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# Information Acquisition and Strategic Disclosure in Oligopoly*

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**Abstract**

I study the incentives of oligopolists to acquire and disclose information on a common demand intercept. Since firms may fail to acquire information even when they invest in information acquisition, firms can credibly conceal unfavorable news while disclosing favorable news. Firms may earn higher expected profits under such a selective disclosure regime than under the regimes where firms commit to share all or no information. In particular, this holds under both Cournot and Bertrand competition, if the firms have sufficiently flat information acquisition cost functions. For steeper cost functions Cournot duopolists prefer strategic disclosure, if their goods are sufficiently differentiated.

**Keywords:** oligopolistic competition, information acquisition, information sharing, commitment, common value, product differentiation
**JEL Codes:** D82, D83, L13, L40

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# 1 Introduction

A firm that introduces a new product in a market does not always know the demand for the product or its production cost. The firm can do market research to learn the demand or cost. Doing market research is both costly and risky. It is costly, because the firm needs to invest in the acquisition of relevant information. An investment in information acquisition is risky, since it may fail to generate the valuable information.[1]

Alternatively, the firm may want to learn about an industry-wide shock to the marginal cost of production, such as a future government intervention (e.g. environmental regulation).[2] The firm may invest in lobbying a government official to find out the government's future plans. The more time, effort and money is spent on the official, the more likely it is that she confides relevant information to the firm.

The firm may also learn about the demand for the new product (or the common cost of production) through information disclosed by the firm's competitors. But competitors know the role their information plays for the firm, and will bias the information they share to their strategic advantage. Clearly, the firm's incentives to acquire and share information are related, and have an impact on the firm's production incentives. This paper studies the interaction between information acquisition, information sharing, and product market incentives, and analyzes the consequences for the firms' profits.

How much information will an oligopolist disclose to its rivals? Should firms be allowed to precommit to information sharing rules, or should coordination on information sharing be prohibited, and let firms disclose strategically? I address these questions in a Cournot duopoly with differentiated goods where firms invest in information acquisition to learn a common demand intercept.

Since the 1980s the literature on information sharing in oligopolistic markets analyzes the incentives of firms that precommit to particular information sharing rules, e.g. by establishing a trade association.[3] Typically, two extreme information disclo-

[1] For instance, on several occasions an internet book store invited me to participate in a survey on my reading habits in exchange for a gift certificate. If the amount on the gift certificate is low, it is likely that consumers decline to participate, and nothing is learned. Further, if the retailer invests little effort in the survey design, it is likely that an error is made in the design, and no relevant information is obtained. The higher the amount on the gift certificate, and the more care is invested in designing the survey, the greater the likelihood that information is acquired.

[2] The common shocks to production costs could also be related to the cost of common inputs of production, or wages in a unionized industry (see e.g. Sankar, 1995, footnote 9).

[3] For recent surveys of this literature, see Kühn and Vives (1995), Raith (1996), and Vives (1999). In particular, my model is related to Novshek and Sonnenschein (1982), Clarke (1983), Vives (1984), Gal-Or (1985), Li (1985), Kirby (1988), and Vives (1990).

sure regimes are compared: full information sharing, and no pooling of information. An important insight from this literature is that information sharing agreements often yield efficiency gains among competing firms. In particular, information sharing about a demand intercept is profitable, unless firms are Cournot competitors who supply close substitutes.[4] That is, the existence of an information sharing agreement is not necessarily an indication of collusion between firms.

Information sharing may also emerge endogenously from the strategic choices of firms that do not precommit. In particular, if there are no verification and disclosure costs, and if it is known that firms have information, then often the unraveling result holds. If this powerful result applies, then strategic firms will disclose all information, since they cannot credibly conceal unfavorable news, e.g. see Milgrom (1981), Milgrom and Roberts (1986), and Okuno-Fujiwara *et al.* (1990).[5]

The assumption that information is verifiable, which I adopt in this paper, is consistent with some empirical findings. Doyle and Snyder (1999) find that US car makers' announcements of production plans are informative, and not mere cheap talk, since they affect market outcomes. Furthermore, the car makers share information about a common value. This creates product market responses that are consistent with the theoretical prediction of the model in this paper (see section 3.1): "Specifically, rival firms tend to adjust their production upward in response to an announcement of aggressive production" (Doyle and Snyder, 1999, p. 1329). Genesove and Mullin (1999) make a related observation on US sugar cane refiners participating in the Sugar Institute trade association between 1928 and 1936. The paper finds no indication that the association's members were making untruthful reports. The authors observe that, "it may be too difficult to construct a credible, systematic lie, since a variety of bits of information, both internal and external to the firm, have to be made consistent with any false report" (Genesove and Mullin, 1999, p. 109). This suggests that the reported information can be verified.[6]

[4] In particular instances information sharing may even be profitable for Cournot competitors with close substitutes. For example, information sharing increases the expected profits of Cournot duopolists with close substitutes, if it is sufficiently likely that a firm receives an informative signal, and sufficiently unlikely that a firm receives no signal, as is shown in section 4.1. For more examples, see e.g. Nalebuff and Zeckhauser (1986), and Malueg and Tsutsui (1998).

[5] On the other hand, if information is non-verifiable and revelation is costless, then strategic firms will not reveal their information truthfully, as Ziv (1993) shows.

[6] The market conduct of firms in the Sugar Institute differs from the firms' conduct in my model. Whereas the firms in my model are non-cooperative duopolists, members of the Sugar Institute were colluding. However, the observation about verifiablity of information does not appear to depend on the product market conduct of firms.

In markets where information acquisition plays an important role, a focus on the two extreme information regimes may be too restrictive. If a firm's market research or its lobbying efforts can turn out to be fruitless (in which case the firm remains uninformed), it is no longer known whether firms are informed. Although information is verifiable, it is not verifiable whether or not a firm is informed. In such an environment the unraveling result may fail to hold since firms can credibly conceal unfavorable news by claiming to be uninformed, see e.g. Dye (1985), Farrell (1986), and Jung and Kwon (1988). Oligopolists have an incentive to disclose information selectively, e.g. Cournot competitors disclose bad news (low demand), while they conceal good news (high demand) to discourage their rivals. The selective disclosure of information is also consistent with some empirical observations. Krishnan *et al.* (1999) confirm that financial market participants infer that firms disclose earnings evidence selectively, and adjust their beliefs on the firm's value accordingly, as in Shin (1994, 2003). Moreover, Ackert *et al.* (2000) provide experimental support for the strategic disclosure rule that I study in this paper. The experiment confirms that Cournot duopolists use selective disclosure strategies on a common cost parameter to discourage their rival. The economic properties of such a regime of strategic disclosure in oligopolistic markets are not well established. This paper intends to fill the gap.

I study how incentives and profits of firms under strategic information disclosure compare with the incentives and profits under the two precommitment regimes. Naturally, strategic disclosure is chosen by firms that cannot precommit. Moreover, I show that, even if firms can precommit to full or no sharing, there are important instances where firms prefer strategic disclosure to precommitment.

First, I find that, for a given level of information acquisition investments, a firm's expected equilibrium profit under strategic disclosure is always lower than under one of the precommitment regimes. Hence, if the probability of receiving information were exogenous, then firms would be best off by precommitting to either full or no information sharing. This result reinforces some basic insights from the literature on information sharing in oligopoly.

However, if the probability of receiving information is endogenously determined by firms' information acquisition investments, then strategic disclosure may yield the highest expected profits. For example, this is the case when firms' costs of information acquisition investment are not too steep. Firms with relatively flat investment cost functions have excessive information acquisition incentives under precommitment, i.e. they overinvest under full concealment while they underinvest under full sharing.

Strategically disclosing firms have intermediate information acquisition incentives, which yields a higher expected profit in equilibrium. Hence, for flat costs of investment firms are best off if they do *not* precommit to either of the extreme information sharing rules. This result is robust to several extensions of the model (see section 5). In particular, this result does not depend on the way in which firms interact in the product market, since it also emerges in a model with Bertrand competition.

Conversely, for steep investment cost functions, the firms may have excessive information acquisition incentives under strategic disclosure. For steep investment cost functions the information acquisition incentives are non-monotonic in the amount of information disclosed in the industry. Whereas firms do not acquire any information under precommitment, they still invest under strategic disclosure (see section 3). Whether such a positive investment level is excessive or not depends on the degree of product differentiation. If the goods are sufficiently differentiated (close substitutes), then firms expect higher equilibrium profits under strategic disclosure (precommitment).

These results have immediate implications for antitrust analysis. For example, consider Cournot competitors with sufficiently differentiated goods. Previously (i.e. with exogenously given levels of information acquisition), the formation of a *quid pro quo* information sharing agreement was compatible with the incentives of competing firms. That is, information sharing does not necessarily occur to facilitate collusion. This could convince an antitrust authority to allow it. However, when information is acquired by individual firms, the antitrust authority should adopt a more severe policy towards the formation of information sharing agreements. Since competing firms prefer not to precommit, the formation of an information sharing agreement can now only be seen as a vehicle to sustain collusion among the firms.

In addition, if the costs of information acquisition investment are declining over time (Kirby, 2004), then my results imply that an antitrust authority should be especially severe towards the formation of *quid pro quo* information sharing agreements in mature industries. In mature industries the information acquisition cost functions can be expected to be relatively flat, and competing firms would expect a higher profit from strategic disclosure.[7]

Papers in the accounting literature, such as Darrough (1993) and Sankar (1995),

[7] These policy conclusions are drawn within the context of this paper's model under the assumption that the antitrust authority can observe the demand and cost parameters. In practice this assumption may turn out to be too strong (see e.g. Kühn and Vives, 1995, and Kühn, 2001), and in that case the policy implications are ambiguous.

study related models.[8] These papers focus on strategic disclosure incentives, but they do not analyze consequences for the incentives to precommit. Interestingly, also the information sharing models in Nalebuff and Zeckhauser (1986, model A) and Malueg and Tsutsui (1998, example 1) are related. But, while these papers make profit comparisons for the regimes under disclosure precommitment, they ignore the opportunity for strategic disclosure. My paper studies the consequences of strategic disclosure for incentives, and profits, by comparing strategic disclosure with the two precommitment regimes.

The aforementioned papers treat the probability of receiving information as exogenous parameters. I show that endogenizing this probability matters greatly for the firms' expected profits. There are papers, such as Li *et al.* (1987), Hwang (1995), Hauk and Hurkens (2001), and Sasaki (2001), that study the information acquisition incentives of Cournot oligopolists.[9] These papers assume that firms do not disclose their acquired information, and make complementary comparisons. Conversely, papers, such as Matthews and Postlewaite (1985), Verrecchia (1990), and Shavell (1994), study the interaction between a monopolist's incentives to acquire and disclose information, i.e. these papers ignore externalities from product market competition. Admati and Pfleiderer (2000) and Kirby (2004) study the information acquisition and disclosure incentives of competing firms. In these papers firms commit *ex ante* to disclosure rules, while I also study *interim* disclosure incentives. Moreover, Admati and Pfleiderer study firms' incentives in a different context, i.e. a financial market, and Kirby assumes that firms make their information acquisition and information sharing choices cooperatively.

The paper is organized as follows. Section 2 describes the model. Section 3 derives the equilibrium strategies of firms: the output levels, the *interim* information disclosure rules, and the information acquisition investments. Section 4 compares the expected equilibrium profits with the expected profits under the precommitment regimes. Section 5 discusses the robustness of the paper's result with respect to several extensions of the model. Finally, section 6 concludes the paper. The proofs of the paper's results are relegated to the Appendices.

[8] For recent surveys of this literature, see e.g. Verrecchia (2001), and Dye (2001).

[9] Persico (2000) studies the incentives for secret information acquisition of bidders in auction models with affiliated values.

## 2 The Model

Consider an industry where two firms compete in quantities of differentiated products. Firms have symmetric demand functions, with intercept $\theta$. This demand intercept is unknown to the firms.[10] The intercept is either low or high, i.e. $\theta \in \{\underline{\theta}, \overline{\theta}\}$ with $0 < \underline{\theta} < \overline{\theta}$, where the probability of having a high (low) intercept is $q$ (resp. $1-q$), with $0 < q < 1$.

In the first stage firms can learn their demand by acquiring information. Firms choose their information acquisition investments, $r_i \in [0,1]$ for firm $i$, simultaneously. Information acquisition investments are not observable. Firm $i$ expects its rival invests $r$ in information acquisition. The costs of information acquisition are linear in investment: $c(r_i) = \eta r_i$, with $\eta > 0$ for $i = 1, 2$.[11] After investing in information acquisition firm $i$ receives a signal, $\Theta_i$, about demand. With probability $r_i$ firm $i$ learns the true demand intercept, $\Theta_i = \theta$, but with probability $1 - r_i$ the firm learns nothing, $\Theta_i = \varnothing$. Hence, the more a firm invests in information acquisition, the more likely it is that the firm will be informed. The signals are independent, conditional on $\theta$.

In stage 2 each firm chooses whether to disclose or conceal its signal. The information that firms acquire is verifiable. However, the fact whether or not a firm is informed is not verifiable. If firm $i$ receives information $\Theta_i = \theta$, it chooses the probability with which it discloses this information, $\delta_i(\theta) \in [0,1]$, i.e. with probability $\delta_i(\theta)$ firm $i$ discloses $\theta$, while with probability $1 - \delta_i(\theta)$ firm $i$ sends uninformative message $\varnothing$. An uninformed firm can only send message $\varnothing$. It therefore suffices to denote firm $i$'s disclosure rule as $(\delta_i(\underline{\theta}), \delta_i(\overline{\theta}))$. I denote the message sent by firm $i$ (i.e. the realization of the firm's disclosure rule) as $D_i$ for $i = 1, 2$. Firms make their disclosure decisions simultaneously.

In the final stage firms simultaneously choose their output levels, $x_i \geq 0$ for firm $i$, i.e. firms are Cournot competitors. Without loss of generality I assume that firms have zero marginal costs of production. Firm $i$'s profit of output levels $(x_i, x_j)$ for demand intercept $\theta$ is:

$$\pi_i(x_i, x_j; \theta) = (\theta - x_i - \gamma x_j)\, x_i, \tag{1}$$

with $i, j \in \{1, 2\}$ and $i \neq j$, and $0 < \gamma \leq 1$. Parameter $\gamma$ captures the degree of

[10] Naturally, this model is conceptually identical to a model with incomplete information about a common constant marginal production cost. Hence, all results hold for such a model as well.

[11] I adopt the assumption of linear information acquisition cost functions to make the model easy to solve. The main qualitative result also holds for convex cost functions, as is shown in section 5.

product substitutability. If $\gamma = 1$, then goods are homogeneous, while if $\gamma \to 0$, then firms supply to independent markets. Firms are risk-neutral.

The analysis is restricted to symmetric (Bayes perfect) equilibria.

# 3 Equilibrium Strategies

This section solves the game backwards, and characterizes the equilibrium strategies.

## 3.1 Product Market Competition

In this subsection I study the equilibrium output levels for given symmetric disclosure rules, $(\delta_i(\underline{\theta}), \delta_i(\overline{\theta})) = (\delta(\underline{\theta}), \delta(\overline{\theta}))$ for all $i = 1, 2$, and symmetric expected information acquisition investments, $r$.

First, I study the equilibrium outputs under complete information. Whenever one of the firms sends an informative signal, $D_j = \theta$ for some $j \in \{1, 2\}$ and $\theta \in \{\underline{\theta}, \overline{\theta}\}$, all firms know that the demand intercept is $\theta$. Firm $i$'s first-order condition of profit maximization with respect to $x_i$, given $\theta \in \{\underline{\theta}, \overline{\theta}\}$, is as follows:

$$2x_i(\theta) = \theta - \gamma x_j(\theta) \tag{2}$$

for $i, j = 1, 2$ and $i \neq j$. The first-order conditions give the following equilibrium outputs:

$$x^f(\theta) = \frac{\theta}{2 + \gamma}, \tag{3}$$

with $\theta \in \{\underline{\theta}, \overline{\theta}\}$. This is a standard result.

