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Disclosure Policy and Competition: Cournot vs. Bertrand

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SYNOPSIS AND INTRODUCTION: Disclosure of financial information is an essential ingredient of a well-functioning capital market. However, public disclosure of information can affect a disclosing firm negatively if market participants make strategic use of the information to their advantage. In the presence of such a "proprietary cost," a firm has to trade off the positive and negative effects of disclosure.

In an oligopolistic environment, disclosure causes rival firms to respond. The response depends on the nature of competition and private information. Some firms benefit by hiding, and others by sharing, information. If firms do not disclose information voluntarily, mandating disclosures will force firms to disclose information that they wish hidden. Mandating has no incremental effect if firms would have voluntarily disclosed the information. To promote more efficient (welfare-maximizing) disclosure policies, it is essential to understand how firms would behave in the absence of mandatory disclosure requirements. The purpose of this article is to analyze that behavior.

A two-stage model of a duopoly is formulated to analyze firms' incentives to disclose private information. The incentives depend on whether firms are engaged in Cournot or Bertrand competition, and whether the private information is about demand or cost. Both *ex ante* incentives to precommit to a disclosure policy and *ex post* incentives to disclose voluntarily are examined.

Ex ante, firms would not commit to disclosure in Cournot/demand and Bertrand/cost cases. Although Cournot duopolists would not commit to disclosure of information about demand, both firms and consumers might be better off *if disclosure were enforced* by regulatory agencies such as the Securities Exchange Commission (SEC) or the Financial Accounting Standards Board (FASB). Firms would commit to share information in the cases

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of Cournot/cost and Bertrand/demand. However, firms' incentives diverge *ex post* because the benefit of disclosure depends on the realized value of the signal. When the existence of private information is suspected, but not disclosed, nondisclosure is attributed to the type of signal that is better undisclosed. Thus, in equilibrium, it is difficult for firms to hide information successfully. In the Cournot/demand case, virtually all values of private information would be disclosed. In contrast, in Bertrand/cost, disclosure would seldom be observed when products are good substitutes.

The model developed in this article identifies the environments in which mandatory disclosure rules are most effective: (1) when firms have the incentive to precommit to nondisclosure and (2) when voluntary disclosure is least likely in the absence of precommitment.

Key Words: *Disclosure, Cournot and Bertrand competition,* ex ante *and* ex post *incentives.*

I. Background and Overview

FIRMS release financial reports to various stakeholders to provide timely and relevant information that is useful for investment decisions, monitoring and rewarding performance, and writing contracts. Since the demand for financial information comes from various sources (shareholders, creditors, employees, suppliers, government agencies, etc.), it is possible that the disclosure of particular information has differential effects on these parties. For example, detailed disclosure about new products conveys information about the future prospects of a firm to its shareholders. But it might also reveal strategic information to competitors, thereby reducing the disclosing firm's competitive advantage. The disclosure in this case involves both positive and negative effects on the welfare of shareholders of the firm. The negative effect is often referred to as a "proprietary cost."[1] In the presence of such a cost, a firm has to trade off the positive against the negative effects of disclosure. Revealing information to competitors, however, does not always reduce the disclosing firm's future profit. In fact, in some situations, firms are better off sharing information so as to coordinate actions to their mutual advantage. The consequences of disclosure depend on the specific type of competition firms are engaged in and the type of private information firms have.

Since there are conflicting incentives for disclosure, it is not at all clear whether firms will *voluntarily* disclose all relevant information. Anticipating potentially conflicting incentives, the users of financial information will try to infer the underlying information that is withheld. In equilibrium, firms are successful in withholding information only in limited cases. Mandating disclosures through regulatory agencies such as the SEC or the FASB will force firms to disclose the type of informaton that firms wish hidden. In such a case, mandating has a real effect on the workings of the market, with potentially different effects on the stakeholders. In other situations, mandating might have no incremental effect because firms would have voluntarily disclosed the information anyway. It is important for regulatory agencies to sort out the disclosure incentives

[1] Foster (1986) uses the term "competitive disadvantage costs."

of firms in order to promote more efficient disclosure policies that are consistent with the goals of the agencies.[2] In particular, it is crucial to understand how firms would behave in the absence of mandatory disclosure requirements. Only then is it possible to determine the welfare implications of mandating various disclosure requirements. The purpose of this article is to provide the necessary analysis.

The particular setting considered is a two-stage, noncooperative game of duopoly with private information. Two firms, which are engaged in either Cournot or Bertrand competition, decide on disclosure in the first stage, and quantity (or price) in the second stage. Firms might commit themselves in advance to a particular disclosure policy before they receive their private information on demand or cost. Alternatively, firms might choose their disclosure strategy after the receipt of private signals. In making decisions, firms take into account the strategic effect of their decisions on their rival firms. If firms find it beneficial to share private information, they are likely to precommit themselves to such a disclosure *ex ante*. (This commitment may be coordinated and enforced by the FASB or the SEC.) Once firms receive signals, however, some firms might find that withholding the information would have been better. The precommitted disclosure policy need not be sequentially rational. Whether firms want to precommit themselves to a particular disclosure policy *ex ante*, or whether they prefer to disclose private information voluntarily *ex post* depends critically on the type of competition they are engaged in and the type of private information they receive.

If firms are willing to disclose information on a voluntary basis, mandating disclosure is redundant. If voluntary disclosure is not forthcoming, however, mandatory disclosure can significantly affect the welfare of various stakeholders. For example, both Cournot duopolists and consumers might be better off if disclosure of information on demand is enforced, even though, *ex ante*, the duopolists would not commit to disclosure voluntarily.

Such a clear-cut Pareto improvement does not exist for the case of Bertrand competition with cost information. *Ex post*, firms make disclosure decisions on the basis of the realized values of the signals they receive. Their decisions also depend on how nondisclosure is interpreted by the market. For example, if firms are expected to possess private information, nondisclosure will be attributed to their having information that is better undisclosed, rather than to lack of private information. In such an environment, it is difficult to hide information. Even in environments in which firms would have made prior commitments to nondisclosure, if they failed to precommit, they are more likely than not to disclose the information. Virtually all values of information would be disclosed when firms compete Cournot-style with demand uncertainty. Disclosure, however, is less likely in the Bertrand/cost combination. In fact, disclosure is likely to be rarely observed, when two products are very good substitutes.

The contribution of this article is best understood by placing it in the literature on disclosure incentives. An important result in Grossman (1981) and Milgrom (1981) is that full disclosure is the unique equilibrium when firms are privately informed and are concerned with financial market valuation. The impetus for disclosure comes from the desire of better-type firms to communicate with the financial market. Since a lack of disclosure indicates that a firm is of a worse type, the firm is forced to disclose to differ-

[2] Although we place the SEC and the FASB in the same category, it is quite possible that their goals differ in many respects. We abstract from these issues in this article.

entiate itself from even worse firms. Thus, the whole process unravels so that full disclosure obtains.

Typical assumptions in these full disclosure models are that (1) it is common knowledge that firms have private information; (2) if firms disclose information, they do so truthfully; and (3) firms are concerned with financial market valuation. Without these assumptions, full disclosure might not obtain. If the market does not know whether firms have private information, then a lack of disclosure will not necessarily be attributed to bad news, but possibly to lack of private information (Jung and Kwon 1988). If certain types of information are not verifiable, truthful disclosure is not always credible, which results in partial disclosure of only "certifiable" information (Okuno-Fujiwara et al. 1990). Nondisclosure might also prevail because of the existence of proprietary costs. Verrecchia (1983) shows that in the presence of (exogenously imposed) proprietary costs, a manager withholds information when it falls below some threshold value. The threshold, furthermore, decreases with the quality of information (Verrecchia 1990b).

Proprietary costs have been endogenized in the context of an entry game (Darrough and Stoughton 1990; Dye 1986; Feltham and Xie 1992; Wagenhofer 1990) in which an incumbent considers the effect of disclosure on both financial and product markets.[3] An incumbent with favorable information about demand has conflicting incentives, since good news might raise its valuation in the financial market but might also trigger the entry of competitors into the market. Conversely, an incumbent with unfavorable information might suffer downgrading in the financial market but might succeed in deterring entry by a disclosure.

An interesting implication of the analysis in Darrough and Stoughton (1990) is that competition through a threat of entry encourages voluntary disclosure. The strongest incentive for disclosure to discourage entry comes from an incumbent with unfavorable information, since entry takes place only if the prospect is favorable. Darrough and Stoughton conclude that when entry deterrence is important, the unique equilibrium is one of full disclosure.[4] By construction, entry deterrence is given disproportionate importance, in part to highlight the notion of proprietary costs. The question of how competition in general affects disclosure behavior remains unresolved. If one takes the viewpoint that Bertrand is more competitive than Cournot competition (for each level of substitutability), or associates the degree of substitutability with competition, then the finding in this article is consistent with the conjecture that the less competitive an industry, the more likely disclosure is to prevail (Verrecchia 1983).

An extensive literature also concerns disclosure in the context of information sharing through the voluntary (precommitment) mechanism of trade associations.[5] Most of the models have analyzed settings of duopoly or oligopoly to establish that the type of competition, whether Cournot or Bertrand, makes a significant difference in choosing, *ex ante*, whether to share information on demand or cost.[6]

[3] A similar analysis was made in the context of duopoly by Dontoh (1990) and Gertner et al. (1988).

[4] Verrecchia (1990a) correctly points out that in some sense an entry game "exaggerates the usefulness of 'bad news' to discourage market entrants. . . ."

