.

[39] Li, H., and X. Shi (2013), "Discriminatory Information Disclosure." Mimeo, University of British Columbia and University of Toronto.

[40] Lizzeri, A. (1994), "Information Revelation and Certification Intermediaries." Mimeo, Northwestern University.

[41] Lizzeri, A. (1999), "Information Revelation and Certification Intermediaries." *RAND Journal of Economics*, 30(2), 214-231.

[42] Martin, S. (1993), "Endogenous Firm Efficiency in a Cournot Principal-Agent Model." *Journal of Economic Theory,* 59, 445-450.

[43] Martimort, D. (1996), "Exclusive Dealing, Common Agency, and Multiprincipals Incentive Theory." *RAND Journal of Economics*, 27, 1-31.

[44] McAfee, P., and M. Schwartz (1994), "Opportunism in Multilateral Vertical Contracting: Nondiscrimination, Exclusivity, and Uniformity." *American Economic Review*, 84, 210-230.

[45] Milgrom, P., and R. Weber (1982), "A Theory of Auctions and Competitive Bidding." *Econometrica*, 50(5), 1089-1122.

[46] Mylovanov, T., and T. Tröger (2014), "Mechanism Design by an Informed Principal: the Quasi-Linear Private-Values Case." *Review of Economic Studies*, forthcoming.

[47] O'Brien, D., and G. Shaffer (1992), "Vertical Control with Bilateral Contracts." *RAND Journal of Economics*, 23, 299-308.

[48] Ottaviani, M., and A. Prat (2011), "The Value of Public Information in Monopoly." *Econometrica*, 69(6), 1673-1683.

[49] Pagnozzi, M., S. Piccolo and M. Bassi (2016), "Entry and Product Variety with Competing Supply Chains." *Journal of Industrial Economics*, 64, 520-556.

[50] Piccolo, S., P. Tedeschi and G. Ursino (2015), "How Limiting Deceptive Practices Harms Consumers." *RAND Journal of Economics*, 46, 611-624.

[51] Raith, M. (2003), "Competition, Risk and Managerial Incentives." *American Economic Review,* 93, 1425-1436.

[52] Rayo, L., and I. Segal (2010), "Optimal Information Disclosure." *Journal of Political Economy*, 118(5), 949-987.

[53] Segal, I., and M. Whinston (2003), "Robust Predictions for Bilateral Contracting with Externalities." *Econometrica*, 71(3), 757-791.

[54] Townsend, R. M. (1979), "Optimal Contracts and Competitive Markets with Costly State Verification." *Journal of Economic Theory*, 21(2), 265–293.