Second, I consider the equilibrium after no firm disclosed any information, i.e. $(D_1, D_2) = (\varnothing, \varnothing)$. I restrict attention to beliefs consistent with symmetric expected information acquisition investments and disclosure rules. In that case, an informed firm with $\Theta_i = \theta$ assigns probability $R(\theta; \boldsymbol{\delta})$ to competing against an informed rival $j$ ($\Theta_j = \theta$), and probability $1 - R(\theta; \boldsymbol{\delta})$ to facing an uninformed rival ($\Theta_j = \varnothing$), where:

$$R(\theta; \boldsymbol{\delta}) \equiv \frac{r\,[1 - \delta(\theta)]}{1 - r\delta(\theta)} \tag{4}$$

and $\boldsymbol{\delta} \equiv (\delta(\underline{\theta}), \delta(\overline{\theta}))$. Each uninformed firm ($\Theta_i = \varnothing$) has the following beliefs. The firm expects demand intercept:

$$E(\theta|\varnothing; \boldsymbol{\delta}) \equiv (1 - Q(\boldsymbol{\delta}))\underline{\theta} + Q(\boldsymbol{\delta})\overline{\theta}, \tag{5}$$

with posterior belief

$$Q(\boldsymbol{\delta}) \equiv \frac{q\left[1-r\delta(\overline{\theta})\right]}{(1-q)\left[1-r\delta(\underline{\theta})\right]+q\left[1-r\delta(\overline{\theta})\right]}. \tag{6}$$

The uninformed firm assigns probability $(1-Q(\boldsymbol{\delta}))R(\underline{\theta};\boldsymbol{\delta})$ (respectively $Q(\boldsymbol{\delta})R(\overline{\theta};\boldsymbol{\delta})$) to competing against an informed firm $j$ with $\Theta_j = \underline{\theta}$ (resp. $\Theta_j = \overline{\theta}$). With the remaining probability, $1-E\{R(\theta;\boldsymbol{\delta})|\varnothing;\boldsymbol{\delta}\}$, firm $j$ is believed to be uninformed. Hence, firm $i$'s first-order conditions after no information disclosure, and beliefs consistent with symmetric expected investments and disclosure rules, are as follows (for $i, j = 1, 2$ $(i \neq j)$, and $\Theta_i \in \{\underline{\theta}, \overline{\theta}, \varnothing\}$ where $E(\theta|\theta;\boldsymbol{\delta}) = \theta$):

$$2x_i(\Theta_i) = E(\theta|\Theta_i;\boldsymbol{\delta}) - \gamma E\left\{ R(\theta;\boldsymbol{\delta})x_j(\theta) + \left[1-R(\theta;\boldsymbol{\delta})\right] x_j(\varnothing) \right| \Theta_i;\boldsymbol{\delta}\}. \tag{7}$$

Using symmetry, I derive the following equilibrium output (for $\Theta_i \in \{\underline{\theta}, \overline{\theta}, \varnothing\}$):

$$x^*(\Theta_i;\boldsymbol{\delta}) = E\left\{ x^f(\theta) + \frac{\gamma\left[1-R(\theta;\boldsymbol{\delta})\right]\cdot\left[\theta - E(\theta|\varnothing;\boldsymbol{\delta})\right]}{(2+\gamma)\left[2+\gamma\left(Q(\boldsymbol{\delta})R(\underline{\theta};\boldsymbol{\delta})+(1-Q(\boldsymbol{\delta}))R(\overline{\theta};\boldsymbol{\delta})\right)\right]} \right| \Theta_i;\boldsymbol{\delta}\right\} \tag{8}$$

In the remainder of this subsection I briefly analyze the properties of the equilibrium outputs under three disclosure regimes. First, I characterize outputs under the two regimes that are extensively studied in the literature on information sharing in oligopoly, i.e. the full information sharing regime, $f$, and the no sharing regime, $o$. In the full sharing regime the firms commit to share all available information, i.e. $(\delta^f(\underline{\theta}), \delta^f(\overline{\theta})) = (1, 1)$. If there is an informed firm $j$ with $\Theta_j = \theta$, all firms know that the demand intercept is $\theta$, and supply $x^f(\theta)$ as in (3). If all firms are uninformed, i.e. $(\Theta_1, \Theta_2) = (\varnothing, \varnothing)$, each firm supplies $x^f(\varnothing) \equiv x^*(\varnothing; 1, 1) = E\{x^f(\theta)\}$, since $R(\theta; 1, 1) = 0$ for any $\theta$ and $Q(1, 1) = q$ in (8).

Disclosure rules in the no sharing regime $o$ are uninformative, i.e. $(\delta^o(\underline{\theta}), \delta^o(\overline{\theta})) = (0, 0)$. Under this regime firm $i$ with signal $\Theta_i$ supplies $x^o(\Theta_i) \equiv x^*(\Theta_i; 0, 0)$ in equilibrium, with $R(\theta; 0, 0) = r$ for any $\theta$ and $Q(0, 0) = q$ in (8), and $\Theta_i \in \{\underline{\theta}, \overline{\theta}, \varnothing\}$. I call regimes $f$ and $o$ the precommitment regimes, since they may emerge if firms can commit *ex ante* to disclosure rules.

Besides the precommitment regimes, I characterize production under the strategic information sharing regime $s$. Under strategic disclosure firms disclose low demand information while they conceal high demand information, i.e. the firms' disclosure rules are $(\delta^s(\underline{\theta}), \delta^s(\overline{\theta})) = (1, 0)$. I show in the next subsection that such a disclosure regime is chosen in equilibrium if firms do not precommit. Naturally, whenever there is a firm that discloses a low demand intercept, all firms supply $x^f(\underline{\theta})$. If no firm discloses information, then each firm infers that its competitor did not receive a low demand signal ($\Theta_j \neq \underline{\theta}$), i.e. $R(\underline{\theta}; 1, 0) = 0$ while $R(\overline{\theta}; 1, 0) = r$, and $Q(1, 0) = \widetilde{q}$ with:

$$\widetilde{q} \equiv \frac{q}{q + (1 - q)(1 - r)}. \tag{9}$$

In that case, firm $i$ with signal $\Theta_i \in \{\overline{\theta}, \varnothing\}$ supplies $x^s(\Theta_i) \equiv x^*(\Theta_i; 1, 0)$ in equilibrium, with $x^*$ as in (8).

The comparison of outputs $x^f$, $x^o$, and $x^s$ is summarized in the following lemma.

**Lemma 1** *For all $r \in (0, 1)$, the equilibrium outputs are such that:*
***(a)*** $x^o(\underline{\theta}) < x^s(\underline{\theta}) = x^f(\underline{\theta}) < x^f(\varnothing) = x^o(\varnothing) < x^s(\varnothing) < x^f(\overline{\theta}) < x^s(\overline{\theta}) < x^o(\overline{\theta})$;
***(b)*** $\partial x^o(\underline{\theta})/\partial r > 0$, $\partial x^o(\overline{\theta})/\partial r < 0$, *and* $\partial x^s(\varnothing)/\partial r > 0$, $\partial x^s(\overline{\theta})/\partial r < 0$.
*Furthermore,* $\lim_{r \to 0} x^s(\Theta) = \lim_{r \to 0} x^o(\Theta)$ *for* $\Theta \in \{\overline{\theta}, \varnothing\}$, *while* $\lim_{r \to 1} x^o(\theta) = x^f(\theta)$ *for* $\theta \in \{\underline{\theta}, \overline{\theta}\}$, *and* $\lim_{r \to 1} x^s(\Theta) = x^f(\overline{\theta})$ *for* $\Theta \in \{\overline{\theta}, \varnothing\}$.

The comparison between $x^f(\theta)$ and $x^o(\theta)$ results from comparing the first-order conditions (2) and (7) for $\Theta_i = \theta$ and $R(\theta; 0, 0) = r$. A firm with a low (high) demand signal expects more optimistic (pessimistic) rivals under no information sharing than under full sharing, and, consequently, produces less (more) in equilibrium, i.e. $x^o(\underline{\theta}) < x^f(\underline{\theta})$, and $x^o(\overline{\theta}) > x^f(\overline{\theta})$.

Subsequently, the first-order conditions (7) under the regimes $o$ and $s$ provide intuition for relative sizes of outputs $x^o$ and $x^s$. A firm that received a high demand signal has the same first-order condition under strategic disclosure as under no information sharing. However, an uninformed firm is more optimistic about demand under strategic disclosure, but expects a more optimistic, "aggressive" rival than under the precommitment regimes. I show in lemma 1 (a) that the demand effect dominates, i.e. $x^f(\varnothing) = x^o(\varnothing) < x^s(\varnothing)$. This implies in turn, through first-order condition (7) for $\Theta_i = \overline{\theta}$ and $R(\overline{\theta}; 1, 0) = R(\overline{\theta}; 0, 0) = r$, that informed, high demand firms produce less under strategic disclosure than under no disclosure, i.e. $x^s(\overline{\theta}) < x^o(\overline{\theta})$.

An increase of the expected information acquisition investment, $r$, has the following effects on equilibrium outputs. The only effect of an increase in $r$ under no information sharing, is that a firm considers it more likely that its competitor is informed. Hence, an informed firm with a low (high) demand signal expects a less (more) "aggressive" competitor, and consequently expands (reduces) its output. Under strategic information sharing an informed, high demand firm has similar incentives as under no sharing, and therefore the firm's output decreases in $r$. An uninformed firm faces the following trade-off under strategic information sharing. On the one hand, the firm becomes more optimistic about demand ($\partial\widetilde{q}/\partial r > 0$), but, on the other hand, it expects a more "aggressive" competitor. In lemma 1 (b) I show that the former effect dominates the latter, i.e. $\partial x^s(\varnothing)/\partial r > 0$.

Finally, for $r = 1$ the unraveling result applies under strategic disclosure, since firms are expected to be informed with certainty. If a firm sends an uninformative message, then its competitor infers that the firm is concealing a high demand intercept, and chooses the output accordingly, i.e. $\lim_{r\to 1} x^s(\Theta) = x^f(\overline{\theta})$, for $\Theta \in \{\overline{\theta}, \varnothing\}$.

Under each regime $\ell$, given information $\Theta \in \{\underline{\theta}, \overline{\theta}, \varnothing\}$ and equilibrium output $x^\ell(\Theta)$, a firm's expected equilibrium profit equals: $\pi^\ell(\Theta) = x^\ell(\Theta)^2$ for $\ell \in \{f, o, s\}$. Hence, the comparisons of lemma 1 also hold for expected profits. These comparisons play therefore an important role in the profit analysis below.

## 3.2 Information Sharing

In this subsection I study the firms' incentives to share information after firms received their signals, i.e. the firms' *interim* incentives to share information.

First, firms do not have an incentive to share all information. Suppose a firm's competitor has beliefs consistent with full information sharing. In that case a firm that learned the market is big, $\Theta_i = \overline{\theta}$, has an incentive to unilaterally conceal this information. The concealment of high demand information gives an uninformed rival a lower incentive to supply output, since concealment makes the rival more pessimistic about demand. This makes the unilateral deviation from full information sharing, through the concealment of high demand information, profitable.

Full concealment is not chosen in equilibrium without *ex ante* commitment either. If competitors have beliefs consistent with full concealment, then it is profitable for an individual firm to unilaterally disclose a low demand signal, $\Theta_i = \underline{\theta}$. On the one hand, disclosure of bad news discourages uninformed rivals, which increases the firm's expected profit. On the other hand, an informed rival is encouraged to supply after disclosure (since $x^f(\underline{\theta}) > x^o(\underline{\theta})$). The positive effect on expected profit of an output reduction by an uninformed rival outweighs the negative effect of an informed rival's output expansion. Therefore, unilaterally disclosing low demand to a rival with beliefs consistent with full concealment is profitable.

The profitable unilateral deviations from full information sharing and full concealment suggest that firms disclose information selectively in equilibrium. This is indeed typically the case, as I show in the following proposition.

**Proposition 1** *If $r < 1$, then firms disclose a low demand intercept, and conceal a high intercept in the unique symmetric equilibrium, i.e.* $(\delta^*(\underline{\theta}), \delta^*(\overline{\theta})) = (1, 0)$*. If $r = 1$, then any disclosure rule may be chosen in equilibrium, and an informed firm with $\Theta_i = \theta$ expects to earn the profit $\pi^f(\theta)$ for any disclosure rule, with $\theta \in \{\underline{\theta}, \overline{\theta}\}$.*

The result for $r < 1$ is consistent with the experimental results in Ackert *et al.* (2000), and is intuitive. Hence, the strategic disclosure regime, $s$, with $(\delta^s(\underline{\theta}), \delta^s(\overline{\theta})) = (1, 0)$, emerges endogenously in industries where firms choose not to precommit to information sharing, or where they cannot precommit.[12]

If $r = 1$, informed firms are indifferent between disclosure and concealment of their signal. After either disclosure or concealment each firm expects full information sharing actions from its competitors, since the "unraveling result" applies here.

## 3.3 Information Acquisition

In this subsection I compare the equilibrium information acquisition investments under the three disclosure regimes.

The expected equilibrium profits of firm $i$ under regime $\ell$, given information acquisition investment $r_i$ and expected investments $r$, are (for $i = 1, 2$ and $\ell \in \{f, o, s\}$):

$$\Pi^\ell(r_i, r) = E\left\{\pi^\ell(\theta)\right\} - \psi^\ell(r) + r_i\left[\psi^\ell(r) - \eta\right], \tag{10}$$

where

$$\psi^\ell(r) \equiv E\left\{\pi^\ell(\theta)\right\} - \pi^\ell(\varnothing) - rE\left\{\delta^\ell(\theta)\left[\pi^\ell(\theta) - \pi^\ell(\varnothing)\right]\right\}. \tag{11}$$

The first part of expression (10), i.e. $E\left\{\pi^\ell(\theta)\right\} - \psi^\ell(r)$, is the expected profit in the absence of information acquisition by firm $i$. For example, under full disclosure the firm earns the expected profit $rE\{\pi^f(\theta)\} + (1-r)\pi^f(\varnothing)$ from the disclosure by its competitor, while it earns only $\pi^o(\varnothing)$ under no disclosure. The second part of (10), i.e. $r_i[\psi^\ell(r) - \eta]$, captures the effect of the firm's own information acquisition investment on the expected profit. This term is linear in firm $i$'s investment $r_i$. The equilibrium information acquisition investment $r^\ell$ is determined by the trade-off between the marginal cost of investment, $\eta$, and the marginal revenue, $\psi^\ell(r)$.

[12] In fact, the disclosure rule $\boldsymbol{\delta}^s$ is also chosen in the unique symmetric equilibrium of the game in which firms precommit noncooperatively to disclosure rules. This is shown formally in proposition 8 in the Supplementary Appendix. Therefore, one could also refer to the disclosure rule $\boldsymbol{\delta}^s$ more generally as the symmetric equilibrium rule for noncooperative information disclosure (instead of strategic information disclosure). I am grateful to a referee for pointing this out to me.

The marginal revenue of information acquisition (11) consists of two components. The first component is the idiosyncratic value of information, which is the difference between the expected profits of being informed and the expected profit of remaining uninformed, i.e. $E\{\pi^\ell(\theta)\} - \pi^\ell(\varnothing)$. Second, the idiosyncratic value of information is reduced by the expected value of information acquired and disclosed by the competitor, i.e. $rE\{\delta^\ell(\theta)[\pi^\ell(\theta) - \pi^\ell(\varnothing)]\}$. This second component of (11) captures the free-rider effect due to information disclosure by rivals. Both components play an important role in the analysis of a firm's information acquisition incentives, as is shown below.