[5] See, e.g., Clarke (1983), Fried (1984), Gal-Or (1985, 1986), Novshek and Sonnenschein (1982), Shapiro (1986), and Vives (1984).

[6] In a recent article, Vives (1990) focuses on monopolistic competition, which prevents any single firm from influencing the aggregate market.

Although there are similarities between trade associations and regulatory agencies, there are also important differences. Trade associations collect and disseminate information on behalf of their members. Membership is voluntary, and information sharing can be exclusionary (i.e., can exclude nonmembers from obtaining information). In contrast, the SEC or the FASB has enforcement power. Compliance is mandatory, and most disclosure requirements are of a public nature. In addition, the constituencies these regulatory agencies serve are varied. For these reasons, the SEC and the FASB can choose a policy that enhances desired social objectives, even at the expense of some stakeholders. For example, line-of-business reporting can be interpreted as a requirement of accurate disclosure mandated by the FASB. Feltham et al. (1992) interpret aggregate-profit reporting as noisy disclosure (or less information sharing) and line-of-business reporting as noiseless disclosure (full information sharing). In Hughes and Kao (1991), capitalizing R&D spending reveals firms' costs, while expensing does not.

In this article, I analyze disclosure incentives with the particular goal of identifying how the types of competition and private information influence incentives for voluntary disclosure. This is necessary because the incentives for, and effects of, disclosure critically depend on the specific configuration of competition and private information. A market with two firms already in place (duopoly) is better suited for this purpose than an entry game, since duopoly reduces the effect of a rival's behavior. Thus, bad news would not play a disproportionate role in strategic behavior. By focusing on the effect of disclosure on the product market, one is able to classify when a disclosure involves a proprietary cost and when it results in beneficial outcomes. In particular, the findings are that mandatory disclosure rules are most effective: (1) when firms have the incentive to precommit to nondisclosure and (2) when voluntary disclosure is least likely in the absence of precommitment.

The remainder of this article is organized as follows. In the next section, I present a two-stage model of duopoly under both Cournot and Bertrand competition with private information on demand or cost. The incentive to disclose *ex ante* is analyzed by having firms decide on a disclosure policy before they receive a signal on the uncertain parameter. In the *ex post* setting of section III, firms that have not precommitted to a specific disclosure policy decide on disclosure after the receipt of a signal. Different types of firms will have different incentives, depending on how nondisclosure will be perceived by the competitor, and I delineate how disclosure incentives are affected by the type of competition and the nature of the information. It is shown that in the Cournot/demand case, virtually all signals will be disclosed, whereas in the Bertrand/cost case, firms can succeed in hiding information more frequently. The final section presents a brief summary and concluding remarks. All proofs are presented in the appendix.

II. *Ex Ante* Setting

The *ex ante* setting has been analyzed extensively in the context of information sharing via trade associations that collect and disseminate information on behalf of their members.[7] Since members give instruction as to what type of information is to be collected and disclosed, they in effect choose, and commit themselves to, a disclosure

[7] Gal-Or (1985) and Kirby (1988) study incentives for information sharing in a Cournot oligopoly with demand uncertainty, whereas Shapiro (1986) focuses on cost uncertainty. Both Cournot and Bertrand settings are analyzed by Vives (1984) with demand uncertainty, and by Gal-Or (1986) with cost uncertainty.

policy *ex ante*. In this analysis, I focus on disclosure policies that are mandated and enforced by regulatory agencies. Firms lobby for or against various disclosure principles, such as generally accepted accounting principles (GAAP) or disclosure requirements for exchange listing, some of which allow more leeway with respect to "quality" or "the degree of aggregation." Disclosure with noise, however, need not be fraudulent; it might simply be imprecise or not very informative. Since I focus on information on *future* demand and costs, it is quite plausible that disclosure does not provide a completely accurate representation of the private signals received. It is assumed that disclosure is therefore truthful in the sense of not containing fraudulent information, but that, depending on the level of noise chosen, information content or quality may vary. Further, I assume that whatever is disclosed has already been verified by auditors or is easily verifiable at a negligible cost.[8]

Benchmark Under Certainty

Before uncertainty about demand or cost is introduced, it is worthwhile to review a standard model of duopoly under Cournot or Bertrand competition. Assume a linear inverse demand function of the form for firm i, $i=1, 2$,[9]

$$P_i = a - bQ_i - btQ_j, \qquad a>0,\ b>0,$$

where P_i is the (net) price, Q_i is the quantity sold by firm i, a is the demand intercept, b is the slope of the demand curve, and $t(0<t\leq 1)$ represents the degree of substitutability between products i and j.[10] Let $b=1$ without loss of generality, by normalizing Q_i and Q_j appropriately. With constant and identical marginal costs of production for both firms, P_i is defined as net of the marginal costs.

To maximize profit of $\Pi_i = P_iQ_i = (a-Q_i-tQ_j)\cdot Q_i$, firm i sets $2Q_i = a - tQ_j$ to satisfy the first-order condition.[11] This derives firm i's reaction function as $Q_i = a/2 - t/2Q_j$, which is negatively related to Q_j. The unique equilibrium output is then $Q_i = a/(2+t)$, and the equilibrium price is $P_i = a/(2+t)$. Substituting the first-order condition into the profit function yields $\Pi_i = Q_i^2$: firm i's profit is its equilibrium output squared. This further suggests that expected profits are convex in the expected equilibrium quantity under uncertainty. When faced with a choice on disclosure (and subsequent output choice), firms will choose the option that will maximize variance in equilibrium outputs.

A similar analysis can be carried out for Bertrand competition. Rewrite the demand function as $Q_i = \alpha - \beta P_i + \beta t P_j$, where $\alpha = a/(1+t)$ and $\beta = 1/(1-t^2)$. The first-order condition yields the reaction function as $P_i = \alpha/2\beta + (t/2)P_j$, which is positively related to P_j. This unique price and output of firm i are $P_i = \alpha/\beta(2-t) = a(1-t)/(2-t)$ and $Q_i = \alpha/(2-t) = a/(1+t)(2-t)$. Substituting the first-order condition in the profit equation yields $\Pi_i = \beta P_i^2$. Again, this suggests that expected profits will be convex in the equilibrium price under uncertainty. The two features that are useful in understanding the

[8] In the subsequent analysis, it turns out that firms will choose either no noise or infinite noise. Thus, henceforth, the word "disclosure" will mean disclosure of private information with no noise and "no disclosure" will mean disclosure with infinite noise.

[9] Since I am interested in symmetric equilibrium, I will present equations for only one firm to save space. When clear, I omit references to the indices, e.g., $i \neq j = 1, 2$.

[10] Substituting equilibrium quantities and prices below, one can compute cross-price elasticity of demand at equilibrium as $t/(1-t^2)$ for Cournot, and t for Bertrand, competition.

[11] The analysis for firm j is omitted, since it is completely symmetrical.

ensuing analysis under uncertainty are that (1) the reaction functions are sloped negatively (positively) and (2) the equilibrium profits are convex in the equilibrium quantity (*net* price) in Cournot (Bertrand) competition.

Uncertainty

In introducing uncertainty about demand or cost, I rely heavily on the techniques of Gal-Or (1985, 1986).[12] Industry demand is stochastic as:

$$P_i = a + \Delta a - Q_i - tQ_j, \qquad a>0,\ 0<t\leq 1, \qquad i\neq j=1,2,$$

where Δa is a stochastic disturbance in the demand intercept. Again, the value of a is interpreted as *net* of the constant (and known portion of) marginal costs. In addition, marginal costs can have a stochastic portion, Δc_i. Although the source of uncertainty is twofold, I analyze each separately below. Further assumptions are made as follows. Demand uncertainty Δa_i is normally distributed with zero mean and variance of $\sigma>0$. Each firm receives an imperfect signal, $x_i = \Delta a_i + e_i$, with $e_i \sim N(0,m)$ and $m \geq 0$. The aggregate signal is the average $\Delta a = (\Delta a_1 + \Delta a_2)/2$ with $\Delta a \sim N(0, \sigma/2)$.

Each firm decides how to disclose its signal by choosing a noise level in the message. The firm's message is denoted as $\hat{x}_i = x_i + f_i$, with $f_i \sim N(0, s_i)$. The variance terms in the signal and the message may be interpreted as their "quality" or "precision." A similar information structure is assumed for costs. Marginal costs are distributed normally, $\Delta c_i \sim N(0, \sigma_c)$. After receiving a signal, $z_i = \Delta c_i + \epsilon_i$ with $\epsilon_i \sim N(0,n)$, each firm reports $\hat{z}_i = z_i + g_i$ with $g_i \sim N(0, v_i)$. Throughout the analysis, signals (x_i and z_i) and costs (Δc_i) are assumed to be independent and identically distributed. Note that stochastic costs are firm-specific (private values), whereas stochastic demand is common to both firms (common values); all the results on demand and cost hinge on this difference.

The assumptions of linear inverse demand and normal distributions allow computation of expectations to derive the unique equilibria.[13] With this basic structure, four cases with different market and information configurations are analyzed: Cournot versus Bertrand for market competition, and demand versus cost for private information.[14]

Demand Uncertainty

In a Cournot duopoly game, firms are choosing quantities, and the precise value of the demand intercept is uncertain ($\sigma>0$). Each firm is concerned with disclosure (how much noise to add) and quantity choice. Given the aggregate information structure, σ, m, and the firm-specific information x_i, the strategy choice is then a pair (s_i, Q_i). The

[12] The basic model is a synthesis of models developed in the literature on information sharing, particularly those by Gal-Or. Gal-Or (1985) investigates Cournot competition with demand uncertainty in a homogeneous product market, whereas Gal-Or (1986) investigates both Cournot and Bertrand competition with cost uncertainty.

[13] In particular, the assumption of normal distribution is convenient for obtaining linear posterior values. Other density functions, such as the gamma or beta functions, also yield linear posteriors.

[14] With the assumption of constant marginal costs, it is possible to have equilibria in which one firm is choosing quantity and the other price, but the present analysis is restricted to more familiar Cournot and Bertrand competition. See Klemperer and Meyer (1986) for an analysis of how the strategic variables chosen by firms are affected by the shape of marginal costs and the nature of demand uncertainty.

game is played sequentially: firms decide first on disclosure and then on quantity. In the two scenarios, firms either commit to a disclosure strategy before receiving private signals (*ex ante* scenario), or decide on disclosure after receiving their respective signals (*ex post* scenario).

Since each firm makes decisions sequentially, it is logical to analyze the second stage first. This guarantees a subgame perfect equilibrium such that firms will have no incentive to deviate once they reach the second stage. At that stage, each picks an optimal quantity level, given s_1 and s_2 (committed to and made public in the first stage). The unique Bayesian-Nash equilibrium output is a linear function of private signal x_i and disclosed messages ($\hat{x}_i$ and $\hat{x}_j$) as:[15]

$$Q_i = \frac{1}{(2+t)}\left[a + E(\Delta a_j|\hat{x}_j) - \frac{t}{4}E(\Delta a_i|\hat{x}_i) + \frac{(2+t)}{4}E(\Delta a_i|x_i)\right], \qquad i \neq j = 1,2, \quad (1)$$

where $E(\bullet\,|\,\bullet)$ is the expectation operator. By substituting posterior distributions, the Bayesian-Nash equilibrium quantity is formally stated in the following lemma.

Lemma 1: For given (precommitted) s_1 and s_2, the unique Bayesian-Nash equilibrium quantity for firm i in a Cournot duopoly game with demand uncertainty is:

$$Q_i = \frac{1}{(2+t)}\left[a + \frac{\sigma}{2(m+\sigma+s_j)}\hat{x}_j - \frac{t\sigma}{4(m+\sigma+s_i)}\hat{x}_i + \frac{\sigma(2+t)}{4(m+\sigma)}x_i\right], \qquad i \neq j = 1,2. \quad (2)$$

A close inspection of equation (2) reveals insights that will be useful for later analysis. Obviously, without any private signal, the quantity chosen will be identical to that under certainty (quantity of $a/(2+t)$ since $E(\Delta a)=0$). If the message from firm j is infinitely noisy, firm i will adjust its quantity by using only its private information. Sending a message affects i's own equilibrium quantity since j would respond to the message. This process is depicted in figure 1 (top panel). Without any signal, both firms expect a market equilibrium at E. Suppose now that firm 1 has received a favorable signal ($x_1 > 0$), while firm 2 has not received any signals at all. Firm 1 will shift its reaction curve to the right. If firm 1 committed (in the first stage) not to send any message (or send a message with infinite noise), firm 2 will plan to produce Q_2^{ND}. The expected equilibrium, then, is the point depicted by *ND*. Alternatively, if firm 1 were to send a message (say, with no noise), firm 2 would update the expected value of Δa upward and shift its reaction curve upward.[16] The ensuing equilibrium is depicted by point *D*. As equation (2) shows, *D* is expected to be to the left of *ND* (i.e., $Q_1^D < Q_1^{ND}$).

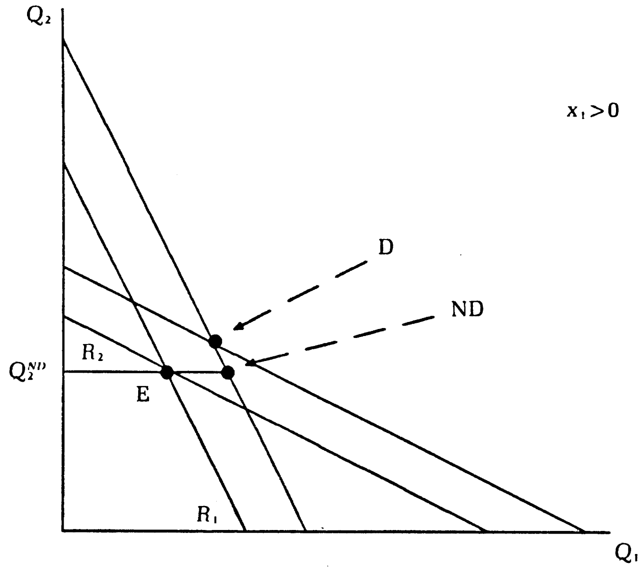
An important observation is that the equilibrium quantity of a firm, *ceteris paribus*,

[15] With the assumption of linear demand and normally distributed signals, it is possible to have nonpositive quantities or prices. Typically, the literature ignores this possibility by assuming relatively small variance so that such an event becomes unlikely. See Novshek and Sonnenschein (1982) and Vives (1984).

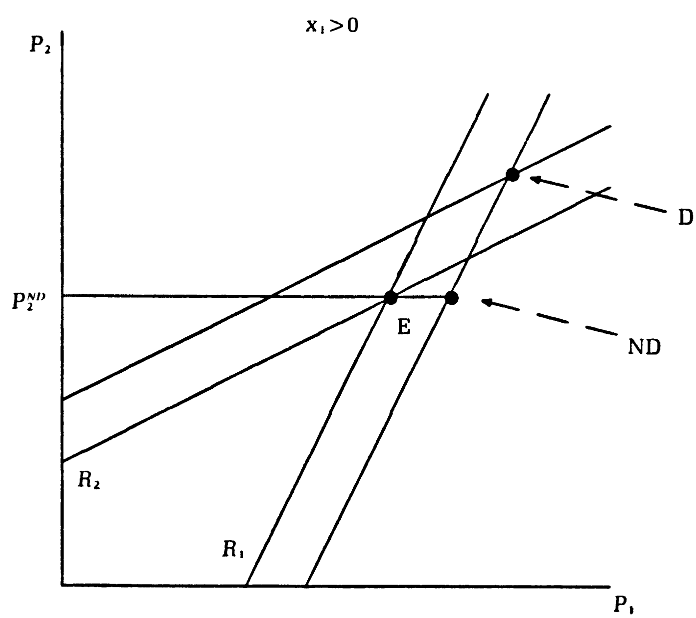
[16] How much reaction curves shift depends on the accuracy of signals and messages in relation to the underlying variability of demand. The more accurate signals become ($m \to 0$), the larger the effect. In fact, if signals are perfect ($m=0$) and firms disclose without noise ($s_1 = s_2 = 0$), both Q_1 and Q_2 will adjust fully (by $E(\Delta a|x_1,x_2) = (x_1+x_2)/2$).

Figure 1
***Ex Ante* Equilibrium with Demand Uncertainty**

Cournot



Bertrand



is positively correlated to its own signal but negatively correlated to its message.[17] This is because a disclosure induces the rival firm to respond in the same direction, which reduces the first firm's equilibrium quantity. The two products are strategic substitutes in Cournot competition.

Since the response to a private signal is larger than that to the message sent, the overall effect is a positive correlation between two firms' outputs. Without any disclosure, however, firm outputs are uncorrelated.

Positive correlation implies that disclosure will increase j's output at the expense of i's output, when i's signal is favorable. Absent disclosure, firm i would be able to increase its output even more. Recall that expected profits under uncertainty are convex in the equilibrium quantity. Hence firm i can increase its expected profit by remaining silent about its private signal. This implies that, in choosing a disclosure policy *ex ante*, no disclosure (or infinitely noisy disclosure) will be the Bayesian-Nash equilibrium strategy. Formally:

Proposition 1: The unique Bayesian-Nash equilibrium of the two-stage Cournot game with demand uncertainty is a pair, $s_i = \infty$ and Q_i, which satisfies equation (2).

This result is easy to interpret in figure 1. The fact that Q_1^{ND} is larger then Q_1^D when $x_1 > 0$ implies that the variability of equilibrium quantity is higher without disclosure. Since expected profits are convex in the equilibrium quantity, a policy that provides higher variability is optimal.[18] It should be noted that no disclosure forms a dominant strategy *ex ante*. This suggests that firms might be reluctant to support any mandatory disclosure policy involving information on uncertain demand.

When $s_1 = s_2 = \infty$, expected profit is:

$$E\Pi_i = \frac{1}{(2+t)^2}\left[a^2 + \frac{\sigma^2(2+t)^2}{16(m+\sigma)}\right]. \tag{3}$$

This shows that expected profits are larger than those under certainty ($\sigma = m = 0$), in which case, $\Pi_i = a^2/(2+t)^2$. This obtains because, when demand is stochastic, firms are able, by using available information, to exploit fluctuations in demand; the increased profits when demand is favorable more than compensate for the reduction in profits when demand is unfavorable. As signals get better ($m \to 0$), firms' expected profits, of course, increase.

When products are not good substitutes, it is interesting to note that expected profits are higher if both firms always disclose, say, with zero noise. In such a case,

$$E\Pi_i = \frac{1}{(2+t)^2}\left[a^2 + \frac{\sigma^2}{2(m+\sigma)}\right],$$

which is strictly larger than the expected profit under no disclosure as in equation (3) as long as, $t < 2\sqrt{2} - 2$, or about 0.828. In other words, if firms can negotiate a binding

[17] This is the case regardless of the signal received or the message sent by the other firm.