For convenience I denote the marginal revenue of information acquisition under regime $\ell$ when no information is acquired as follows:

$$\psi_0^\ell \equiv \psi^\ell(0), \text{ for } \ell \in \{f, o, s\}. \tag{12}$$

Notice that for extreme investments, the marginal revenues of information acquisition are ranked as follows (see lemma 1):

$$0 = \psi^f(1) = \psi^s(1) < \psi^o(1) = \psi_0^f < \psi_0^o < \psi_0^s. \tag{13}$$

This ranking is useful for the characterization of equilibrium investments in the following proposition.

**Proposition 2** *Information acquisition investments in the unique symmetric equilibrium are decreasing in marginal cost $\eta$. The investments under full disclosure are lowest, i.e. $r^f \leq \min\{r^s, r^o\}$. Furthermore, there are critical values $\underline{\eta}'$ and $\overline{\eta}'$, with $\psi_0^f < \underline{\eta}' \leq \overline{\eta}' < \psi_0^o$, such that firms invest less (more) in information acquisition under strategic disclosure than under full concealment for all $\eta < \underline{\eta}'$ (respectively, $\eta > \overline{\eta}'$).*

I illustrate the equilibrium information acquisition investments in figure 1. The investment curves are downward-sloping in the marginal cost parameter $\eta$, which is intuitive. The analytical expressions of the equilibrium investments are given in the Appendix (see expressions A.11, A.13, and A.14).

The comparison of investment incentives reduces to the comparison of the marginal revenues of information acquisition, i.e. the idiosyncratic value of information and the free-rider effect. First, I compare the investment $r^f$ with $r^o$. The idiosyncratic value of information is greater under the no sharing regime, i.e. $E\{\pi^o(\theta)\} - \pi^o(\varnothing) > E\{\pi^f(\theta)\} - \pi^f(\varnothing)$ as was shown in lemma 1 (a). Moreover, there are no free-rider incentives in information acquisition when firms do not share information. Both

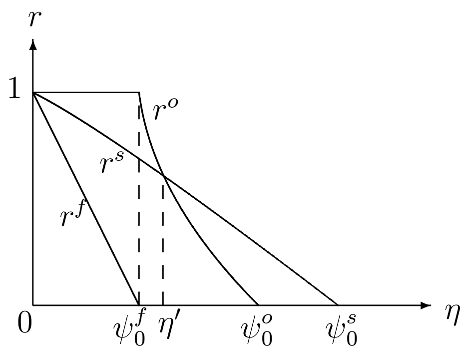

Figure 1: Information acquisition investments

effects imply that the firms' information acquisition incentives under no disclosure exceed those under full disclosure. Second, the comparison of $r^f$ and $r^s$ is as follows. There may be instances (e.g. for large $r$) where the idiosyncratic effect gives bigger information acquisition incentives under full information sharing than under strategic disclosure. But in those instances the free-rider effect is the dominating effect. Hence, the information acquisition investments are lowest if information is shared, i.e. $r^f \leq \min\{r^s, r^o\}$, as is shown formally in proposition 2.

The remaining comparison, between $r^o$ and $r^s$, is more subtle. On the one hand, if $r$ is sufficiently close to one, the value of information is greatest under full concealment. In particular, if $r \to 1$, the unraveling result applies under strategic disclosure. That is, each firm infers that a concealing rival hides a high demand signal, which reduces the value of information to zero. However, if firms commit not to share information, then the unraveling result does not apply, and information is still valuable even if $r \to 1$. Hence, $\psi^s(1) = 0 < \psi^o(1)$. On the other hand, if $r$ is sufficiently close to zero, then the marginal revenue of information acquisition under strategic disclosure is greater than under no disclosure. In the limit when $r \to 0$, the information free-rider effect under strategic disclosure disappears, since rivals do not acquire information. The investment incentives in both regimes are then only determined by the idiosyncratic value of information, i.e. the expected profit gain of turning from an uninformed firm into an informed firm. And the product market profits are such that $\psi^s(0) > \psi^o(0)$, since firms expect fiercer product market competition under full concealment, i.e. $\pi^s(\underline{\theta}) > \pi^o(\underline{\theta})$ and $\pi^s(\Theta) = \pi^o(\Theta)$ for $\Theta \in \{\overline{\theta}, \varnothing\}$ and $r \to 0$ (see lemma 1). This implies that the relative size of information acquisition investments under strategic and no disclosure, depends on the marginal cost of information acquisition, $\eta$. For sufficiently low costs, i.e. $\eta < \underline{\eta}'$, firms invest most in information acquisition under no disclosure. But for sufficiently high costs, i.e. $\eta > \overline{\eta}'$, firms have greater incentives to acquire information under strategic disclosure. In fact, numerical examples suggest that $\underline{\eta}' = \overline{\eta}' = \eta'$, as in figure 1.

I conclude from these results that for sufficiently small costs of information acquisition, $\eta < \underline{\eta}'$, the information acquisition incentives are monotonic in the amount of information disclosed in the industry. For these costs the free-rider incentives are sufficiently great. However, for greater costs of information acquisition, $\overline{\eta}' < \eta < \psi_0^s$, I obtain a non-monotonicity result. The value of information is greatest under strategic disclosure, since expected product market profits under strategic disclosure are greatest, while the value of information from free-riding on rivals' information is negative.

# 4 Profit Analysis

In this section I compare the *ex ante* expected profits of firms under the three regimes.

## 4.1 Expected Product Market Profits

First, I compare the expected equilibrium profits under the three disclosure regimes for given (symmetric) information acquisition investments. This analysis is instructive to evaluate the effect of endogenizing information acquisition investments on the expected equilibrium profits. For symmetric information acquisition investments and fulfilled beliefs, i.e. $r_i = r$, the expected profit $\Pi^\ell(r, r)$ in (10) can be decomposed as follows (for $\ell \in \{f, o, s\}$):

$$\Pi^\ell(r,r) = rE\left\{\pi^\ell(\theta)\right\} + (1-r)\pi^\ell(\varnothing) + (1-r)rE\left\{\delta^\ell(\theta)\left[\pi^\ell(\theta) - \pi^\ell(\varnothing)\right]\right\} - \eta r. \quad (14)$$

The expected revenue in this expression contains two terms. The first term, $rE\{\pi^\ell(\theta)\} + (1-r)\pi^\ell(\varnothing)$, is the firm's expected product market profit conditional on receiving no information from the competitor. The second term, $(1-r)rE\{\delta^\ell(\theta)[\pi^\ell(\theta) - \pi^\ell(\varnothing)]\}$, represents the effect of information disclosure by the competitor. If the firm failed to acquire information itself while the firm's competitor acquires and discloses $\theta$, then the firm earns product market profit $\pi^\ell(\theta)$ instead of $\pi^\ell(\varnothing)$. The expected value of information disclosure by the competitor is positive under full disclosure, i.e. $(1-r)r[E\{\pi^f(\theta)\} - \pi^f(\varnothing)] > 0$, but negative under strategic disclosure, i.e. $(1-r)r(1-q)[\pi^s(\underline{\theta}) - \pi^s(\varnothing)] < 0$. Clearly, under full concealment the second term is zero, since the competitor never discloses information. The comparison of expected profits under the different regimes yields the following proposition.

**Proposition 3** *If $r_i = r$ for $i = 1, 2$, with $0 < r < 1$, then the ex ante expected profits are as follows. The firms' ex ante expected profits are greater under precommitment than under strategic information sharing, i.e.* $\max\{\Pi^f(r,r), \Pi^o(r,r)\} > \Pi^s(r,r)$. *Furthermore, for critical value $\gamma^* \equiv 2\sqrt{2} - 2$ the following holds.* ***(a)*** *If $\gamma \leq \gamma^*$, then ex ante expected profits are greatest under full disclosure, i.e.* $\Pi^f(r,r) > \Pi^o(r,r)$; ***(b)*** *If $\gamma > \gamma^*$, then a critical value $r^*$ exists, with $0 < r^* < 1$, such that expected profits are greatest under full disclosure (concealment) iff $r > r^*$ (resp. $r < r^*$), i.e.* $\Pi^f(r,r) \lesseqqgtr \Pi^o(r,r)$ *if* $r \lesseqqgtr r^*$.

The comparison of expected profits $\Pi^f$ and $\Pi^o$ in (14) gives the following trade-off. On the one hand, a firm's expected profit, conditional on receiving no information from the competitor, is greater under full concealment than under full disclosure, i.e. $rE\{\pi^o(\theta)\} + (1-r)\pi^o(\varnothing) > rE\{\pi^f(\theta)\} + (1-r)\pi^f(\varnothing)$. On the other hand, it is more likely that a firm is informed under full disclosure for given levels of information acquisition. The expected revenue from information disclosure by the competitor is positive under full disclosure, since $E\{\pi^f(\theta)\} > \pi^f(\varnothing)$, and zero under full concealment. Notice that this trade-off is similar to the basic trade-off in the information sharing literature. Also Vives (1984) and Kirby (1988) find a critical value $\gamma^*$ below which firms prefer full disclosure. For degrees of differentiation above $\gamma^*$ the trade-off depends on the size of $r$. If information acquisition investments are below (above) $r^*$, then expected profits are lowest (highest) under full disclosure, as is shown in proposition 3 above. Nalebuff and Zeckhauser (1986), and Malueg and Tsutsui (1998) obtain this result for homogeneous goods ($\gamma = 1$). My contribution is to show how this result depends on the degree of product substitutability $\gamma$.

The comparison of the expected profits under full and strategic information sharing results in the following trade-off. On the one hand, the expected profit, conditional on receiving no information from the rival, is higher under strategic disclosure than under full disclosure, i.e. $rE\{\pi^s(\theta)\} + (1-r)\pi^s(\varnothing) > rE\{\pi^f(\theta)\} + (1-r)\pi^f(\varnothing)$. On the other hand, the value of information disclosure by the competitor is greatest under full disclosure, i.e. $E\{\pi^f(\theta)\} - \pi^f(\varnothing) > 0 > (1-q)[\pi^s(\underline{\theta}) - \pi^s(\varnothing)]$ in (14). If the degree of product substitutability is sufficiently low, e.g. $\gamma \leq \gamma^*$, then the latter effect outweighs the former effect. That is, the expected profit is greatest under full disclosure. For sufficiently high $\gamma$ the trade-off between these two conflicting effects yields a critical value $\underline{r}$, with $0 \leq \underline{r} < r^*$. For all $r$ below (above) $\underline{r}$ the expected profit under strategic disclosure is greater (smaller) than under full information sharing. While the firms expect higher profits under strategic disclosure than under full disclosure for $r < \underline{r}$, their expected profits are even higher under the commitment to conceal all information. Therefore, for all $r < r^*$, the firms' expected profits are highest under full concealment, as is shown in proposition 3 above.

Finally, the difference of expected profits under full concealment and strategic disclosure contains the following two principal components. On the one hand, conditional on receiving no information from competitors, firms expect higher profits under strategic disclosure, since $rE\{\pi^s(\theta)\} + (1-r)\pi^s(\varnothing) > rE\{\pi^o(\theta)\} + (1-r)\pi^o(\varnothing)$. But, on the other hand, firms are more likely to receive bad news under strategic disclosure, which depresses their expected profits, since $\pi^s(\underline{\theta}) < \pi^s(\varnothing)$. If goods are sufficiently differentiated, then the former effect outweighs the latter, and the expected profit is lowest under full concealment. For higher values of $\gamma$ there exists a critical value $\overline{r}$, with $r^* \leq \overline{r} \leq 1$, such that for all $r$ below (above) $\overline{r}$ the expected profit under strategic disclosure is smaller (greater) than under no pooling of information. Although the expected profit under strategic disclosure is higher than under no disclosure for low $\gamma$, and for high $\gamma$ and $r > \overline{r}$, it does not exceed the expected profit under full disclosure. Hence, expected profits under strategic disclosure are never highest, as is shown in the proposition above.

Proposition 3 shows that, for given (symmetric) levels of information acquisition, strategic disclosure would never be *ex ante* profit-maximizing. That is, firms would prefer to precommit to either full sharing or full concealment. However, the *interim* incentives are such that firms typically choose the strategic disclosure rule in the unique equilibrium. A firm that makes a strategic disclosure choice does not internalize any externality that its choice inflicts on other types. The *ex ante* commitment to a disclosure rule enables firms to internalize such externalities.

Moreover, in contrast to the assumption of proposition 3, in my model the level of information acquisition is not given, but determined endogenously by investment decisions. In the next subsection I show that endogenizing the firms' probabilities of receiving information changes the profit ranking of proposition 3 dramatically.

## 4.2 Expected Equilibrium Profits

For given levels of information acquisition investments, firms prefer to precommit. Here I evaluate the expected profits at the equilibrium investment levels.

Under precommitment the expected equilibrium profits are as follows (for $\mathbf{r}^\ell \equiv$

$(r^\ell, r^\ell)$ with $\ell \in \{f, o, s\}$):

$$\Pi^f(\mathbf{r}^f) = \Pi^o(\mathbf{r}^o) = \begin{cases} E\left\{\pi^f(\theta)\right\} - \eta, \text{ if } \eta < \psi_0^f, \\ \pi^f(\varnothing), \text{ otherwise.} \end{cases} \tag{15}$$

In equilibrium firms are indifferent between the two precommitment regimes. If the cost of investment is sufficiently flat ($\eta \leq \psi_0^f$), then firms acquire information with certainty under full concealment, i.e. $r^o = 1$. Consequently, firms earn the expected equilibrium profit of $\Pi^o(\mathbf{r}^o) = E\{\pi^f(\theta)\} - \eta$. Under full disclosure firms invest less in information acquisition, i.e. $r^f < 1$ where $r^f$ is such that $\psi^f(r^f) = \eta$. On the one hand, the lower investment generates lower product market profits under full disclosure, i.e. firms incur a revenue loss of $(1 - r^f)\psi^f(r^f)$. On the other hand, firms incur a lower cost of investment under full sharing, which creates a cost saving of $(1 - r^f)\eta$. In equilibrium the revenue loss exactly offsets the cost saving. For steeper investment cost functions ($\eta > \psi_0^f$) a similar trade-off emerges, and consequently $\Pi^f(\mathbf{r}^f) = \Pi^o(\mathbf{r}^o)$ for all $\eta$.[13]

The expected equilibrium profit under strategic disclosure equals:

$$\Pi^s(\mathbf{r}^s) = \begin{cases} E\left\{\pi^s(\theta)\right\}\big|_{r=r^s} - \eta, \text{ if } \eta < \psi_0^s, \\ \pi^f(\varnothing), \text{ otherwise.} \end{cases} \tag{16}$$

The comparison of this profit with the expected equilibrium profits $\Pi^f(\mathbf{r}^f)$ and $\Pi^o(\mathbf{r}^o)$ in (15) is summarized in the following proposition.

**Proposition 4** *For all $\eta > 0$ the expected equilibrium profits under full information sharing and no sharing are identical, i.e. $\Pi^f(\mathbf{r}^f) = \Pi^o(\mathbf{r}^o)$. Furthermore, for the critical value $\gamma^{**} \equiv \left[E(\theta) - \underline{\theta}\right]/E(\theta)$ the following holds.* ***(a)*** *If $\gamma \leq \gamma^{**}$, then the expected equilibrium profits are greatest under strategic disclosure for all $0 < \eta < \psi_0^s$;* ***(b)*** *If $\gamma > \gamma^{**}$, then a critical value $\eta^{**}$ exists, with $\psi_0^f < \eta^{**} < \psi_0^s$, such that expected profits are greatest (smallest) under strategic disclosure iff $0 < \eta < \eta^{**}$ (resp. $\eta^{**} < \eta < \psi_0^s$), i.e. $\Pi^s(\mathbf{r}^s) \gtreqless \Pi^f(\mathbf{r}^f)$ if $\eta \lesseqgtr \eta^{**}$.*

Figure 2 illustrates the expected equilibrium profits under precommitment (the thin lines) and strategic disclosure (the bold lines) for different degrees of product substitutability. Fig. 2 (a) and (b) illustrate the expected equilibrium profits in proposition 4 (a) and (b), respectively.

[13] In fact, this identity depends on linearity of the cost of information acquisition, as I discuss in section 5. The introduction of information acquisition investments at convex costs typically yields higher expected profits under full information sharing than under no pooling of information.

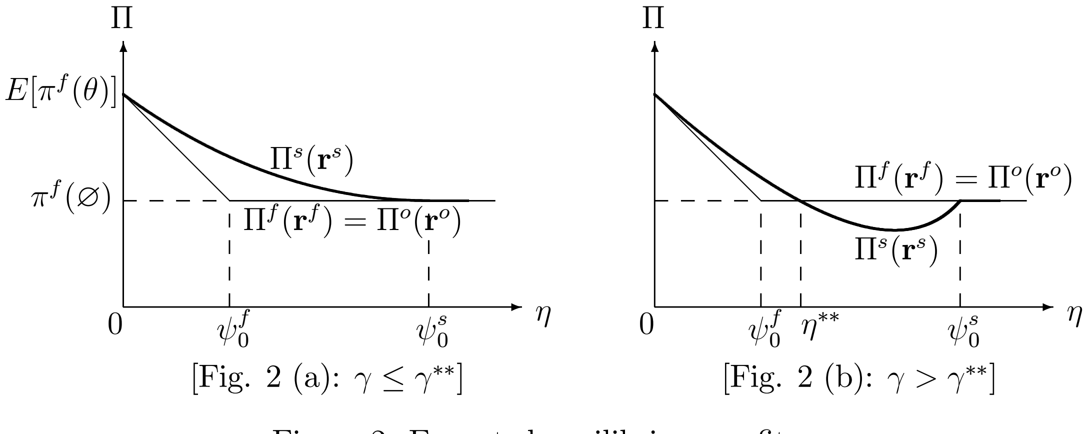


Figure 2: Expected equilibrium profits

For low marginal costs of investment the equilibrium information acquisition investment level under strategic disclosure is between the investment levels under precommitment, i.e. $r^f < r^s < r^o$. The information acquisition incentives under precommitment are such that firms underinvest under full disclosure, while they overinvest under full concealment. The intermediate information acquisition investment under strategic disclosure yields a higher expected profit. This results from the concavity of the expected product market profits under strategic disclosure.

A more detailed analysis involves the comparison of equilibrium revenues and costs. As in (10), a firm's revenue under regime $\ell$ consists of the expected equilibrium product market profit under this regime (for $\ell \in \{f, o, s\}$):

$$R^\ell(r) \equiv E\{\pi^\ell(\theta)\} - (1-r)\psi^\ell(r). \tag{17}$$

The cost that a firm bears is the cost of investment, $\eta r$. For example, if $\eta \leq \psi_0^f$, then the expected equilibrium profits are as follows. Under full concealment firms invest in certain information acquisition, i.e. $r^o = 1$, which generates the expected equilibrium profit: $R^o(1) - \eta$, where $R^o(1) = E\{\pi^f(\theta)\}$. Firms choose a lower investment level under strategic information disclosure, i.e. $0 < r^s < 1$. This investment level yields an expected profit of $R^s(r^s) - \eta r^s$. The comparison of revenues and costs under full concealment and strategic disclosure yields the following trade-off. On the one hand, firms earn a lower expected product market profit under strategic disclosure, since firms invest less in information acquisition, i.e. $R^s(r^s) < R^o(1)$. On the other hand, firms have a lower cost of information acquisition under strategic disclosure, i.e. $\eta r^s < \eta$. The cost saving of $(1-r^s)\eta$ outweighs the revenue loss of $R^o(1) - R^s(r^s) = E\{\pi^f(\theta) - \pi^s(\theta)\} + (1-r^s)\psi^s(r^s)$, since $E\{\pi^f(\theta)\} < E\{\pi^s(\theta)\}$ for $r^s < 1$, and

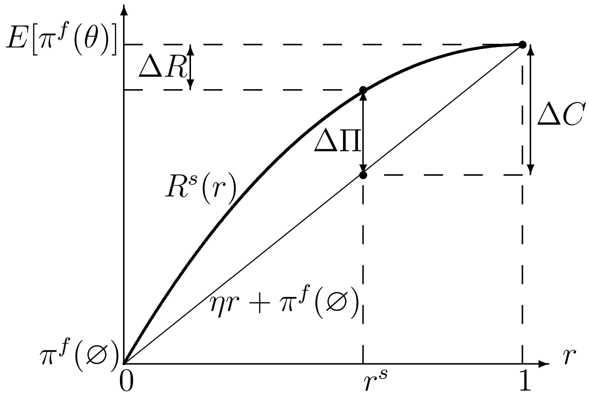


Figure 3: Revenue-cost analysis ($\eta = \psi_0^f$)

$\psi^s(r^s) = \eta$. Figure 3 illustrates the trade-off for $\eta = \psi_0^f$. Clearly, the concavity of the product market profit curve $R^s$ (the bold line) implies that for $r = r^s$ the cost saving $\Delta C$ outweighs the revenue loss $\Delta R$. The expected profit difference illustrated in the figure reduces to: $\Delta\Pi = q[\pi^s(\overline{\theta}) - \pi^f(\overline{\theta})] > 0$ for $r = r^s$.

For sufficiently high information acquisition cost parameters, i.e. $\psi_0^o < \eta < \psi_0^s$, firms do not invest in information acquisition under precommitment, i.e. $r^f = r^o = 0$. The equilibrium investment under strategic disclosure remains positive, i.e. $r^s > 0$. This positive investment level yields the expected product market profit $R^s(r^s)$, which exceeds the product market profits under precommitment, i.e. $\pi^f(\varnothing)$. However, also the cost of investment is greater under strategic disclosure. The sign of the net effect depends on the degree of product substitutability, $\gamma$.

In particular, if goods are sufficiently differentiated, i.e. $\gamma \leq \gamma^{**}$, then the expected product market profit under strategic disclosure is initially steeper than the investment cost function, i.e. $dR^s(0)/dr > \psi_0^s$. In that case, the expected product market profit gain outweighs the investment cost increase. Figure 4 illustrates the trade-offs for a parameter value $\eta$ close to $\psi_0^s$ (i.e. $\varepsilon > 0$ and small). For this parameter value the equilibrium investment under strategic disclosure, $r^s$, is positive and close to zero. Fig. 4 (a) illustrates the trade-off for $\gamma \leq \gamma^{**}$. Analogous to the previous analysis (figure 3), the product market profit increase outweighs the investment cost increase for $r^s$ close to zero. Consequently, firms are best off under strategic disclosure.

If, on the other hand, goods have a degree of substitutability above $\gamma^{**}$ and the cost parameter $\eta$ is sufficiently close to $\psi_0^s$, then the cost function is steeper than the product market profits under strategic disclosure, i.e. $dR^s(0)/dr < \psi_0^s$. Consequently, the expected product market profit gain under strategic disclosure is outweighed by

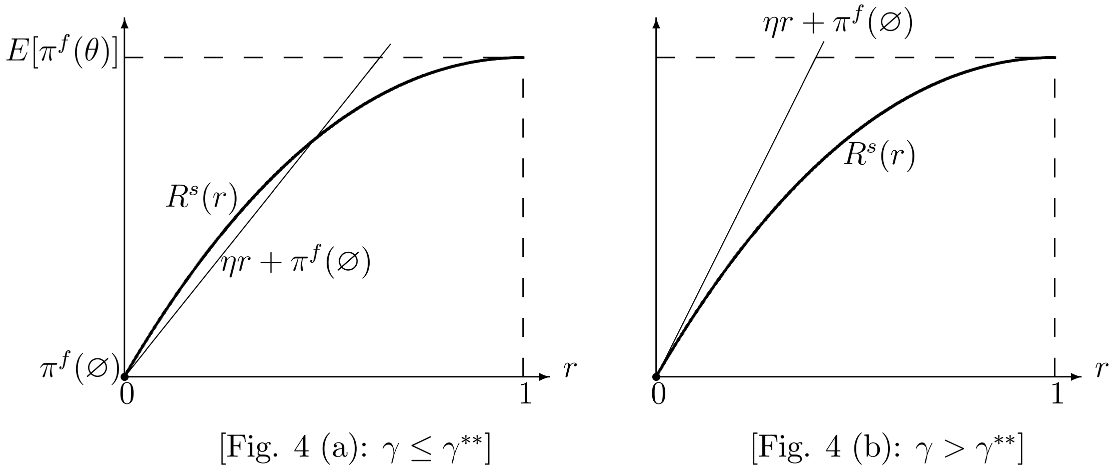


Figure 4: Revenue-cost analysis ($\eta = \psi_0^s - \varepsilon$)

the higher cost of investment. This case is illustrated in fig. 4 (b). Here any positive investment yields an overall expected profit below $\pi^f(\varnothing)$. Since the equilibrium investment under strategic disclosure is positive, the expected equilibrium profit is greatest under precommitment.

Whereas firms prefer precommitment for any given level of information acquisition (proposition 3), the profit ranking is often reversed after endogenizing information acquisition investments (proposition 4). If the costs of information acquisition are sufficiently low, or if goods are sufficiently differentiated, then firms prefer not to precommit to information disclosure. Hence, strategic disclosure does not only emerge in markets where firms cannot precommit, but it can also emerge since firms choose not to precommit. Only if the marginal cost of investment and the degree of product substitutability are high, then firms prefer precommitment to full information sharing or full concealment.

This reversal of the profit ranking may have the following policy implication. For given signal precisions a *quid pro quo* information sharing agreement often yields efficiency gains among competing firms (proposition 3). Whether firms enter an information sharing agreement to facilitate collusion or to generate efficiency gains is in that case often ambiguous. This ambiguity may result in a relatively lenient policy towards information sharing agreements. However, an antitrust authority should perhaps be less lenient when information acquisition investments are endogenous. In that case the efficiency gains among competing firms are often greatest under strategic disclosure (proposition 4). Then the only remaining motive for firms to enter an information sharing agreement is to facilitate collusion.

First, an antitrust authority should be severe when evaluating *quid pro quo* information sharing agreements between firms that produce sufficiently differentiated goods (proposition 4a). Second, if information acquisition investment costs are flattening out over time (Kirby, 2004), then an antitrust authority should always adopt a severe policy towards information sharing agreements in mature industries (proposition 4a-b).[14]

# 5 Extensions

An important result from the previous section is that firms prefer strategic disclosure, if the investment cost curve is sufficiently flat. The current section discusses the robustness of this result with respect to changes in the specification of the cost of information acquisition, the distribution of types, the number of firms, and the nature of product market competition.

## 5.1 Cost of Information Acquisition

The analysis of the previous section is made easier by the assumption of linear costs of information acquisition. In this subsection I show that strategic disclosure also generates the highest expected equilibrium profits for flat, convex cost curves. In particular, suppose that firm $i$ has the following convex cost of information acquisition: $C(r_i;\eta) \equiv \eta \cdot c(r_i)$, with $\eta > 0$, and $c'(r) > 0$, $c''(r) \geq 0$ for all $r > 0$, and $c'(0) = c''(0) = 0$. Firm $i$'s expected profit under regime $\ell$ is now (for $i = 1, 2$ and $\ell \in \{f, o, s\}$):

$$\Pi^{\ell}(r_i, r) = E\left\{\pi^{\ell}(\theta)\right\} - (1 - r_i)\psi^{\ell}(r) - \eta c(r_i). \tag{18}$$

Again, the trade-off between the marginal revenue and marginal cost of information acquisition determines the equilibrium information acquisition investment, i.e. $r^{\ell}$ is such that for any $\ell \in \{f, o, s\}$:

$$\psi^{\ell}(r^{\ell}) = \eta c'(r^{\ell}), \text{ if } \psi^{\ell}(1) \leq \eta c'(1), \tag{19}$$

and $r^{\ell} = 1$, otherwise. Clearly, the ranking of equilibrium investments from proposition 2 is not affected by the introduction of cost convexity.

The comparison of the expected equilibrium profits yields the following.

[14] By contrast, if evidence on the degree of product differentiation or the marginal cost of information acquisition is not available to the antitrust authority, then the policy implications of my model remain ambiguous.

**Proposition 5** *If firms have strictly convex costs of information acquisition, $C(r_i;\eta)$, the following holds. Critical value $\eta^c \geq \psi_0^f/c'(1)$ exists such that for all $\eta \leq \eta^c$ the expected equilibrium profit under full information sharing is greater than under full concealment, i.e. $\Pi^f(\mathbf{r}^f) > \Pi^o(\mathbf{r}^o)$ for all $\eta \leq \eta^c$. Furthermore, a critical value $\eta^s > 0$ exists such that for all $\eta \leq \eta^s$ the expected equilibrium profit is highest under strategic information sharing, i.e. $\Pi^s(\mathbf{r}^s) > \Pi^f(\mathbf{r}^f)$ for all $\eta \leq \eta^s$.*

First, notice that a firm with convex information acquisition costs is no longer indifferent between the precommitment regimes. In particular, firms that share information expect a higher equilibrium profit. The information acquisition cost saving under full information sharing now outweighs the loss of expected product market profit.

Second, for sufficiently flat information acquisition cost curves the firms' preference for strategic information sharing (proposition 4) is not affected by the introduction of convex costs. This preference for strategic disclosure was already driven by the concavity of the expected equilibrium profit function. The introduction of convex information acquisition costs only increases the relative profitability of strategic disclosure. That is, a firm's expected equilibrium profit remains highest under strategic disclosure.

## 5.2 Continuum of Types

So far the analysis was conducted in a model with discrete types. In this subsection I illustrate that this simplification does not drive the results.

Suppose that demand intercepts are drawn from the interval $[\underline{\theta}, \overline{\theta}]$ with p.d.f. $g : [\underline{\theta}, \overline{\theta}] \to \mathbb{R}_+$, and corresponding c.d.f. $G : [\underline{\theta}, \overline{\theta}] \to [0,1]$. Firms have an incentive to discourage their competitor by disclosing only low demand intercepts, since product market strategies are strategic substitutes. That is, there is a threshold value $\theta^* \in (\underline{\theta}, \overline{\theta})$ such that firms choose the following disclosure rule in equilibrium:

$$\delta^S(\theta) = \begin{cases} 1, \text{ if } \theta \leq \theta^*, \\ 0, \text{ if } \theta > \theta^*. \end{cases} \tag{20}$$

An uninformed firm that receives an uninformative message, $\varnothing$, and has beliefs consistent with this disclosure rule, infers that it does not compete with an informed rival who received a signal below $\theta^*$. That is, either the demand intercept is below $\theta^*$ and the firm's rival is not informed, or the intercept is above $\theta^*$. The firm's posterior belief equals therefore:

$$g(\theta|\varnothing) = \begin{cases} \frac{(1-r)g(\theta)}{1-rG(\theta^*)}, \text{ if } \theta \leq \theta^*, \\ \frac{g(\theta)}{1-rG(\theta^*)}, \text{ if } \theta > \theta^*. \end{cases} \tag{21}$$

Firms, that hold these beliefs, choose their output levels optimally, which yields first-order condition (7) with

$$R(\theta;\delta^S) = \begin{cases} 0, \text{ if } \theta \leq \theta^*, \\ r, \text{ if } \theta > \theta^*, \end{cases} \tag{22}$$

and

$$E\left\{\theta|\varnothing;\delta^S\right\} \equiv \int_{\underline{\theta}}^{\theta^*} \frac{(1-r)g(x)}{1-rG(\theta^*)} x dx + \int_{\theta^*}^{\overline{\theta}} \frac{g(x)}{1-rG(\theta^*)} x dx. \tag{23}$$

The first-order conditions give equilibrium output levels, $x^S(\Theta)$, as defined in the Supplementary Appendix, and profits, $\pi^S(\Theta) = x^S(\Theta)^2$ for $\Theta \in \{\theta, \varnothing\}$, and $\theta \in \{\underline{\theta}, \overline{\theta}\}$.