[18] This suggests that, when firms are risk-averse, the higher variability is not unambiguously preferred.

agreement for disclosure they are better off, as in the "prisoners' dilemma." This, however, is not a viable agreement in a noncooperative setting. When the mechansism of information transmission is a voluntary organization, such as a trade association, it is difficult to imagine that the association can enforce such an agreement. If, however, the mechanism is either the FASB or the SEC, the enforcement power is substantially greater. Since these agencies can penalize firms that do not comply with the regulation, firms facing demand uncertainty in a higher differentiated Cournot industry might have an incentive to lobby for mandating disclosure of demand-related information, even though they would choose not to share the same information through trade associations.

In a Bertrand game, firms are choosing prices rather than quantities. All the parameters are identical to the Cournot game. (Again assume that costs are certain.) The following proposition summarizes the equilibrium first-stage choice of disclosure and the second-stage choice of price.

Proposition 2: The unique Bayesian-Nash equilibrium of the two-stage Bertrand game with demand uncertainty is a pair, $s_i=0$ and P_i which satisfies:

$$P_i=\frac{(1-t)}{(2-t)}\left[a+\frac{\sigma}{(m+\sigma+s_j)}x_j+\frac{t\sigma}{2(m+\sigma+s_i)}x_i\right.$$
$$\left.+\frac{(2-t)\sigma}{4(m+\sigma)}x_i\right], \qquad i\neq j=1,2. \tag{4}$$

It is immediately clear that the expected profit decreases with the value of s_i. Again, the optimal strategy forms a dominant strategy.

Notice that a firm's responses to its private signal and to its own message are positively correlated. This implies that disclosure increases the variability of the equilibrium price. Hence, noiseless disclosure forms a dominant strategy. Positive correlation follows from the fact that the two firms are strategic complements. Thus, while prospects of higher demand increase prices, the disclosure of favorable information *raises* the prices of *both* firms even more and results in higher expected profits. This is depicted in the bottom panel of figure 1. Again, assume that firm 1 received a favorable signal. Without disclosure, firm 2 would expect to price at P_2^{ND}; with a favorable message, firm 2 shifts its reaction curve upward. The resulting expected equilibrium prices are depicted at *D*. Since expected profits are convex in equilibrium (net) prices, noiseless disclosure increases expected profits by increasing the variability of equilibrium prices.

In contrast to Cournot, Bertrand competition is more "intense" as it drives prices down. This can be easily seen from the fact that, if products were perfect substitutes ($t=1$), then expected (net) prices and profits would be identically zero. The only reason for generating strictly positive expected profits is product differentiation. Cournot competition does not drive prices down to the same extent. Although the Cournot prices are lower than the monopoly price (because two firms might have colluded), they are still higher than the Bertrand prices. Given the cut-throat nature of Bertrand competition, mutually providing more accurate information benefits firms only when demand is uncertain. Otherwise, firms will miss the opportunities to set prices higher when demand is high. Firms are better able to coordinate pricing behavior and reduce the damaging effect of severe competition by sharing information.

Cost Uncertainty

Now assume that demand is certain ($\sigma = m = 0$) but marginal costs are random, firm-specific, and independently distributed. Although an exactly analogous analysis applies to the second-stage quantity and price choices, the first-stage choice is now reversed. *Ex ante*, firms would commit to noiseless disclosure under Cournot, but infinitely noisy disclosure under Bertrand.

Proposition 3: The unique Bayesian-Nash equilibrium strategy of the two-stage Cournot game with cost uncertainty is a pair, $v_i = 0$ and Q_i, which satisfies,

$$Q_i = \frac{1}{(2-t)}\left[a + \frac{t\sigma_c}{(2-t)(n+\sigma_c+v_j)}\hat{z}_j - \frac{t^2\sigma_c}{2(2-t)(n+\sigma_c+v_i)}\hat{z}_i - \frac{(2+t)\sigma_c}{2(n+\sigma_c)}z_i\right]. \tag{5}$$

Similarly when firms are playing Bertrand, we have:

Propositon 4: The unique Bayesian-Nash equilibrium strategy of the two-stage Bertrand game with cost uncertainty is a pair, $v_i = \infty$ and P_i, which satisfies:

$$P_i = \frac{(1-t)}{(2-t)}\left[a + \frac{t\sigma_c}{(2+t)(1-t)(n+\sigma_c+v_j)}\hat{z}_j + \frac{t^2\sigma_c}{2(2+t)(1-t)(n+\sigma_c+v_i)}\hat{z}_i - \frac{(2-t)\sigma_c}{2(1-t)(n+\sigma_c)}z_i\right], \tag{6}$$

where P_i is net of expected marginal costs.

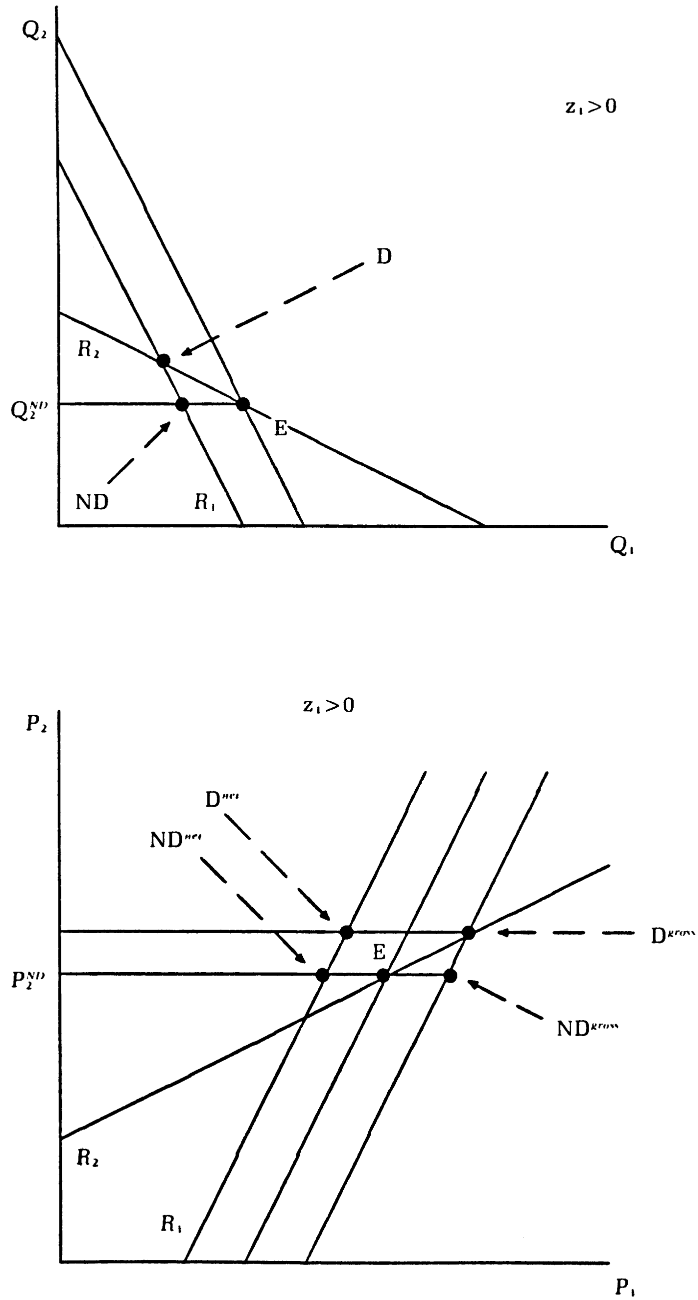
Again, opposite disclosure incentives obtain when costs are certain. To understand why uncertainty about either demand or cost makes a difference in resulting equilibria, recall that demand is a common value, whereas costs are private values. In fact, a higher demand intercept can be viewed as equivalent to a lower (constant) marginal cost. What is important, therefore, is not demand or cost uncertainty *per se*, but rather how uncertain parameters are incorporated in decision making. The specific assumption about demand is additivity, which in effect forces firms to become interdependent.

The intuition behind Propositions 3 and 4 is straightforward. In both cases, absent disclosure (or with infinitely noisy disclosure), the choice variables are uncorrelated, as before. When signals are transmitted, the equilibrium quantity is further reduced (increased) if a signal is unfavorable (favorable), which causes larger (smaller) variance in equilibrium quantity. Positive correlation here is attributed to the fact that the other firm responds better to the cost condition when information is less noisy (by moving along the reaction curve), but it cannot respond without disclosure. Thus, when firm 1's cost is high, its output falls more because firm 2 increases its output, and so on. This is depicted in the first panel of figure 2.

Figure 2
***Ex Ante* Equilibrium with Cost Uncertainty**

Cournot

Bertrand



With Bertrand competition, however, the coefficients on the private signal received and the firm's own message sent are negatively correlated. Disclosure will dampen the disclosing firm's response to a signal and reduces the variability of equilibrium net price. For example, the receipt of an unfavorable signal ($z_1 > 0$) will shift firm 1's reaction curve to the right (starting with the curve in the middle). Without disclosure, firm 2 will price at P_2^{ND} to result in an equilibrium at ND^{gross}. With disclosure, however, an equilibrium will obtain at D^{gross}. Minus $E(\Delta c_1/z_1)$, the net prices firm 1 receives, however, would be ND^{net} and D^{net}. It is clear that no disclosure yields higher variability in net prices. Thus, when firms have the option to commit to a disclosure policy *ex ante*, they would rather not pool the information. This is true even if firms were able to come to a binding agreement for disclosure. It turns out that the effect of disclosure on expected profit is negative when $v_j = v_i < \infty$. Even if a mandatory disclosure rule guaranteed no defection, firms would not want information sharing, quite contrary to the situation in the Cournot/demand case. Again, firms will have different preferences *ex post*, after the realization of their private signals.