Anticipating the strategic disclosure rule $\delta^S$ and output levels $x^S$, the equilibrium information acquisition investments of firms, $r^S$, are determined by the trade-off between the marginal cost of investment, $\eta$, and the marginal revenue $\psi^S(r)$, as defined in (11) with $\ell = S$. Substituting $r^S$ in profit function (10) for $\ell = S$ yields the expected equilibrium profit: $\Pi^S(\mathbf{r}^S) = E\{\pi^S(\theta)\} - \eta$ for all $0 < \eta < \psi_0^S$, with $\psi_0^S \equiv \psi^S(0)$. Essentially the same intuition as in the model with discrete types applies for the comparison of expected equilibrium profits under precommitment and strategic disclosure. Consequently, the expected equilibrium profit in regime $S$ exceeds the expected equilibrium profits under the precommitment regimes $f$ and $o$, if the investment cost function is sufficiently flat, as is shown in the following proposition.

**Proposition 6** *There exists a value $\theta^* \in (\underline{\theta}, \overline{\theta})$ such that a symmetric equilibrium exists in which firms choose disclosure rule $\delta^S$ as in (20). For all $\eta < \psi_0^S$ the symmetric equilibrium investment given disclosure rule $\delta^S$, $r^S$, is such that $\psi^S(r^S) = \eta$. A critical value $\eta^S > \psi_0^f$ exists such that for all cost parameters $0 < \eta < \eta^S$: the expected equilibrium profits are greatest under disclosure rule $\delta^S$, i.e. $\Pi^S(\mathbf{r}^S) > \Pi^f(\mathbf{r}^f) = \Pi^o(\mathbf{r}^o)$.*

That is, the result from proposition 4 for small information acquisition cost parameters also holds in a model where types are drawn from the interval $[\underline{\theta}, \overline{\theta}]$.

## 5.3 Cournot Oligopoly

The previous analysis characterized the expected equilibrium profits in a Cournot duopoly. In this subsection I summarize how an increase in the number of firms affects the results.

Jansen (2004) characterizes the expected equilibrium profits in a Cournot oligopoly with homogeneous goods ($\gamma = 1$). An increase in the number of firms makes commitment to full concealment more profitable than commitment to full disclosure for given information acquisition investment levels. In particular, in oligopolies with more than three firms the expected profits for given information acquisition investments are always greatest under no pooling of information, as in related information sharing models, see e.g. Clarke (1983), Vives (1984), Gal-Or (1985), and Li (1985).

An increase in the number of firms has no qualitative effect on the relative sizes of expected profits for equilibrium levels of information acquisition. For any number of firms, expected equilibrium profits are greatest (smallest) under strategic disclosure, if the cost of information acquisition is sufficiently low (high), as is shown in Jansen (2004). That is, the qualitative result of proposition 4 for $\gamma = 1$ also holds in a Cournot oligopoly.

## 5.4 Bertrand Competition

This subsection analyzes the effects of changing from Cournot competition ($\gamma > 0$) to Bertrand competition ($\gamma < 0$). If $-1 < \gamma < 0$, then the product market strategies are strategic complements, and the action $x_i$ can be interpreted as firm $i$'s price.

One insight from the literature on information sharing in oligopoly is that information sharing incentives often depend on the nature of product market competition, see e.g. Vives (1984, 1990), and Darrough (1993). Also here the equilibrium strategies and product market profits of firms are affected by the nature of product market competition.

Bertrand competitors have an incentive to render their competitor less "aggressive" in the product market. This gives the firms an incentive to disclose only good news (a high demand intercept) to their rival, i.e. $(\delta^b(\underline{\theta}), \delta^b(\overline{\theta})) = (0, 1)$. I define the equilibrium prices $x^b$ given disclosure rule $\boldsymbol{\delta}^b$ as follows: $x^b(\overline{\theta}) \equiv x^f(\overline{\theta})$, and $x^b(\Theta_i) \equiv x^*(\Theta_i; 0, 1)$ for $\Theta_i \in \{\underline{\theta}, \varnothing\}$ with $x^*$ as in (8), $R(\underline{\theta}; 0, 1) = r$, $R(\overline{\theta}; 0, 1) = 0$, and $Q(0, 1) = q(1-r)/(q(1-r)+1-q)$. The expected product market profit for a given signal equals: $\pi^b(\Theta) \equiv x^b(\Theta)^2$ for any $\Theta \in \{\underline{\theta}, \overline{\theta}, \varnothing\}$. The expected profit $\Pi^b$ is as in (10) for $\ell = b$. The marginal revenue of information acquisition $\psi^b(r)$ is defined in (11) for $\ell = b$, with $\psi_0^b \equiv \psi^b(0)$. Given these definitions I first characterize some properties of the equilibrium strategies in the following lemma.

**Lemma 2** *If $-1 < \gamma < 0$, then the equilibrium strategies are as follows.*
***(a)*** $x^f(\underline{\theta}) < x^b(\underline{\theta}) < x^o(\underline{\theta}) < x^b(\varnothing) < x^f(\varnothing) = x^o(\varnothing) < x^o(\overline{\theta}) < x^b(\overline{\theta}) = x^f(\overline{\theta})$ *for*

*any* $0 < r < 1$*; Furthermore,* $\lim_{r\to 0} x^b(\Theta) = \lim_{r\to 0} x^o(\Theta)$ *for* $\Theta \in \{\underline{\theta}, \varnothing\}$*, while* $\lim_{r\to 1} x^b(\Theta_i) = x^f(\underline{\theta})$ *for* $\Theta_i \in \{\underline{\theta}, \varnothing\}$*, and* $\lim_{r\to 1} x^o(\theta) = x^f(\theta)$ *for* $\theta \in \{\underline{\theta}, \overline{\theta}\}$*.*
***(b)*** *For all* $r < 1$ *firms conceal a low demand intercept, and disclose a high intercept in the unique symmetric equilibrium, i.e.* $(\delta^*(\underline{\theta}), \delta^*(\overline{\theta})) = (0, 1)$*.*
***(c)*** *For all* $0 < \eta < \psi_0^o$ *the information acquisition investments in any symmetric equilibrium are highest under full concealment, and lowest under full disclosure, i.e.* $r^f < r^b < r^o$*.*

Although the equilibrium strategies under Bertrand competition are different from the equilibrium strategies under Cournot competition, the expected equilibrium profit ranking is not affected (for small information acquisition cost parameters). That is, also under Bertrand competition does strategic disclosure yield the highest expected equilibrium profit for sufficiently small information acquisition cost parameters, as I show below.

**Proposition 7** *If* $-1 < \gamma < 0$*, then a critical value* $\eta^b > \psi_0^f$ *exists such that for all cost parameters* $0 < \eta < \eta^b$*: the expected equilibrium profits are greatest under strategic disclosure, i.e.* $\Pi^b(\mathbf{r}^b) > \Pi^f(\mathbf{r}^f) \geq \Pi^o(\mathbf{r}^o)$*.*

The intuition for this result is similar to the intuition under Cournot competition. Again, if $\eta \leq \psi_0^f$, then the comparison of the expected equilibrium profits under precommitment and strategic disclosure reduces to the comparison of $E\{\pi^f(\theta)\}$ and $E\{\pi^b(\theta)\}$ for $r = r^b$, respectively. The expected equilibrium profit of an informed firm is highest under strategic disclosure, since $x^b(\underline{\theta}) > x^f(\underline{\theta})$ while $x^b(\overline{\theta}) = x^f(\overline{\theta})$, as shown in lemma 2 (a). A firm that learns the demand is low expects a more optimistic, less "aggressive" competitor under strategic disclosure. Consequently, on average informed firms charge a higher price, and earn a higher expected product market profit under strategic disclosure.

In contrast to many early contributions to the literature on information sharing in oligopoly, the equilibrium profit ranking in this paper does not depend on the nature of product market competition.

# 6 Conclusion

The paper studied the information acquisition, disclosure, and production incentives of oligopolists. In industries where it is not known whether firms are informed the firms have an incentive to disclose information selectively. I compare the expected profit from strategic disclosure with the expected profits from precommitment to either full disclosure or full concealment. Interestingly, even in markets where firms can precommit to these extreme information sharing rules, strategic disclosure may emerge since firms prefer not to precommit.

The incentive to acquire information has a substantial effect on the profit ranking between strategic disclosure and precommitment. Antitrust authorities should take this into account when they decide whether to allow or prohibit the formation of a *quid pro quo* information sharing agreement in oligopolistic markets. The paper discussed some conditions under which competing firms actually prefer not to enter an information sharing agreement. If the cost of information acquisition is not too steep, or if Cournot competitors supply sufficiently differentiated products, then competing firms expect higher profits under strategic disclosure than under an information sharing agreement. In these cases, the emergence of an information sharing agreement could only serve to facilitate collusion among the firms, and should therefore be prohibited.

In the remaining case, where competing Cournot oligopolists have an incentive to enter a *quid pro quo* information sharing agreement, the establishment of such an agreement may reduce the expected welfare. In this case (i.e. the products are close substitutes, and the cost of information acquisition investment is sufficiently steep), precommitted firms invest less in information acquisition than strategically disclosing firms. The lower investments under precommitment create a smaller quantity adjustment effect (see e.g. Kühn and Vives, 1995), which may yield a lower expected consumers' surplus under precommitment. As the preliminary analysis in Jansen (2004) suggests, the expected welfare may indeed be lowest under precommitment in this case. That is, even in the case where the establishment of an information sharing agreement is no proof for collusion, a welfare-maximizing antitrust authority may still want to prohibit such agreements, since precommitment could reduce expected social welfare. A more detailed welfare analysis awaits future research.

# A Proofs for Section 3

## Proof of Lemma 1

**(a)** For any $\boldsymbol{\delta}$ the output levels $x_i^*(\theta;\boldsymbol{\delta})$ and $x_i^*(\varnothing;\boldsymbol{\delta})$ can be rewritten as follows:

$$x_i^*(\theta;\boldsymbol{\delta}) = x^f(\theta) + \frac{\gamma\,[1-R(\theta;\boldsymbol{\delta})]\,[\theta - E(\theta|\varnothing;\boldsymbol{\delta})]}{[2+\gamma]\,\left[2+\gamma\left(Q(\boldsymbol{\delta})R(\underline{\theta};\boldsymbol{\delta}) + (1-Q(\boldsymbol{\delta}))R(\overline{\theta};\boldsymbol{\delta})\right)\right]}, \quad (A.1)$$

$$x_i^*(\varnothing;\boldsymbol{\delta}) = x^f(\theta) - \frac{[2+\gamma R(\theta;\boldsymbol{\delta})]\,[\theta - E(\theta|\varnothing;\boldsymbol{\delta})]}{[2+\gamma]\,\left[2+\gamma\left(Q(\boldsymbol{\delta})R(\underline{\theta};\boldsymbol{\delta}) + (1-Q(\boldsymbol{\delta}))R(\overline{\theta};\boldsymbol{\delta})\right)\right]}, \quad (A.2)$$

respectively. The difference between $x_i^*(\theta;\boldsymbol{\delta})$ and $x_i^*(\varnothing;\boldsymbol{\delta})$ therefore equals:

$$x_i^*(\theta;\boldsymbol{\delta}) - x_i^*(\varnothing;\boldsymbol{\delta}) = \frac{\theta - E(\theta|\varnothing;\boldsymbol{\delta})}{\left[2+\gamma\left(Q(\boldsymbol{\delta})R(\underline{\theta};\boldsymbol{\delta}) + (1-Q(\boldsymbol{\delta}))R(\overline{\theta};\boldsymbol{\delta})\right)\right]}. \quad (A.3)$$

Hence, $x^*(\underline{\theta};\boldsymbol{\delta}) \le x^f(\underline{\theta}) \le x^*(\varnothing;\boldsymbol{\delta}) \le x^f(\overline{\theta}) \le x^*(\overline{\theta};\boldsymbol{\delta})$. Inequality $x^f(\varnothing) < x^s(\varnothing)$ follows from monotonicity of $x^s(\varnothing)$ in $r$, i.e. $\partial x^s(\varnothing)/\partial r > 0$ as shown in part (b), and $\lim_{r\to 0} x^s(\varnothing) = x^f(\varnothing)$. This inequality, together with first-order condition (7) for $\Theta_i = \overline{\theta}$ and $R(\overline{\theta};1,0) = R(\overline{\theta};0,0) = r$ gives $x^s(\overline{\theta}) < x^o(\overline{\theta})$. All remaining inequalities are straightforward.

**(b)** First, using the following properties

$$\frac{\partial \widetilde{q}}{\partial r} = \frac{\widetilde{q}(1-\widetilde{q})}{1-r}, \text{ and} \quad (A.4)$$

$$x^s(\overline{\theta}) = x^f(\underline{\theta}) + \frac{[2+\gamma(1-\widetilde{q})](\overline{\theta}-\underline{\theta})}{(2+\gamma)[2+\gamma(1-\widetilde{q})r]}, \quad (A.5)$$

it is straightforward to show that:

$$\frac{\partial x^s(\overline{\theta})}{\partial r} = \frac{-\gamma(1-\widetilde{q})[2(1+\widetilde{q})+\gamma(1-\widetilde{q})](\overline{\theta}-\underline{\theta})}{(2+\gamma)[2+\gamma(1-\widetilde{q})r]^2} < 0. \quad (A.6)$$

Second, since $x^s(\varnothing)$ can be rewritten as follows

$$x^s(\varnothing) = x^f(\underline{\theta}) + \frac{2\widetilde{q}(\overline{\theta}-\underline{\theta})}{(2+\gamma)[2+\gamma(1-\widetilde{q})r]}, \quad (A.7)$$

I obtain:

$$\frac{\partial x^s(\varnothing)}{\partial r} = \frac{2\widetilde{q}(1-\widetilde{q})[2-\gamma(1-2r)](\overline{\theta}-\underline{\theta})}{(1-r)(2+\gamma)[2+\gamma(1-\widetilde{q})r]^2} > 0. \quad (A.8)$$

The remaining monotonicity results for $\partial x^o(\theta)/\partial r$ follow directly from expression (8) with $Q(0,0) = q$ and $R(\theta;0,0) = r$, for $\theta \in \{\underline{\theta},\overline{\theta}\}$. The equalities for $r \in \{0,1\}$ are obvious. $\square$

## Proof of Proposition 1 (Information Disclosure)

Consider an informed firm $i$, i.e. $\Theta_i = \theta$ for some $\theta \in \{\underline{\theta}, \overline{\theta}\}$ and $i \in \{1, 2\}$. Suppose firm $i$'s competitor chooses disclosure rule $(\delta(\underline{\theta}), \delta(\overline{\theta})) \in [0, 1]^2$ and has beliefs consistent with this rule. Firm $i$'s profit from disclosure is: $\pi(\theta|\theta) \equiv x^f(\theta)^2$. The firm's expected profit from concealment of $\Theta_i$ is: $\pi(\varnothing|\theta) \equiv r\delta(\theta)x^f(\theta)^2 + [1 - r\delta(\theta)]\, x^*(\theta; \boldsymbol{\delta})^2$. Clearly, if $r < 1$, then the comparison of $\pi(\theta|\theta)$ and $\pi(\varnothing|\theta)$ reduces to the comparison of expressions (3) and (8) for $\Theta_i = \theta$, respectively.