The *ex ante* preferences of firms are summarized below. Firms will choose infinite noise (*ND*, no disclosure) as a dominant strategy in the cases of Cournot/demand and Bertrand/cost. Similarly they will choose zero noise (*D*, full disclosure) in Cournot/cost and Bertrand/demand cases. Recall, however, that firms are better off if they can bind themselves into disclosure in the case of Cournot/demand (when products are highly differentiated), but not in the case of Bertrand/cost.

	Competition	
	Cournot	*Bertrand*
Demand	*ND*	*D*
Cost	*D*	*ND*

Ex ante preferences are chosen by considering the effect of disclosure on expected profits. Since firms are identical *ex ante* and the distribution of signals is common knowledge, the financial market will be able, on average, to value firms correctly. The potential tension between the financial-market valuation and product-market competition does not exist in the *ex ante* setting. Such a tension, however, might arise in the *ex post* setting once a firm receives a signal and considers the effect of its disclosure on the two markets.

III. *Ex Post* Setting

In the absence of a precommitted disclosure policy, whether a firm finds it in its best interest to disclose and communicate private signals partially depends on how lack of disclosure is interpreted by the competitor. In the *ex ante* model, a firm adheres to a particular disclosure policy regardless of the realized value of the signal. Therefore, even if there is no disclosure, the very act of nondisclosure does not provide any information as to what type of private signal a firm has received. In the *ex post* scenario, however, upon observing nondisclosure by a firm, the other firm rationally asks why a firm would not disclose when it may do so. One possibility is that the firm has not received any signal. Another possibility is that the firm has received a signal of the type that is better undisclosed.

The assumption in this section is that firms do not always receive a signal, but the market has (common) prior expectations about the likelihood of firms' receiving signals. In such a setting, it is useful to analyze the *ex post* model as a convex combination of two polar cases: one in which firms expect to receive private signals for sure, the other in which firms do not expect to receive any signal. In the first case, nondisclosure is interpreted as private information of certain types; in the second, nondisclosure is attributed to lack of information. In an intermediate case, a firm may suspect that the other firm received a signal, but cannot be sure. Nondisclosure is then attributed partially to lack of private information and to the receipt of the type of signal that is better undisclosed.

Again, the setting is duopolists competing in a two-stage game. In the first stage, each firm receives a signal about demand or cost with probability, $\gamma_i = \gamma_j = \in [0,1]$.[19] This prior probability is assumed to be common knowledge. If a firm receives a signal, it then decides whether to disclose it to the other firm. In the second stage, firms decide output (price) levels, taking into account the private signals they may have received as well as publicly disclosed messages, or the absence thereof, in the first stage. The two periods can be viewed as any two consecutive periods in which information transmission and production take place sequentially in an infinite-period game. If demand or cost is stochastic, and independently and identically distributed in each time period, there is nothing firms can learn over time. Thus, it is sufficient to investigate only two periods.

In the *ex post* setting, it is straightforward to show that the unique equilbrium is full disclosure in Cournot/cost and Bertrand/demand combinations, when the precommitment policy is full disclosure. Firms with more favorable signals are better off with disclosure, while firms with more unfavorable signals want to hide their information. Because a nondisclosing firm will be considered the average of nondisclosing firms, those nondisclosing firms that are better than the average, however, will want to disclose their private information rather than be judged worse than average. Hence, nondisclosure unravels. This is precisely the situation of full revelation examined in Grossman (1981) and Milgrom (1981). Only in a limiting case in which the market believes that there is absolutely no private information, will nondisclosing firms be considered as average. Thus, in these two configurations of competition and information, full disclosure is the unique equilibrium in both *ex ante* and *ex post* settings.

Interesting cases are Cournot/demand and Bertrand/cost configurations. Without precommitment to the nondisclosure, firms find it difficult to withhold information. Signals that firms want to disclose *ex post* might bring pressure for further disclosure. Yet, nondisclosure need not unravel completely in the *ex post* setting because firms with nonextreme signals would disclose, but firms with extreme (both favorable and unfavorable) signals would hide behind nondisclosure. Then a nondisclosing firm would be attributed with the average of signals that firms want withheld. A firm with a signal equal to the average would be indifferent between disclosure and nondisclosure, which implies a sustainable equilibrium.

To simplify the analysis, assume that (1) signals are perfect ($m=n=0$); (2) the disclosure strategy of firms is dichotomous, with two pure strategies, $d \in (D, ND)$; and (3) any disclosure (D) is noiseless, accurate, and credible. Since disclosure with infinite noise is equivalent to absence of disclosure, I refer to this as nondisclosure (ND).

[19] The more general case where $\gamma_i \neq \gamma_j$ is considered by Sankar (1992).

Cournot with Demand Uncertainty

A first conjecture is that firms will disclose only some values of $x_i \in X_i^D(\gamma)$ and will not disclose $x_i \in X_i^{ND}(\gamma)$, $0<\gamma\leq 1$.[20] Similarly, firm j will disclose $x_j \in X_j^D(\gamma)$ and not disclose $x_i \in X_j^{ND}(\gamma)$. Let $\phi_i(\gamma)=\text{Prob}[x_i \in X_i^{ND}(\gamma)]$ and $\phi_j(\gamma)=\text{Prob}[x_j \in X_j^{ND}(\gamma)]$.

Firm i will produce the following output in the second stage (See Lemma 1).[21]

$$Q_i^d=\frac{1}{(2+t)}\left[a+\frac{1}{2}\bar{x}_j-\frac{t}{4}(\bar{x}_i-x_i)+\frac{1}{2}x_i\right]. \tag{7}$$

Expected profits for firm i are:

$$E\Pi_i^d=(Q_i^d)^2$$

$$=\frac{1}{(2+t)^2}\left[a+\frac{1}{2}\bar{x}_j-\frac{t}{4}(\bar{x}_i-x_i)+\frac{1}{2}x_i\right]^2, \tag{8}$$

where $Q_i^d, d\in(D,ND)$ is the output chosen after disclosure or nondisclosure, given the private signal and the (possible) messages to and from firm j, $\bar{x}_i$, and $\bar{x}_j$. For most values of signals and messages, Q_i^d are nonnegative; however, since the distribution of x_i and x_j are unbounded, it is possible to have a negative quantity giving rise to a positive profit. This is possible, for example, if a firm receives a subsidy from the government for nonproduction.[22] In equation (8), $\bar{x}_i=x_i$ when firm i discloses its signal. If there is no disclosure, $\bar{x}_i$ is the expected value of $x_i \in X_i^{ND}(\gamma)$, and is also denoted by $E[x_i|x_i \in X_i^{ND}(\gamma)], \gamma\in[0,1]$. To see how the expected value changes with γ, consider first the case of $\gamma=1$.[23] (The more general case of $0<\gamma<1$ will follow.)

Expecting a receipt of a signal, x_i, firm i formulates an equilibrium disclosure policy, $X_i(\gamma)\in[X_i^D(\gamma),X_i^{ND}(\gamma)]$, by selecting the disclosure region $X_i^D(\gamma)$ and the nondisclosure region $X_i^{ND}(\gamma)$ to maximize expected profit, given by equation (8). Let $\gamma=1$. Any Bayesian-Nash equilibrium must satisfy the condition that, given firm j's disclosure strategy $X_j(1)$, firm i chooses $X_i(1)$ such that:

$$E\Pi_i^D[x_i|X_j(1)]\geq E\Pi_i^{ND}[x_i|X_j(1)] \qquad \forall x_i \in X_i^D(1),$$

$$E\Pi_i^D[x_i|X_j(1)]\leq E\Pi_i^{ND}[x_i|X_j(1)] \qquad \forall x_i \in X_i^{ND}(1), \tag{9}$$

where $E\Pi_i^D(\cdot\,|\,\cdot)$ is firm i's expected profit from disclosure and $E\Pi_i^{ND}(\cdot\,|\,\cdot)$ from nondisclosure. Given the disclosure policy of the other firm j,

[20] This analysis is based on the model developed by Clinch and Verrecchia (1991), in which Cournot/demand configuration is analyzed with $\gamma=1$.

[21] The upper bars in the following equations indicate both disclosed and expected values of private information.

[22] Another possible interpretation of negative quantity is that the producing firm becomes a net consumer of the product.