First, the comparison of (3) and (8) for $\Theta_i = \overline{\theta}$ immediately yields: $x^f(\overline{\theta}) < x^*(\overline{\theta}; \boldsymbol{\delta})$, iff $R(\overline{\theta}; \boldsymbol{\delta}) < 1$ and $Q(\boldsymbol{\delta}) < 1$. Clearly, if $r < 1$, then $R(\overline{\theta}; \boldsymbol{\delta}) < 1$ and $Q(\boldsymbol{\delta}) < 1$. Hence, if $r < 1$, then concealment is a dominant strategy for a firm with $\Theta_i = \overline{\theta}$. Second, the comparison of (3) and (8) for $\Theta_i = \underline{\theta}$ yields: $x^f(\underline{\theta}) > x^*(\underline{\theta}; \boldsymbol{\delta})$, iff $R(\underline{\theta}; \boldsymbol{\delta}) < 1$ and $Q(\boldsymbol{\delta}) > 0$. Clearly, if $r < 1$, then $R(\underline{\theta}; \boldsymbol{\delta}) < 1$ and $Q(\boldsymbol{\delta}) > 0$. Hence, if $r < 1$, then disclosure is a dominant strategy for a firm with $\Theta_i = \underline{\theta}$.

Finally, if $r = 1$, then $R(\theta; \boldsymbol{\delta}) = 1$ and $x^*(\theta; \boldsymbol{\delta}) = x^f(\theta)$ for $\theta \in \{\underline{\theta}, \overline{\theta}\}$. Consequently, firm $i$ is indifferent between disclosure and concealment of $\theta$. Hence, any $\big(\delta(\underline{\theta}), \delta(\overline{\theta})\big) \in [0, 1]^2$ is an equilibrium rule. $\square$

## Proof of Proposition 2 (Information Acquisition)

First, notice that the expected equilibrium profits in (10) are linear in $r_i$ for each regime $\ell \in \{f, o, s\}$. Hence, firm $i$'s profit-maximizing investments are as follows:

$$r_i \in \begin{cases} \{1\}, \text{ if } \eta < \psi^\ell(r), \\ [0, 1], \text{ if } \eta = \psi^\ell(r), \\ \{0\}, \text{ otherwise,} \end{cases} \tag{A.9}$$

for each regime $\ell \in \{f, o, s\}$. Hence, the investment that is chosen in a symmetric equilibrium is unique and decreasing in $\eta$, if the marginal revenue of information acquisition $\psi^\ell$ is decreasing in $r$.

Marginal revenue $\psi^f(r)$, as defined in (11) for $\ell = f$, can be written as follows:

$$\psi^f(r) = (1 - r) \cdot \frac{\sigma_\theta^2}{(2 + \gamma)^2}, \text{ with } \sigma_\theta^2 \equiv q(1 - q)(\overline{\theta} - \underline{\theta})^2, \tag{A.10}$$

which is decreasing in $r$. In particular, the symmetric equilibrium investment equals:

$$r^f = \begin{cases} 1 - \eta/\psi_0^f, \text{ if } \eta \leq \psi_0^f, \\ 0, \text{ otherwise.} \end{cases} \tag{A.11}$$

With no pooling of information firm $i$'s marginal revenue of information acquisition is decreasing in $r$, as follows immediately from rewriting $\psi^o$ as follows:

$$\psi^o(r) = \frac{\sigma_\theta^2}{(2+\gamma r)^2}. \tag{A.12}$$

The symmetric equilibrium information investment under regime $o$ therefore equals:

$$r^o = \begin{cases} 1, \text{ if } \eta \leq \psi_0^f, \\ \frac{2}{\gamma}\left[\sqrt{\psi_0^o/\eta} - 1\right], \text{ if } \psi_0^f < \eta < \psi_0^o, \\ 0, \text{ otherwise.} \end{cases} \tag{A.13}$$

Under strategic disclosure the marginal revenue of information acquisition is $\psi^s(r)$, as in (11). The trade-off between marginal cost and revenue yields the following equilibrium investments:

$$r^s = \begin{cases} \text{s.t. } \psi^s(r) = \eta, \text{ if } \eta < \psi_0^s, \\ 0, \text{ otherwise.} \end{cases} \tag{A.14}$$

Under strategic information sharing we need to evaluate:

$$\begin{aligned} \frac{\widetilde{q}/q}{2} \cdot \frac{d\psi^s(r)}{dr} &= \frac{1}{2}\left(\widetilde{q}\frac{\partial \pi^s(\overline{\theta})}{\partial r} - \frac{\partial \pi^s(\varnothing)}{\partial r} + \frac{1-\widetilde{q}}{1-r}\left[\pi^s(\varnothing) - \pi^s(\underline{\theta})\right]\right) \\ &= \widetilde{q}x^s(\overline{\theta})\frac{\partial x^s(\overline{\theta})}{\partial r} - x^s(\varnothing)\frac{\partial x^s(\varnothing)}{\partial r} + \frac{1-\widetilde{q}}{2(1-r)}\left[x^s(\varnothing)^2 - x^s(\underline{\theta})^2\right]. \end{aligned} \tag{A.15}$$

Using the results from lemma 1 (b), i.e. expressions (A.5), (A.6), (A.7) and (A.8), I can show that:

$$\begin{aligned} &\frac{(1-r)(2+\gamma)^2[2+\gamma(1-\widetilde{q})r]^2}{2q(1-\widetilde{q})(\overline{\theta}-\underline{\theta})} \cdot d\psi^s(r)/dr \\ &= -\left(\underline{\theta} + \frac{[2+\gamma(1-\widetilde{q})](\overline{\theta}-\underline{\theta})}{2+\gamma(1-\widetilde{q})r}\right)\gamma[2(1+\widetilde{q}) + \gamma(1-\widetilde{q})](1-r) \\ &\quad + \left(\underline{\theta} + \frac{2\widetilde{q}(\overline{\theta}-\underline{\theta})}{2+\gamma(1-\widetilde{q})r}\right)2\left[\gamma(1-r) - (2+\gamma r)\right] \\ &\quad + \left(\underline{\theta} + \frac{\widetilde{q}(\overline{\theta}-\underline{\theta})}{2+\gamma(1-\widetilde{q})r}\right)2[2+\gamma(1-\widetilde{q})r], \end{aligned} \tag{A.16}$$

which clearly is negative for all $r \in [0,1)$. Uniqueness of the symmetric equilibrium investment $r^\ell$ follows immediately from the monotonicity of marginal revenue $\psi^\ell$ for any $\ell \in \{f, o, s\}$.

For the investment comparisons it suffices to compare the marginal revenues of information acquisition, since the marginal cost remains the same in all regimes.

First, I prove that $r^f \leq r^s$ by showing that: $\psi^s(r) > \psi^f(r)$ for all $r \in (0,1)$. The difference in marginal revenues under full and strategic information sharing can be decomposed as follows:

$$\begin{aligned}\psi^s(r) - \psi^f(r) &= q\left[\pi^s(\overline{\theta}) - \pi^f(\overline{\theta})\right] + qr\left[\pi^f(\overline{\theta}) - \pi^f(\varnothing)\right] \\ &\quad - \left[q + (1-q)(1-r)\right]\left[\pi^s(\varnothing) - \pi^f(\varnothing)\right]. \qquad \text{(A.17)}\end{aligned}$$

Clearly, the first term of this expression is positive. Hence, it suffices to show that the sum of the second (positive) and third (negative) terms is positive. As shown in the proof of lemma 1, the last term of (A.17) can be rewritten as follows (for $r \in (0,1)$):

$[q + (1-q)(1-r)]\left[\pi^s(\varnothing) - \pi^f(\varnothing)\right]$

$$\begin{aligned}
&= [q + (1-q)(1-r)]\left[x^s(\varnothing) - x^f(\varnothing)\right]\left[x^s(\varnothing) + x^f(\varnothing)\right] \\
&= [q + (1-q)(1-r)]\left(\frac{2\widetilde{q}(\overline{\theta} - \underline{\theta})}{(2+\gamma)[2+\gamma(1-\widetilde{q})r]} - \frac{q(\overline{\theta} - \underline{\theta})}{2+\gamma}\right)\left[x^s(\varnothing) + x^f(\varnothing)\right] \\
&= \frac{q(\overline{\theta} - \underline{\theta})\left(2 - [q + (1-q)(1-r)][2+\gamma(1-\widetilde{q})r]\right)}{(2+\gamma)[2+\gamma(1-\widetilde{q})r]}\left[x^s(\varnothing) + x^f(\varnothing)\right] \\
&= \frac{q(1-q)r(\overline{\theta} - \underline{\theta})\left(2 - \gamma(1-r)\right)}{(2+\gamma)[2+\gamma(1-\widetilde{q})r]}\left[x^s(\varnothing) + x^f(\varnothing)\right] \\
&< qr\frac{(1-q)(\overline{\theta} - \underline{\theta})}{2+\gamma}\left[x^s(\varnothing) + x^f(\varnothing)\right] = qr\left[x^f(\overline{\theta}) - x^f(\varnothing)\right]\left[x^s(\varnothing) + x^f(\varnothing)\right] \\
&< qr\left[x^f(\overline{\theta}) - x^f(\varnothing)\right]\left[x^f(\overline{\theta}) + x^f(\varnothing)\right] = qr\left[\pi^f(\overline{\theta}) - \pi^f(\varnothing)\right].
\end{aligned}$$

To complete the proof of $r^f \leq \min\{r^s, r^o\}$, observe that $r^f < 1 = r^o$ if $0 < \eta \leq \psi_0^f$, $r^f = 0 < r^o$ if $\psi_0^f < \eta < \psi_0^o$, and $r^f = r^o = 0$ for all other $\eta$.

Finally, notice that for all $0 < \eta < \psi_0^s$: $0 < r^s < 1$. Consequently, for all $0 < \eta \leq \psi_0^f$ we have $r^o = 1 > r^s$, while for all $\psi_0^o \leq \eta < \psi_0^s$ investments are such that $r^o = 0 < r^s$. Continuity of marginal revenue functions $\psi^o(r)$ and $\psi^s(r)$ therefore gives the existence of values $\underline{\eta}'$ and $\overline{\eta}'$ immediately. □

# B Proofs for Section 4

## Proof of Proposition 3 (Expected Product Market Profit)

First, I compare the expected profits under full disclosure and no disclosure. The difference between the profits under no and full information sharing can be rewritten as follows (for $r_i = r$ and using the expressions A.10 and A.12):

$$\begin{aligned}\Pi^o(r,r) - \Pi^f(r,r) &= r\psi^o(r) - \left[1-(1-r)^2\right]\psi^f(0) \\ &= \frac{r(1-r)\sigma_\theta^2}{(2+\gamma)^2(2+\gamma r)^2}K(r;\gamma), \end{aligned} \tag{B.1}$$

with

$$K(r;\gamma) \equiv (1+r-r^2)\gamma^2 + 4(1-r)\gamma - 4. \tag{B.2}$$

Hence, $\Pi^f(r,r) > \Pi^o(r,r)$ iff $K(r;\gamma) < 0$. The existence of critical values $\gamma^*$ and $r^*$ then follows immediately from the fact that $K$ is continuous and increasing in $\gamma$, and continuous and decreasing in $r$. In particular, monotonicity and the fact that $K(0;\gamma) = \gamma^2 + 4\gamma - 4$ equals zero for $\gamma = \gamma^*$ ($\equiv 2\sqrt{2} - 2$) imply $K(r;\gamma) < 0$ for all $0 < r < 1$ and $\gamma \leq \gamma^*$. If $\gamma > \gamma^*$, then $r = r^*$ solves the equation $K(r;\gamma) = 0$.

Second, the difference between the expected profit under full disclosure and strategic disclosure equals:

$$\begin{aligned}\Pi^f(r,r) - \Pi^s(r,r) &= rq\left[\pi^f(\overline{\theta}) - \pi^s(\overline{\theta})\right] + (1-r)\left[q + (1-q)(1-r)\right]\left[\pi^f(\varnothing) - \pi^s(\varnothing)\right] \\ &\quad +(1-r)qr\left[\pi^f(\overline{\theta}) - \pi^f(\varnothing)\right]. \end{aligned} \tag{B.3}$$

After substitution of (A.5) and (A.7), and application of basic algebra, this expression can be rewritten as follows:

$$\Pi^f(r,r) - \Pi^s(r,r) = \frac{(1-\widetilde{q})r(1-r)\sigma_\theta^2}{(2+\gamma)^2[2+\gamma(1-\widetilde{q})r]^2}\left[\widetilde{q}r(2-r)\gamma^2 - K(r;\gamma)\right]. \tag{B.4}$$

Clearly, if $\gamma \leq \gamma^*$, then $K(r;\gamma) < 0$ for all $r \in (0,1)$, and consequently $\Pi^f(r,r) > \Pi^s(r,r)$. Also if $\gamma > \gamma^*$ and $r > r^*$, then $K(r;\gamma) < 0$, and $\Pi^f(r,r) > \Pi^s(r,r)$.

Finally, the difference of expected profits under full concealment and strategic disclosure is (using B.1 and B.4):

$$\begin{aligned}\Pi^o(r,r) - \Pi^s(r,r) &= \left[\Pi^o(r,r) - \Pi^f(r,r)\right] + \left[\Pi^f(r,r) - \Pi^s(r,r)\right] \\ &= \frac{r(1-r)\sigma_\theta^2}{(2+\gamma)^2(2+\gamma r)^2[2+\gamma(1-\widetilde{q})r]^2}L(r;\gamma), \end{aligned} \tag{B.5}$$

where

$$\begin{aligned}L(r;\gamma) &\equiv \left[(2+\gamma(1-\widetilde{q})r)^2 - (1-\widetilde{q})(2+\gamma r)^2\right]K(r;\gamma) + (1-\widetilde{q})(2+\gamma r)^2\widetilde{q}r(2-r)\gamma^2 \\ &= \left[4 - (1-\widetilde{q})\gamma^2 r^2\right]\widetilde{q}\cdot K(r;\gamma) + (1-\widetilde{q})(2+\gamma r)^2\widetilde{q}r(2-r)\gamma^2. \end{aligned} \tag{B.6}$$

If $\gamma > \gamma^*$ and $r < r^*$, then $K(r;\gamma) > 0$, and consequently $\Pi^o(r,r) > \Pi^s(r,r)$. Hence, $\max\{\Pi^f(r,r), \Pi^o(r,r)\} > \Pi^s(r,r)$ for all $r \in (0,1)$ and $\gamma > 0$. □

## Proof of Proposition 4 (Expected Equilibrium Profit)

First, expression (15) follows immediately from substitution of (A.11) in (10) for $\ell = f$, and (A.13) in (10) for $\ell = o$. Second, for $0 < \eta \leq \psi_0^f$, equilibrium information acquisition incentives are such that $r^s \in (0,1)$. Hence, $\pi^s(\overline{\theta}) > \pi^f(\overline{\theta})$ and $\pi^s(\underline{\theta}) = \pi^f(\underline{\theta})$ for $r = r^s$, as shown in lemma 1 (a), and therefore:

$$\Pi^s(\mathbf{r}^s) = E\{\pi^s(\theta)\}|_{r=r^s} - \eta > E\{\pi^f(\theta)\} - \eta = \Pi^f(\mathbf{r}^f) = \Pi^o(\mathbf{r}^o). \tag{B.7}$$