[23] It should be noted that in this case the existence of nondisclosure regions depends crucially on a positive probability of negative production that is beneficial to the firm. This will be discussed further subsequently.

$$E\Pi_i^D(\bullet\mid\bullet)=\phi_j(1)\left(a+\frac{1}{2}x_i+\frac{1}{2}\bar{x}_j\right)^2$$

$$+[1-\phi_j(1)]E\left[\left(a+\frac{1}{2}x_i+\frac{1}{2}x_j\right)^2 \mid x_j\in X_j^D(1)\right] \text{ and}$$

$$E\Pi_i^{ND}(\bullet\mid\bullet)=\phi_j(1)\left(a+\frac{1}{2}x_i+\frac{1}{2}\bar{x}_j-\frac{t}{4}(\bar{x}_i-x_i)\right)^2$$

$$+[1-\phi_j(1)]E\left[\left(a+\frac{1}{2}x_i+\frac{1}{2}x_j-\frac{t}{4}(\bar{x}_i-x_i)\right)^2 \mid x_j\in X_j^D(1)\right],$$

where $\phi_j(1)$ is the probability that firm j does not disclose its signal when $\gamma=1$. Recall that (truthful) disclosure implies $\bar{x}_i=x_i$, but without disclosure $\bar{x}_i=E[x_i\mid x\in X_i^{ND}(1)]$. This further implies:

$$E\Pi_i^{ND}(\bullet\mid\bullet)-E\Pi_i^D(\bullet\mid\bullet)=\phi_j(1)\left[\frac{t^2}{16}(\bar{x}_i-x_i)^2-\frac{t}{2}(a+\frac{1}{2}x_i+\frac{1}{2}\bar{x}_j)(\bar{x}_i-x_i)\right]$$

$$+[1-\phi_j(1)]E\left[\frac{t^2}{16}(\bar{x}_i-x_i)^2-\frac{t}{2}(a+\frac{1}{2}x_i+\frac{1}{2}x_j)\right.$$

$$\left.(\bar{x}_i-x_i)\mid x_j\in X_j^D(1)\right]$$

$$=(\bar{x}_i-x_i)\left(\frac{t^2}{16}(\bar{x}_i-x_i)-\frac{t}{2}(a+\frac{1}{2}x_i)-\frac{t}{2}\left\{\phi_j(1)\bullet\frac{1}{2}\bar{x}_j\right.\right.$$

$$\left.\left.+[1-\phi_j(1)]E\left[\frac{1}{2}x_j\mid x_j\in X_j^D(1)\right]\right\}\right)$$

$$=\frac{t}{2}(\bar{x}_i-x_i)\left(\frac{t}{8}\bar{x}_i-a-\frac{t+4}{8}x_i\right),$$

since,

$$\phi_j(\gamma)\bar{x}_j+[1-\phi_j(\gamma)]E[x_j\mid x_j\in X_j^D(\gamma)]=0 \qquad \forall\gamma.$$

The following proposition from Clinch and Verrecchia (1991) summarizes the equilibrium.

Proposition 5: In Cournot competition with demand uncertainty, the Bayesian-Nash equilibrium strategy of firm i in the *ex post* setting in which firms are expected to possess private information is characterized by:

$$X_i^D(1)=\left(\frac{t\bar{x}_i-8a}{t+4},\bar{x}_i\right),$$

where $\bar{x}=E[x_i\mid x_i\in X_i^{ND}(1)]$ and $0<\bar{x}_i<8a/t$.[24]

A firm will disclose a signal from the interval, but will not disclose a signal from below or above the interval. In other words, relatively extreme values will not be transmitted. A firm chooses whether to disclose by comparing expected profits with and without disclosure. Without disclosure, a firm will be regarded as an average firm of the nondisclosing group. Notice that a firm with $x_i = \bar{x}_i$ will be indifferent between disclosure and nondisclosure. If the nondisclosure region were a single interval, the expected value could not be at either end of the region. For any nondisclosure region to exist then, it has to be accompanied by at least one more nondisclosure region on a real line.

Note that this particular disclosure region is based on the assumption that firms sometimes produce negative quantities that result in positive profits. Since this assumption is somewhat difficult to interpret, it might be more acceptable to restrict quantities to be nonnegative. It has been shown by Sankar (1992) that a similar nondisclosure region exists at the lower tail, if we assume that firms choose nondisclosure over disclosure when output is zero.[25] Thus, the qualitative results are the same even when negative output is precluded.[26]

Clinch and Verrecchia (1991) show that such an equilibrium exists and that the disclosure interval decreases with the value of t. Since their model does not assume any density function for the signal, it is not possible to estimate the size of this interval. Assuming normally distributed x_i, I compute the interval for arbitrary chosen values of a and t. For example, let $x_i \sim N(0,1)$ and $a=5$. The interval, which depends on t, is presented below. Note that the area is "virtually" 100 percent of all values of t.

t	*Lower Threshold*	*Upper Threshold*	*Interval*	*Area* (%)
0.7	−7.78	4.90119	12.68	100
0.9	−7.26	4.90116	12.16	100
1.0	−7.02	4.90109	11.92	100

The figures show the lower threshold, the upper threshold, the interval between the two thresholds, and the cumulative area of the disclosure region. Notice that the upper threshold is the expected value of the regions outside the interval. Virtually all values of x_i will be disclosed. For a smaller value of a, the interval does get marginally smaller.[27]

Given this *ex post* equilibrium disclosure strategy, would firms prefer to precommit to nondisclosure *ex ante*? It is straightforward to show that firms would precommit to

[24] The necessary condition follows from the fact that $\bar{x}$ is the expected value of the nondisclosure regions. If $\bar{x}<0, X_i^p(\cdot)$ will consist of only negative values. Then $\bar{x}$ will be positive, a contradiction. Similarly, if $\bar{x}>8a/t$, $X_i^p(\cdot)$ consists of only positive values, $\bar{x}$ will be negative, also a contradiction.

[25] Clearly, it is essential to have at least two nondisclosure regions to sustain nondisclosure in equilibrium. In the Cournot/cost and Bertrand/demand cases, nondisclosure is preferred by firms with mid-range signals (when negative output is allowed) or below some point (when negative output is precluded), which results in at most one potential nondisclosure region. Thus, this nondisclosure region unravels in a rational-expectation equilibrium.

[26] As the lower threshold shifts down, the upper threshold shifts up, which causes a larger disclosure region. The case of nonnegative output is analyzed in detail by Sankar (1992). She investigates a generalized model of disclosure in Cournot oligopoly when firms might receive signals on both firm-specific and industry-wide cost information.

[27] For example, with $a=2$ and $t=0.9$, the area becomes 97.3 percent.

nondisclosure when, $t>2\sqrt{2}-2$, as in the case in the *ex ante* analysis.[28] Thus, nondisclosure is not subgame perfect without precommitment.

The analysis so far shows that it is virtually impossible to hide private information when $\gamma=1$. If $\gamma<0$, however, it becomes possible to withhold information, since nondisclosure can be attributed to lack of information. To see how equilibrium behavior is affected by γ, consider the more general case of $0<\gamma<1$, in which firms are not sure whether the competitor has received a signal. Thus, if firm *j* does not disclose, firm *i* has to make a conjecture about what signal firm *j* has received, if any. If firm *i* conjectures that firm *j* has not received a signal (as if $\gamma=0$), firm *i* will attribute firm *j* with the prior (expected) value, $E[x_i|x_i\in X_i^{ND}(0)]=0$. Alternatively, if firm *i* conjectures that firm *j* received a signal (as if $\gamma=1$) but has chosen not to disclose, then firm *i* will conclude that the signal was of the type that is better withheld. In fact, firm *j* has received a signal with probability γ. Thus, when $0<\gamma<1$, nondisclosure will be attributed with a posterior (expected) value, which is the weighted average of the expected values of the two polar cases. Thus,

$$E(x_i|ND,\gamma)=\frac{1-\gamma}{1-\gamma+\gamma\phi_i(\gamma)}E[x_i|x_i\in X_i^{ND}(0)]+\frac{\gamma\phi_i(\gamma)}{1-\gamma+\gamma\phi_i(\gamma)}E(x_i|x_i\in X_i^{ND}(1)]$$

$$=\frac{\gamma\phi_i(\gamma)}{1-\gamma+\gamma\phi_i(\gamma)}E[x_i|x_i\in X_i^{ND}(1)]>0, \qquad 0<\gamma\leq 1.$$

What happens to the incentive to disclose as $\gamma\to 0$? Clearly, as $\gamma\to 0, E(x_i|ND,\gamma)\to 0$. This implies that the upper nondisclosure region is enlarged to include virtually all positive values. The lower nondisclosure region, however, moves downward. A straightforward calculation shows that as $\gamma\to 0$, the disclosure region approaches:[29]

$$\lim_{\gamma\to 0} X_i^D(\gamma)=\left[\frac{-8a}{t+4},0\right].$$

Thus, the disclosure region is almost the entire nonpositive region in the case of Cournot with demand uncertainty. Similar results hold for the other competition/information configurations: *ex post*, the disclosure incentives diverge according to whether the signal is above or below the prior expected value. For firms with favorable signals, the optimal disclosure policy is identical to the *ex ante* policy. This is summarized in the following proposition.

Proposition 6: When γ is arbitrarily close to zero, a firm that has received a favorable signal would follow the same disclosure policy as in the *ex ante* setting with precommitment, whereas a firm that has received an unfavorable (but not extremely unfavorable) signal would follow the opposite disclosure policy.

The intuition is straightforward. It was shown in the previous section that firms would choose a policy that yields higher variability in the expected equilibrium outputs (or net prices) so as to maximize expected profits. Once a signal is realized, however,

[28] Recall that *ex ante* nondisclosure is a dominant Nash Strategy, but when, $t<2\sqrt{2}-2$, firms are better off if they have a binding agreement to disclosure.