Finally, for $\eta \in [\psi_0^f, \psi_0^s)$: $\Pi^f(\mathbf{r}^f) = \Pi^o(\mathbf{r}^o) = \pi^f(\varnothing)$ and $\Pi^s(\mathbf{r}^s) = E\{\pi^s(\theta)\}|_{r=r^s} - \eta$, with $r^s$ such that $\psi^s(r^s) = \eta$. The first derivative of $\Pi^s(\mathbf{r}^s)$ to $\eta$ equals:

$$\begin{aligned}\frac{d\Pi^s(\mathbf{r}^s)}{d\eta} &= q\frac{\partial\pi^s(\overline{\theta})}{\partial r}\cdot\left.\frac{dr^s}{d\eta}\right|_{r=r^s} - 1 = q\frac{\partial\pi^s(\overline{\theta})}{\partial r}\cdot\left.\frac{1}{d\psi^s(r)/dr}\right|_{r=r^s} - 1\\ &= \left.\frac{-\partial\pi^s(\varnothing)/\partial r + \frac{1-\widetilde{q}}{1-r}\left[\pi^s(\varnothing) - \pi^s(\underline{\theta})\right]}{-d\psi^s(r)/dr\cdot\widetilde{q}/q}\right|_{r=r^s},\end{aligned} \tag{B.8}$$

since $d\psi^s(r)/dr$ is as in expression (A.15). The sign of the numerator of (B.8) determines the sign of $d\Pi^s(\mathbf{r}^s)/d\eta$, since the denominator of (B.8) is positive for all $\eta < \psi_0^s$. Expressions (A.7) and (A.8) in the proof of lemma 1 give the following:

$$\begin{aligned}\frac{\partial\pi^s(\varnothing)}{\partial r} &= 2x^s(\varnothing)\frac{\partial x^s(\varnothing)}{\partial r} = \frac{4\widetilde{q}(1-\widetilde{q})(\overline{\theta}-\underline{\theta})}{(1-r)(2+\gamma)[2+\gamma(1-\widetilde{q})r]}\\ &\quad\cdot\frac{2-\gamma(1-2r)}{2+\gamma(1-\widetilde{q})r}\left(x^f(\underline{\theta}) + \frac{2\widetilde{q}(\overline{\theta}-\underline{\theta})}{(2+\gamma)[2+\gamma(1-\widetilde{q})r]}\right),\\ \frac{1-\widetilde{q}}{1-r}\left[\pi^s(\varnothing) - \pi^s(\underline{\theta})\right] &= \frac{1-\widetilde{q}}{1-r}\left[x^s(\varnothing) - x^s(\underline{\theta})\right]\left[x^s(\varnothing) + x^s(\underline{\theta})\right]\\ &= \frac{4\widetilde{q}(1-\widetilde{q})(\overline{\theta}-\underline{\theta})}{(1-r)(2+\gamma)[2+\gamma(1-\widetilde{q})r]}\left(x^f(\underline{\theta}) + \frac{\widetilde{q}(\overline{\theta}-\underline{\theta})}{(2+\gamma)[2+\gamma(1-\widetilde{q})r]}\right)\end{aligned}$$

Hence, the numerator of (B.8) can be written as follows:

$$\frac{1-\widetilde{q}}{1-r}\left[\pi^s(\varnothing) - \pi^s(\underline{\theta})\right] - \frac{\partial\pi^s(\varnothing)}{\partial r} = \frac{4\widetilde{q}(1-\widetilde{q})(\overline{\theta}-\underline{\theta})}{(1-r)(2+\gamma)^2[2+\gamma(1-\widetilde{q})r]}H(r;\gamma),$$

where

$$\begin{aligned}H(r;\gamma) &\equiv \underline{\theta} + \Delta - \frac{2-\gamma(1-2r)}{2+\gamma(1-\widetilde{q})r}\left(\underline{\theta} + 2\Delta\right),\\ \text{and } \Delta &\equiv \frac{\widetilde{q}(\overline{\theta}-\underline{\theta})}{2+\gamma(1-\widetilde{q})r}.\end{aligned}$$

For any $r$ and $\gamma$ the function $H$ is decreasing in $r$, since:

$$\frac{\partial H}{\partial r}=\frac{\partial \Delta}{\partial r}\cdot\left(1-2\frac{2-\gamma(1-2r)}{2+\gamma(1-\widetilde{q})r}\right)-\frac{\partial}{\partial r}\left(\frac{2-\gamma(1-2r)}{2+\gamma(1-\widetilde{q})r}\right)\cdot(\underline{\theta}+2\Delta),$$

with

$$\begin{aligned}\frac{\partial \Delta}{\partial r} &= \frac{\widetilde{q}(1-\widetilde{q})(\overline{\theta}-\underline{\theta})\left[2-\gamma(1-2r)\right]}{(1-r)[2+\gamma(1-\widetilde{q})r]^2}>0,\\ \frac{\partial}{\partial r}\left(\frac{2-\gamma(1-2r)}{2+\gamma(1-\widetilde{q})r}\right) &= \gamma\frac{(1-r)\left[4-(1-\widetilde{q})(2-\gamma)\right]+r\widetilde{q}(1-\widetilde{q})\left[2-\gamma(1-2r)\right]}{(1-r)[2+\gamma(1-\widetilde{q})r]^2}>0,\end{aligned}$$

and, consequently, $\frac{2-\gamma(1-2r)}{2+\gamma(1-\widetilde{q})r}\geq\frac{1}{2}(2-\gamma)\geq\frac{1}{2}$. Clearly, $H(0;\gamma)=\frac{1}{2}\left[\underline{\theta}+E(\theta)-(2-\gamma)E(\theta)\right]$, which is non-positive iff $\gamma\leq\gamma^{**}\equiv\left[E(\theta)-\underline{\theta}\right]/E(\theta)$. Moreover, $H(1;\gamma)=-\frac{1}{2}\left[(1+\gamma)\overline{\theta}-\underline{\theta}\right]<0$ for all $\gamma>0$. This analysis has the following implications.

**(a)** If $\gamma\leq\gamma^{**}$, then $H(r;\gamma)<0$ for all $r>0$, since $H$ is monotonic in $r$. Consequently, if $\gamma\leq\gamma^{**}$, then $d\Pi^s(\mathbf{r}^s)/d\eta<0$, which, in combination with the observations $\lim_{\eta\downarrow\psi_0^s}\Pi^s(\mathbf{r}^s)=\Pi^s(0,0)=\pi^f(\varnothing)$ and $\Pi^f(\mathbf{r}^f)=\Pi^o(\mathbf{r}^o)=\pi^f(\varnothing)$ for all $\eta\geq\psi_0^f$, implies: $\Pi^s(\mathbf{r}^s)>\Pi^f(\mathbf{r}^f)=\Pi^o(\mathbf{r}^o)$ for all $\eta<\psi_0^s$, if $\gamma\leq\gamma^{**}$.

**(b)** Conversely, if $\gamma>\gamma^{**}$, then there exists a critical value $r^{**}\in(0,1)$ such that $H(r;\gamma)<0$ (resp. $H(r;\gamma)>0$) for all $r>r^{**}$ (resp. $r<r^{**}$). Consequently, if $\gamma\leq\gamma^{**}$, then the critical value $\widehat{\eta}\in(\psi_0^f,\psi_0^s)$ exists such that $d\Pi^s(\mathbf{r}^s)/d\eta\leq 0$ iff $\eta\leq\widehat{\eta}$ (since $r^s$ is decreasing in $\eta$, and $\widehat{\eta}=\psi^s(r^{**})$). Hence (recalling that $\lim_{\eta\downarrow\psi_0^s}\Pi^s(\mathbf{r}^s)=\Pi^s(0,0)=\pi^f(\varnothing)$ and $\Pi^f(\mathbf{r}^f)=\Pi^o(\mathbf{r}^o)=\pi^f(\varnothing)$ for all $\eta\geq\psi_0^f$), if $\gamma>\gamma^{**}$, then the critical value $\eta^{**}\in(\psi_0^f,\widehat{\eta})$ exists such that $\Pi^s(\mathbf{r}^s)\gtreqless\Pi^f(\mathbf{r}^f)$ if $\eta\lesseqgtr\eta^{**}$. □

# C Proofs for Section 5 and Additional Proof

In this Appendix I prove the propositions related to the paper's extensions, and I prove a proposition on the *ex ante* incentives to share information unilaterally.

## Proof of Proposition 5 (Convex Costs)

First, I compare the expected overall profits under precommitment. For all cost parameters $\eta\leq\psi_0^f/c'(1)$ the equilibrium information acquisition are such that: $r^o=1>r^f$. Hence, the overall expected profits under precommitment are as follows:

$$\begin{aligned}\Pi^f(\mathbf{r}^f) &= E\left\{\pi^f(\theta)\right\}-(1-r^f)\psi^f(r^f)-\eta c(r^f),\\ \Pi^o(\mathbf{r}^o) &= \Pi^o(1,1)=E\left\{\pi^f(\theta)\right\}-\eta c(1).\end{aligned}$$

Since information acquisition investment $r^f$ is such that $\psi^f(r^f) = \eta c'(r^f)$, the expected profit difference can be rewritten as follows:

$$\Pi^f(\mathbf{r}^f) - \Pi^o(\mathbf{r}^o) = \eta \cdot \left[c(1) - c(r^f) - (1-r^f)c'(r^f)\right], \tag{C.1}$$

which is positive if $c(.)$ is strictly convex in $r$. The existence of critical value $\eta^c \geq \psi_0^f / c'(1)$ follows immediately from continuity of the profit difference in $\eta$.

Second, for the comparison of the overall expected equilibrium profits under strategic and full information sharing gives the following. From (18) I obtain that for all $\eta > 0$ and $\ell \in \{f, s\}$:

$$\Pi^\ell(\mathbf{r}^\ell) = E\left\{\pi^\ell(\theta)\right\}\Big|_{r=r^\ell} - (1-r^\ell)\psi^\ell(r^\ell) - \eta c(r^\ell).$$

Clearly, $\lim\limits_{\eta\to 0}\Pi^f(\mathbf{r}^f) = \lim\limits_{\eta\to 0}\Pi^s(\mathbf{r}^s) = E\left\{\pi^f(\theta)\right\}$, since $\lim\limits_{\eta\to 0} r^f = \lim\limits_{\eta\to 0} r^s = 1$.

The first derivatives of expected profits with respect to cost parameter $\eta$ reduce to:

$$\begin{aligned}
\frac{d\Pi^f(\mathbf{r}^f)}{d\eta} &= -(1-r^f)\frac{dr^f}{d\eta} \cdot \frac{d\psi^f(r^f)}{dr} - c(r^f), \text{ and} && \text{(C.2)}\\
\frac{d\Pi^s(\mathbf{r}^s)}{d\eta} &= \frac{dr^s}{d\eta} \cdot \left( q \left.\frac{\partial \pi^s(\overline{\theta})}{\partial r}\right|_{r=r^s} - (1-r^s)\frac{d\psi^s(r^s)}{dr}\right) - c(r^s). && \text{(C.3)}
\end{aligned}$$

Application of the envelop theorem to identity $\psi^\ell(r^\ell) = \eta c'(r^\ell)$ gives:

$$\frac{dr^\ell}{d\eta} = \frac{c'(r^\ell)}{d\psi^\ell(r^\ell)/dr - \eta c''(r^\ell)}, \tag{C.4}$$

where, $d\psi^f/dr = -\psi_0^f$ and $d\psi^s/dr$ as in (A.15), with $\widetilde{q}/q = [q + (1-q)(1-r)]^{-1}$. Clearly, $d\psi^f(1)/dr$ is finite and negative, and also $d\psi^s(1)/dr$ is finite and negative, as follows from (A.16). This implies that $\lim\limits_{\eta\to 0} dr^\ell/d\eta = c'(1) \cdot \left[d\psi^\ell(1)/dr\right]^{-1} < 0$ and is finite for $\ell \in \{f, s\}$. Moreover, $\lim\limits_{\eta\to 0}\left(\partial\pi^s(\overline{\theta})/\partial r\big|_{r=r^s}\right) = \partial\pi^s(\overline{\theta})/\partial r\big|_{r=1} = 0$, as follows from (A.6). Hence, $\lim\limits_{\eta\to 0} d\Pi^f(\mathbf{r}^f)/d\eta = \lim\limits_{\eta\to 0} d\Pi^s(\mathbf{r}^s)/d\eta = -c(1) < 0$.

Finally, the second order derivative of $\Pi^f(\mathbf{r}^f)$ with respect to $\eta$ is as follows:

$$\frac{d^2\Pi^f(\mathbf{r}^f)}{d\eta^2} = \frac{dr^f}{d\eta} \cdot \left(\frac{dr^f}{d\eta} \cdot \frac{d\psi^f(r^f)}{dr} - c'(r^f)\right) - (1-r^f)\frac{d^2r^f}{d\eta^2} \cdot \frac{d\psi^f(r^f)}{dr}, \tag{C.5}$$

since $d^2\psi^f/dr^2 = 0$ for any $r$. Using expression (C.4), gives the following:

$$\frac{d^2r^\ell}{d\eta^2} = \frac{dr^\ell}{d\eta} \cdot \frac{2c''(r^\ell) - \frac{dr^\ell}{d\eta}\left[d^2\psi^\ell(r^\ell)/dr^2 - \eta c'''(r^\ell)\right]}{d\psi^\ell(r^\ell)/dr - \eta c''(r^\ell)} \tag{C.6}$$

for $\ell \in \{f,s\}$. Taking $\eta \to 0$ gives: $\lim_{\eta\to 0} d^2r^f/d\eta^2 = 2c'(1)\, c''(1)/\left(\psi_0^f\right)^2$, which is positive and finite, and therefore (C.5) yields $\lim_{\eta\to 0} d^2\Pi^f(\mathbf{r}^f)/d\eta^2 = 0$. The second order derivative of $\Pi^s(\mathbf{r}^s)$ with respect to $\eta$ is as follows:

$$\begin{aligned}\frac{d^2\Pi^s(\mathbf{r}^s)}{d\eta^2} &= \frac{dr^s}{d\eta}\cdot\left(\frac{dr^s}{d\eta}\cdot\frac{d\psi^s(r^s)}{dr} - (1-r^s)\frac{dr^s}{d\eta}\cdot\frac{d^2\psi^s(r^s)}{dr^2} - c'(r^s)\right)\\ &\quad + \frac{d^2r^s}{d\eta^2}\cdot\left(q\left.\frac{\partial\pi^s(\overline{\theta})}{\partial r}\right|_{r=r^s} - (1-r^s)\frac{d\psi^s(r^s)}{dr}\right) + q\left(\frac{dr^s}{d\eta}\right)^2\left.\frac{\partial^2\pi^s(\overline{\theta})}{\partial r^2}\right|_{r=r^s},\end{aligned}$$

where (A.15) yields

$$\frac{d^2\psi^s(r)}{dr^2} = q\frac{\partial^2\pi^s(\overline{\theta})}{\partial r^2} - [q+(1-q)(1-r)]\frac{\partial^2\pi^s(\varnothing)}{\partial r^2} + 2(1-q)\frac{\partial\pi^s(\varnothing)}{\partial r}.$$

It is straightforward to show that $d^2\psi^s(1)/dr^2$ is finite. These observations imply that: $\lim_{\eta\to 0} d^2\Pi^s(\mathbf{r}^s)/d\eta^2 = \lim_{\eta\to 0} q\left(\frac{dr^s}{d\eta}\right)^2\left.\frac{\partial^2\pi^s(\overline{\theta})}{\partial r^2}\right|_{r=r^s} = q\left(\lim_{\eta\to 0}\frac{dr^s}{d\eta}\right)^2\left.\frac{\partial^2\pi^s(\overline{\theta})}{\partial r^2}\right|_{r=1} > 0$. Hence, $\lim_{\eta\to 0} d^2\Pi^s(\mathbf{r}^s)/d\eta^2 > \lim_{\eta\to 0} d^2\Pi^f(\mathbf{r}^f)/d\eta^2$, which, in combination with $\lim_{\eta\to 0} d\Pi^s(\mathbf{r}^s)/d\eta = \lim_{\eta\to 0} d\Pi^f(\mathbf{r}^f)/d\eta < 0$ and continuity of $d\Pi^\ell(\mathbf{r}^\ell)/d\eta$ for $\ell \in \{f,s\}$, implies that there exists a critical cost parameter $\eta^s > 0$ such that for all $\eta \leq \eta^s$: $d\Pi^s(\mathbf{r}^s)/d\eta < \Pi^f(\mathbf{r}^f)/d\eta < 0$. This, in turn (in combination with $\lim_{\eta\to 0}\Pi^s(\mathbf{r}^s) = \lim_{\eta\to 0}\Pi^f(\mathbf{r}^f)$ and continuity of $\Pi^s(\mathbf{r}^s)$ and $\Pi^f(\mathbf{r}^f)$), implies: $\Pi^s(\mathbf{r}^s) > \Pi^f(\mathbf{r}^f)$ for all $\eta \leq \eta^s$. $\square$

## Proof of Proposition 6 (Continuum of Types)

Suppose firms have beliefs consistent with the disclosure rule $\delta^S$, as defined in (20), i.e. (21), (22), and (23). If a firm discloses $\theta$, both firms supply $x^f(\theta)$. If no firm disclosed information, i.e. $(D_1, D_2) = (\varnothing,\varnothing)$, and firm $i$ received signal $\Theta_i \in \{\theta,\varnothing\}$ for any $\theta \in [\underline{\theta},\overline{\theta}]$, then the solution of first-order conditions (7) equals:

$$x^*(\Theta_i) = E\left\{x^f(\theta) + \frac{\gamma\left[1-R(\theta;\delta^S)\right]\cdot\Upsilon(\theta,\theta^*)}{(2+\gamma)\left[2+\gamma R(\theta;\delta^S)\right]\left[2+\gamma E\{r-R(\theta;\delta^S)|\varnothing;\delta^S\}\right]}\,\middle|\,\Theta_i;\delta^S\right\}, \tag{C.7}$$

where

$$\Upsilon(\theta,\theta^*) \equiv (2+\gamma r)\left(\theta - E(\theta|\varnothing;\delta^S)\right) + \gamma r\,\frac{1-G(\theta^*)}{1-rG(\theta^*)}\left(E\{\theta|\theta\geq\theta^*\} - \theta\right). \tag{C.8}$$

Second, I show that an equilibrium exists in which disclosure rule $\delta^S$ in (20) is chosen. Suppose firm $i$'s competitor chooses disclosure rule $\delta^S$, and firm $i$ observes $\theta$

and has beliefs consistent with $\delta^S$. Hence, the expected profit from disclosure equals: $\pi(\theta|\theta) \equiv x^f(\theta)^2$. The expected profit from concealment is: $\pi(\varnothing|\theta) \equiv r\delta(\theta)x^f(\theta)^2 + [1 - r\delta(\theta)]x^*(\theta)^2$, where $x^*(\theta)$ is as in (C.7). The difference between the expected profits from disclosure and concealment equals:

$$\pi(\theta|\theta) - \pi(\varnothing|\theta) = [1 - r\delta(\theta)] \left(x^f(\theta)^2 - x^*(\theta)^2\right).$$

The firm prefers to disclose the intercept $\theta$ if $x^f(\theta) > x^*(\theta)$. This inequality is satisfied if $\Upsilon(\theta, \theta^*) < 0$. Notice that $\Upsilon$ is continuous and increasing in $\theta$, with $\Upsilon(\underline{\theta}, \theta^*) < 0$ and $\Upsilon(\overline{\theta}, \theta^*) > 0$. Consequently, the critical value $\theta^*$ exists, with $\underline{\theta} < \theta^* < \overline{\theta}$, such that $\Upsilon(\theta^*, \theta^*) = 0$, and $\delta^S$ in (20) is an equilibrium disclosure rule for this $\theta^*$.

Firms that adopt the equilibrium disclosure rule $\delta^S$ supply the following output levels in equilibrium:

$$x^S(\theta) = \begin{cases} x^f(\theta), \text{ if } \theta \leq \theta^* \\ x^*(\theta), \text{ if } \theta > \theta^* \end{cases}, \text{ and } x^S(\varnothing) = x^*(\varnothing). \tag{C.9}$$

Anticipating the equilibrium strategies $\delta^S$ and $x^S$, the firms expect the marginal revenue $\psi^S(r)$ in (11) from information acquisition. Clearly, if $\theta > \theta^*$, then $\Upsilon(\theta, \theta^*) > 0$, which implies for all $r < 1$:

$$x^S(\theta) = \begin{cases} x^f(\theta), \text{ if } \theta \leq \theta^*, \\ x^*(\theta) > x^f(\theta), \text{ if } \theta > \theta^*. \end{cases} \tag{C.10}$$

Since $\lim\limits_{r\to 0}\theta^* = E(\theta) < \overline{\theta}$, (C.10) implies: $\psi^S(0) = \lim\limits_{r\to 0}E\{\pi^S(\theta)\} - \pi^f(\varnothing) > \psi_0^f$. Furthermore, $\psi^S(1) = 0$. If $0 < \eta < \psi_0^S$, and firms anticipate actions $\delta^S$ and $x^S$, there exist only interior equilibrium information acquisition investments. Investment $r = 0$ (resp. $r = 1$) is not an equilibrium investment, since $\psi^S(0) > \eta$ (resp. $\psi^S(1) = 0 < \eta$). Since $\psi^S$ is continuous in $r$, the intermediate value theorem implies that for any $0 < \eta < \psi_0^S$ there exists some $r^S \in (0, 1)$ such that $\psi^S(r^S) = \eta$.

Finally, if $0 < \eta \leq \psi_0^f$, then $0 < r^S < 1$, and (C.10) implies the following for the expected equilibrium profits:

$$\Pi^S(\mathbf{r}^S) = E\left\{\pi^S(\theta)\right\}\big|_{r=r^S} - \eta > E\{\pi^f(\theta)\} - \eta = \Pi^f(\mathbf{r}^f) = \Pi^o(\mathbf{r}^o).$$

Continuity of $\Pi^S(\mathbf{r}^S)$ in $\eta$ yields the existence of critical value $\eta^S > \psi_0^f$. $\square$

## Proof of Lemma 2 (Bertrand Competition)

**(a)** Analogous to the proof of lemma 1 (a) with $\gamma < 0$, $R(\underline{\theta}; 0, 1) = r$, $R(\overline{\theta}; 0, 1) = 0$, and $Q(0, 1) = q(1 - r)/(q(1 - r) + 1 - q)$.

**(b)** Analogous to the proof of proposition 1 with $\gamma < 0$.
**(c)** Under full disclosure firms invest $r^f$ as in (A.11) in the unique symmetric equilibrium. Under full concealment the marginal revenue of information acquisition, $\psi^o$ in (A.12), is increasing in $r$, if $\gamma < 0$. Consequently, there exist three symmetric equilibrium investments for $\psi_0^o < \eta < \psi_0^f$:

$$r^o \in \begin{cases} \{1\}, \text{ if } \eta \leq \psi_0^o, \\ \left\{0, \frac{2}{\gamma}\left[\sqrt{\psi_0^o/\eta} - 1\right], 1\right\}, \text{ if } \psi_0^o < \eta < \psi_0^f, \\ \{0\}, \text{ otherwise.} \end{cases}$$

Under strategic disclosure there exist only interior information acquisition solutions if $0 < \eta < \psi_0^b$. Investment $r = 0$ (resp. $r = 1$) is not an equilibrium investment, since $\psi^b(0) > \eta$ (resp. $\psi^b(1) = 0 < \eta$). Since $\psi^b$ is continuous in $r$, the intermediate value theorem implies that for any $0 < \eta < \psi_0^b$ there exists some $r^b \in (0, 1)$ such that $\psi^b(r^b) = \eta$.

Clearly, if $\eta < \psi_0^o$, then $r^o = 1 > \max\{r^b, r^f\}$. The remaining proof of $r^b > r^f$ follows from the inequality $\psi^b(r) > \psi^f(r)$, which can be shown in a similar way as in the proof of proposition 2. □

## Proof of Proposition 7 (Bertrand Competition)

Substituting the equilibrium investments of lemma 2 in expected profit function (10) yields the following.

First, I compare the expected equilibrium profits under full disclosure and full concealment. Obviously, $\Pi^f(r^f, r^f) = \Pi^o(1, 1) = E\{\pi^f(\theta)\} - \eta$ for all $\eta < \psi_0^f$, since $\lim_{r\to 1} x^o(\theta) = x^f(\theta)$. Clearly, if $\eta < \psi_0^f$, then $\Pi^o(1, 1) = E\{\pi^f(\theta)\} - \eta > \pi^f(\varnothing) = \Pi^o(0, 0)$. Define: $r' \equiv \frac{2}{\gamma}\left[\sqrt{\psi_0^o/\eta} - 1\right]$. If $\eta < \psi_0^f$, then $r' < 1$, and

$$\begin{aligned} \Pi^o(r', r') &= E\{\pi^o(\theta)\}|_{r=r'} - \eta \\ &= Var\{x^o(\theta)\}|_{r=r'} + E\{x^o(\theta)\}^2 - \eta \\ &< Var\{x^f(\theta)\} + E\{x^f(\theta)\}^2 - \eta \\ &= E\{\pi^f(\theta)\} - \eta = \Pi^f(r^f, r^f), \end{aligned}$$

since $x^f(\underline{\theta}) < x^o(\underline{\theta}) < x^o(\overline{\theta}) < x^f(\overline{\theta})$ and $E\{x^o(\theta)\} = E\{x^f(\theta)\}$. Obviously, for all $\eta > \psi_0^f$: $\Pi^f(\mathbf{r}^f) = \Pi^o(\mathbf{r}^o) = \pi^f(\varnothing)$. Hence, for all $\eta$: $\Pi^f(\mathbf{r}^f) \geq \Pi^o(\mathbf{r}^o)$.

Finally, I compare the expected equilibrium profit under full disclosure and strategic disclosure. Observe that $\psi_0^f < \psi_0^b$, since $\lim_{r\to 0} x^b(\underline{\theta}) = x^o(\underline{\theta}) > x^f(\underline{\theta})$ and $\lim_{r\to 0} x^b(\Theta) =$

$x^f(\Theta)$ for $\Theta \in \{\overline{\theta}, \varnothing\}$, as shown in lemma 2 (a). If $0 < \eta \leq \psi_0^f$, then under strategic disclosure there only exist equilibria with investment $r^b \in (0,1)$ such that $\psi^b(r^b) = \eta$, as shown in lemma 2 (c). Consequently, the expected equilibrium profit under strategic disclosure equals: $\Pi^b(\mathbf{r}^b) = E\{\pi^b(\theta)\}\big|_{r=r^b} - \eta$. Comparing the expected profits for $0 < \eta \leq \psi_0^f$ immediately yields:

$$\Pi^b(\mathbf{r}^b) = E\left\{\pi^b(\theta)\right\}\big|_{r=r^b} - \eta > E\{\pi^f(\theta)\} - \eta = \Pi^f(\mathbf{r}^f),$$

since $\pi^b(\underline{\theta}) > \pi^f(\underline{\theta})$ and $\pi^b(\overline{\theta}) = \pi^f(\overline{\theta})$ for $r = r^s$, as shown in lemma 2 (a). The existence of critical value $\eta^b > \psi_0^f$ follows immediately from the observation that expected profits are continuous in $\eta$. □

## Noncooperative Commitment to Disclose

Consider the variation to the model, where firms unilaterally precommit to information disclosure rules before they acquire information. By contrast, in the model of section 2 firms choose their information disclosure strategy *after* information is acquired.

First, firms simultaneously choose their disclosure rules. Second, firms simultaneously choose their information acquisition investments. Information acquisition investments are not observable, and firms have symmetric expectations about rival investments. Third, after signals are received, firms send messages in accordance with the disclosure rules chosen in stage 1. Finally, firms simultaneously choose their output levels.

The following proposition shows that firms have an incentive to precommit to selective disclosure in the symmetric equilibrium of this variation of the model.

**Proposition 8** *If $r < 1$, then firms unilaterally precommit to disclose a low demand intercept, and conceal a high intercept in the unique symmetric equilibrium, i.e. $(\delta^*(\underline{\theta}), \delta^*(\overline{\theta})) = (1,0)$. If $r = 1$, then any disclosure rule may be chosen in equilibrium, and an informed firm with $\Theta_i = \theta$ expects to earn the profit $\pi^f(\theta)$ for any disclosure rule, with $\theta \in \{\underline{\theta}, \overline{\theta}\}$.*

**Proof:** The proof is similar to the proof of proposition 1. Suppose firm $i$'s competitor chooses disclosure rule $(\widetilde{\delta}(\underline{\theta}), \widetilde{\delta}(\overline{\theta})) \in [0,1]^2$ and both firms have beliefs consistent with this rule. Firm $i$'s expected profit from choosing disclosure rule $(\delta(\underline{\theta}), \delta(\overline{\theta}))$ is then:

$$\begin{aligned}
\Pi_i(\boldsymbol{\delta}, \widetilde{\boldsymbol{\delta}}) &= r_i E\left\{\left(1 - r\widetilde{\delta}(\theta)\right)\delta(\theta)\left(x^f(\theta)^2 - x^*(\theta; \widetilde{\boldsymbol{\delta}})^2\right)\right\} \\
&\quad + E\left\{\left(1 - r\widetilde{\delta}(\theta)\right)\left(r_i x^*(\theta; \widetilde{\boldsymbol{\delta}})^2 + (1 - r_i)x^*(\varnothing; \widetilde{\boldsymbol{\delta}})^2\right)\right\} \\
&\quad + E\left\{r\widetilde{\delta}(\theta)x^f(\theta)\right\} - \eta r_i,
\end{aligned}$$

with $x^*(\Theta_i; \widetilde{\boldsymbol{\delta}})$ as in (8). Notice that only the first line of this expression depends on firm $i$'s disclosure rule.

If $r < 1$, then $R(\theta; \widetilde{\boldsymbol{\delta}}) < 1$ and $0 < Q(\widetilde{\boldsymbol{\delta}}) < 1$, which implies $x^f(\underline{\theta}) > x^*(\underline{\theta}; \widetilde{\boldsymbol{\delta}})$ and $x^f(\overline{\theta}) < x^*(\overline{\theta}; \widetilde{\boldsymbol{\delta}})$ by (8). Hence, if $r < 1$, then the maximization of $\Pi_i(\boldsymbol{\delta}, \widetilde{\boldsymbol{\delta}})$ yields the disclosure rule $(\delta(\underline{\theta}), \delta(\overline{\theta})) = (1, 0)$. Consistency of the beliefs with the optimal rule requires that $(\widetilde{\delta}(\underline{\theta}), \widetilde{\delta}(\overline{\theta})) = (1, 0)$ in equilibrium. Clearly, no further symmetric equilibria exist.

If $r = 1$, then $R(\theta; \widetilde{\boldsymbol{\delta}}) = 1$ and $x^*(\theta; \widetilde{\boldsymbol{\delta}}) = x^f(\theta)$ for $\theta \in \{\underline{\theta}, \overline{\theta}\}$. Consequently, firm $i$ is indifferent between any disclosure rule, and therefore any rule with $\left(\delta(\underline{\theta}), \delta(\overline{\theta})\right) = (\widetilde{\delta}(\underline{\theta}), \widetilde{\delta}(\overline{\theta}))$ is a symmetric equilibrium rule. □

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