[29] A numerical calculation shows that the disclosure region, $1-\phi(\gamma)$, changes with the value of γ as follows: $1-\phi(0.8)=0.907$; $1-\phi(0.5)=0.797$; $1-\phi(0.3)=0.708$; $1-\phi(0.1)=0.585$. These values are insensitive to the value of t. It is not feasible to characterize an equilibrium disclosure region analytically.

firms are better off with a policy that yields a higher expected output (or net price). For a firm with a favorable signal ($x_i>0$ or $z_i<0$), it is the same policy as in the *ex ante* choice; for a firm with an unfavorable signal (except for extremely unfavorable signals), it is the opposite. If firms receive information that is not routinely expected by the market, the present analysis shows that "bad news" tends to be released in the Cournot/demand and Bertrand/cost cases, while "good news" tends to be released in the Cournot/cost and Bertrand/demand cases.

This analysis offers an interesting insight for the precommitment model, by suggesting conditions under which a firm has incentive to undermine the precommitted policy once an unfavorable signal is realized. Even though firms have precommitted to nondisclosure, those firms that have received unfavorable signals could make themselves better off if they could defect from their precommitted policy. If the policy is being implemented by a trade asssociation, firms with unfavorable cost signals in Cournot and unfavorable demand signals in Bertrand would, if possible, terminate their membership to prevent signal dissemination.[30] Alternatively, if disclosure is mandatory and governed by regulation such as GAAP, these firms have an incentive to add as much noise as possible or otherwise avoid compliance. The assumption of precommitment is even more tenuous when there is no disclosure requirement. Firms with unfavorable demand signals in Cournot and unfavorable cost signals in Bertrand would seek to transmit the information voluntarily, since they are better off doing so. Conceivably, this could be achieved by detailed disclosures about future conditions (on markets, technology, input prices, etc.) in financial reports, announcements to the press, interviews with media journalists, and the like.

Bertrand With Cost Uncertainty

Contrary to the Cournot/demand case, the Bertrand/cost combination generates an equilibrium in which the disclosure region is significantly smaller. Furthermore, the disclosure region becomes smaller as the degree of substitutability increases. Define $Z_i^D(\gamma)$ and $Z_i^{ND}(\gamma)$ as the set of z_i values that firm i would choose to disclose and not to disclose, respectively. We again examine the convex combination of two polar cases: $\gamma=1$ and $\gamma\rightarrow 0$. By following the same procedure, we find the unique equilibria for the two cases, as follows.

Proposition 7: In Bertrand competition with cost uncertainty, the Bayesian-Nash equilibrium strategy of firm i in the *ex post* setting when firms receive private information for certain or with arbitrarily low probability are characterized by:

$$Z_i^D(1)=\begin{cases}\left[\underline{z}_i, \dfrac{t^2\overline{z}_i+4a(2+t)(1-t)}{8-3t^2}\right], & \forall\, t<1,\\ \emptyset & t=1,\end{cases}$$

and

[30] Of course, it must be impossible for the *ex ante* commitments to constitute an equilibrium.

Table 1

t	$\gamma\to 0$ Lower Threshold	Upper Threshold	Area Percent	$\gamma=1$ Lower Threshold	Upper Threshold	Area Percent
0.4	0	3.830	49.99%	−2.887	3.768	99.80%
0.8	0	1.842	46.73%	−0.813	1.757	75.24%
0.95	0	0.557	21.12%	−0.071	0.545	23.54%
0.99	0	0.118	4.70%	−0.003	0.118	4.80%

$$\lim_{\gamma\to 0} Z_i^D(\gamma)=\begin{cases}\left[0,\dfrac{4a(2+t)(1-t)}{8-3t^2}\right], & \forall t<1,\\ \emptyset & t=1,\end{cases}$$

respectively, where $\bar{z}_i=E[z_i|z_i\in Z_i^{ND}(1)]$.

With the assumptions of $z_i\sim N(0,1)$ and $a=5$, for example, the disclosure region is computed as shown in table 1.

Table 1 shows that the disclosure region is smaller than in the Cournot/demand case, although it does increase with γ. When t is extremely small (e.g., $t=0.4$), it becomes virtually impossible to hide information as $\gamma\to 1$. For larger values of t, the disclosure region is quite small. In fact, it is striking how sensitive disclosure incentives are to the value of t.[31] As t increases, firms lose protection from product differentiation. The sensitivity to t is another manifestation of the cut-throat nature of Bertrand competition. Signals disclosed tend to be unfavorable (i.e., higher costs) because a firm with unfavorable information wants to transmit the information to induce price increases. Furthermore, it is also straightforward to check that firms would, *ex ante*, have an incentive to precommit to nondisclosure.[32]

IV. Summary and Discussion

In this article, I have considered the relationship between competition and voluntary disclosure behavior. Incentives to disclose depend upon the type of competition and private information. Those firms in Cournot competition facing cost uncertainty and those in Bertrand competition facing demand uncertainty are willing to commit to information disclosure and will support mandated disclosure of the specific information. Without precommitment to disclosure, firms that receive unfavorable information *ex post* would not want to disclose, but will succeed in concealing this information if and only if other firms cannot determine whether they have information. Otherwise,

[31] To see what sort of values t would take, recall that t is the cross-price elasticities between two products in Bertrand competition evaluated at the equilibrium. Cross-price elasticities of demand have been estimated, to take some examples, as follows: +0.44 for natural gas with respect to (the price of) fuel oil, +0.81 for butter with respect to margarine; +0.28 for beef with respect to pork. See Frank (1991). Substitutability between two brands of cereal, electronic appliances, etc. would be expected to be much higher.

[32] A proof is provided in the appendix.

they end up disclosing information on a voluntary basis. Therefore, it appears that mandating disclosure is not necessary when firms are informed for sure.

Firms would precommit *ex ante* to nondisclosure of demand data under Cournot or cost data under Bertrand. Accordingly, if there are moves to mandate disclosure, these firms are not expected to support such requirements. The strongest resistance would come from firms in Bertrand competition regarding cost data, especially if rules do not leave room for noise.[33] Firms in Cournot competition with a high degree of product differentiation would also oppose mandating disclosure rules (about demand data), if flexibility allowed noncompliance, but would support stringent rules. In such a case, mandated disclosure rules substitute for a binding agreement, and both firms and consumers are better off because their interests are aligned. Also, both are better off with higher variation in outputs. This is not the case, however, when products are good substitutes. Although firms in Bertrand competition with cost uncertainty would also be worse off with mandatory disclosure, consumer surplus would be increased by such a policy.

Notwithstanding precommitted disclosure policies in place, firms with unfavorable signals have incentives to undermine such policies by disclosing information (when precommitment was to nondisclosure) or by providing only noisy data (when precommitment was to disclosure). Without a precommitted disclosure policy, firms are free to make voluntary disclosure. If a firm received a signal when other firms attach little likelihood to such an event, firms with favorable information would choose a disclosure policy that is identical to the one chosen *ex ante*, while firms with all but the most extreme unfavorable information would choose the opposite policy. When firms attach greater likelihood to the receipt of signals, however, it is in general more difficult to withhold information. Since nondisclosure is interpreted as having received extreme signals with high probability, firms would be forced to disclose more frequently.

In the Cournot/demand and Bertrand/cost combinations (where precommitment would have been to nondisclosure), firms with no precommitment would be compelled to disclose virtually all the time in the Cournot/demand case, but much less frequently in the Bertrand/cost case. In Bertrand competition with cost uncertainty, the frequency of disclosure and the range of values disclosed depend on the variability of the signal in relation to the market demand and the degree of substitutability. The higher the variance of the uncertainty parameter and the degree of substitutability, the less disclosure.

Not surprisingly, the implications of the analysis for social welfare are mixed. The welfare of consumers might be diametrically opposed to that of firms. The preference of firms is based on whether they are better off with or without disclosure (i.e., higher expected profits). Higher expected profits are achieved by choosing a disclosure strategy that raises expected equilibrium outputs and (net) prices. Higher expected outputs raise consumer surplus, but higher expected prices do not. An interesting result is that when products are not good substitutes, ($t < 2\sqrt{2} - 2$), mandatory disclosure of demand data for Cournot firms enhances both firm profits and consumer surplus.

[33] An example of a requirement that left room for noise is FASB No. 33 on current costs. Since data on replacement costs were not required to be audited, it was easy to add noise. It is interesting to note that very little cost information is disclosed in financial reports in the United States, whereas Japanese firms typically provide manufacturing cost data broken down into categories of material, labor, and overhead.

Clearly, mandatory disclosure leads to a Pareto improvement and is socially desirable in this particular situation.

The assumption that disclosure is noiseless and credible may not be as innocuous as it seems. When private information concerns future prospects, credible disclosure may not be as easily achievable as it is when the information is about past (realized) performance, such as actual sales or total costs. As has been discussed in Okuno-Fujiwara et al. (1990), it may be more difficult to convince others that the disclosure is credible when a firm has unfavorable information. Favorable market demand may be supported by customer orders or well-documented market research data. Favorable cost conditions could be supported by technology specifications, procurement of raw materials at low prices, discovery of new methods, and the like. Unfavorable information, however, might require negative proof of the nonexistence of favorable conditions. To the extent that disclosure of certain types of information is more difficult, it is easier for firms to succeed in withholding this kind of information.

Another assumption, that the administrative cost of disclosure is negligible, permits a focus on a specific type of proprietary costs.[34] Firms are assumed to choose a disclosure strategy to maximize their expected profits, or "intrinsic value," in a duopolistic product market. Disclosure incentives may be made more complex by introducing additional markets, such as a financial market or another product market. Consider a firm that needs financing. Disclosure of favorable information to the financial market may increase firm valuation, but may compromise competitive strategy in a product market. If firms are playing Bertrand/demand or Cournot/cost games however, there are no conflicts. Disclosure does not involve a proprietary cost from competition. A firm with favorable information benefits from disclosure in both markets, while a firm with unfavorable information would try in vain to withhold the information from both markets. Hence, it is clear that full disclosure will ensue.

Conflicts arise in Cournot/demand and Bertrand/cost combinations.[35] In a Cournot game, a firm with information on high demand would want to conceal it to prevent the other firm from increasing output, yet would want to transmit good news to the financial market to increase its valuation. A firm with information on low demand would wish to withhold this information from the financial market, but disclose it to the rival to discourage overproduction. These conflicting motives are completely parallel in Bertrand competition with cost uncertainty. A low-cost firm would not want its rival to know, but would want the financial market to know the information to achieve more favorable financial valuation.

Another example is a duopolist in a product market who also operates in another product market. Action taken by the firm in one market might affect the equilibrium in the other market. Bulow et al. (1985) discuss a model in which disclosure in one market adversely affects the firm's overall profit from the other markets. This result depends on whether products are "strategic substitutes" "or complements" in the two markets.

[34] Administrative costs may not be negligible; they are, nevertheless, not interesting for analysis.

[35] A Cournot/demand case has been analyzed by Darrough and Stoughton (1990) and Wagenhofer (1990) in an entry game, and by Dontoh (1990) in a duopoly. In a duopoly setting, Gigler (1992) relaxes the assumption of truthful disclosure and establishes partition equilibria.

Since the results depend on the specifics of the model developed, it is worthwhile to examine the implications of some of the assumptions made here: (1) that signals received are independent, (2) that products are (imperfect) substitutes, and (3) that there are only two firms. The assumption of independence simplified the analysis and is easy to justify to the extent that the products are differentiated. Nevertheless, it might be unreasonable to assume totally uncorrelated signals (1) if signals are about a common value such as demand or (2) if they are about firm-specific costs but share similar technology and use similar inputs. An alternative scenario is positive correlation. Firms are then able to conjecture their rival's signal better by looking at their own private signals. To this extent, the incentive to share would diminish. At the same time, the benefit from withholding information would also diminish. The net effect is not obvious. Since perfect correlation negates any effects of disclosure, it is likely that the overall effect of disclosure would diminish as correlation increases. My conjecture is that the basic tradeoffs would remain the same.[36] In the *ex post* scenario, however, as correlation increases, there would be less divergence in the firms' preferences. It is possible that firms in an industry may lobby for a particular disclosure policy *ex ante*, then change their position completely once they receive signals that are highly (and positively) correlated.

The assumption that products are substitutes is obviously important. If they are independent, there is no issue of disclosure. If they are complements, firms help each other rather than divide the market. All the results are reversed.[37] Restricting our analysis to a duopoly does not affect the qualitative results. If the number of firms is large, however, other issues may emerge, such as whether a subgroup of firms wants to form a coalition.[38]

Appendix

Proof of Lemma

At the second stage, firm i's best response is to choose Q_i so as to maximize expected profit, $E\Pi_i$, conditioned on the realization of x_i and its conjecture about firm j's signal, given a disclosure (or lack thereof):

$$E\Pi_i = E_{x_j}\{Q_i[a + E(\Delta a) - Q_i - tE(Q_j)]\}. \tag{A1}$$

Since marginal costs are certain, $\sigma_c = n = 0$ and $\Delta c_1 = \Delta c_2 = 0$. To maximixe equation (A1), taking Q_j as given (since the conjectural variation in a Cournot game is zero), the partial derivative of $E\Pi_i$ with respect to Q_i is set to zero.

$$\frac{\partial E\Pi_i}{\partial Q_i} = a + E[\Delta a - btE(Q_j)] - 2Q_i = 0.$$

[36] Gal-Or (1985) examines a Cournot/demand case with a homogeneous good when private signals are correlated. The equilibrium found is again no disclosure, but equilibrium strategies are strictly Nash rather than dominant. Shapiro (1986) also finds that, when costs are uncertain but correlated, disclosure is optimal as long as correlation is positive and less than 1.

[37] See Vives (1984) for an analysis of a Cournot duopoly with demand uncertainty when products can be either substitutes or complements.

[38] See Kirby (1990) and Vives (1990).

The second-order condition is satisfied, since:

$$\frac{\partial^2 E\Pi}{\partial Q_i^2} = -2 < 0.$$

Hence,

$$Q_i = \frac{1}{2b}\{a + E[\Delta a - tE(Q_j)]\}. \tag{A2}$$

The posterior expected value of Δa is:

$$E(\Delta a) = \frac{1}{2}\left(\frac{\sigma}{m+\sigma+s_j}\hat{x}_j + \frac{\sigma}{m+\sigma}x_i\right). \tag{A3}$$

Given the message by firm j of $\hat{x}_j$, firm i updates $E(\Delta a)$ as a weighted average of j's message and its own private signal, with the weights being the precision of the message and the signal. Furthermore, posterior beliefs (conditional expectations) are:

$$E(x_j|\hat{x}_j) = \frac{m+\sigma}{m+\sigma+s_j}\hat{x}_j, \tag{A4}$$

$$E(x_i|\hat{x}_i) = \frac{m+\sigma}{m+\sigma+s_i}\hat{x}_i, \text{ and} \tag{A5}$$

$$E(\Delta a_i|x_i) = \frac{\sigma}{m+\sigma}x_i. \tag{A6}$$

To derive equation (2), one conjectures that Q_j is linear in information variables as:

$$Q_j = A_0^j + A_1^j\hat{x}_i + A_2^j\hat{x}_j + A_3^j x_j \qquad i \neq j = 1, 2. \tag{A7}$$

Substituting equation (A7) into equation (A2), by using posteriors and making sure that Q_i is also linear in $\hat{x}_j$, $\hat{x}_i$ and x_i, yields the coefficients in equation (2). That is:

$$\begin{aligned} Q_i &= \frac{1}{2b}\{a + E(\Delta a) - t[A_0^j + A_1^j\hat{x}_i + A_2^j\hat{x}_j + A_3^j E(x_j|\hat{x}_j)]\}, \\ &= \frac{1}{2b}\left\{a - btA_0^j - btA_1^j\hat{x}_i - \left[tA_2^j + tA_3^j\frac{(m+\sigma)}{m+\sigma+s_j} - \frac{\sigma}{2(m+\sigma+s_i)}\right]\hat{x}_j + \frac{\sigma}{2(m+\sigma)}x_i\right\}, \\ &= A_0^i + A_1^i\hat{x}_j + A_2^i\hat{x}_i + A_3^i x_i. \end{aligned}$$

Solving for symmetrical A_k^i and A_k^j, $k = 0, 1, 2, 3$ obtains equation (2).

Proof of Proposition 1

Given the second-stage quantity choice, expected profit for firm i at the first stage is:

$$\begin{aligned} E\Pi_i &= E_{x_j, x_i}(Q_i^2) \\ &= \frac{1}{(2+t)^2}\left[a^2 + \frac{\sigma^2}{4(m+\sigma+s_j)} - \frac{t(4+t)\sigma^2}{16(m+\sigma+s_i)} + \frac{\sigma^2(2+t)^2}{16(m+\sigma)}\right], \end{aligned} \tag{A8}$$

when using the relations that $E(x_i) = E(x_j) = E(\hat{x}_j) = E(\hat{x}_i) = 0$. Taking the partial derivative of equation (A8) with respect to s_i yields:

$$\frac{\partial E\Pi_i}{\partial s_i} > 0.$$

Proof of Propositions 2 through 4

The derivation of these propositions is analogous to that for Proposition 1. The expected equilibrium profits are listed below for Bertand/demand (Bd), Cournot/cost (Cc), and Bertrand/cost (Bc) cases, respectively:

$$E\Pi_i^{Bd} = \frac{1}{1-t_2} E_{x_j,x_i}(P_i^2)$$

$$= \frac{(1-t)}{(1+t)(2-t)^2}\left[a^2 + \frac{\sigma^2}{m+\sigma+s_j} + \frac{t\sigma^2}{2(m+\sigma+s_i)} + \frac{(2-t)^2\sigma^2}{16(m+\sigma)}\right].$$

$$E\Pi_i^{Cc} = \frac{1}{(2+t)^2}\left[a^2 + \frac{t^2\sigma_c^2}{(2-t)^2(n+\sigma_c+v_j)} + \frac{t^2\sigma_c^2(8-t^2)}{4(2-t)^2(n+\sigma_c+v_i)} + \frac{(2+t)^2\sigma_c^2}{4(n+\sigma)}\right].$$

$$E\Pi_i^{Bc} = \frac{(1-t)}{(1+t)(2-t)^2}\left[a^2 + \frac{t^2\sigma_c^2}{(2+t)^2(1-t)^2(n+\sigma_c+v_j)} - \frac{t^2\sigma_c^2(8-3t^2)}{4(2+t)^2(1-t)^2(n+\sigma_c+v_i)} + \frac{(2-t)^2(\sigma_c+4n)}{4(1-t)^2(n+\sigma_c)}\right].$$

Proof of Proposition 5

The proof follows from the argument in the text.

Proof of Proposition 6

The remaining three cases are discussed here. Preferences are shown by looking at expected equilibrium prices and quantities.

1. *Bertrand/Demand Case.* Without any private signal or a message from firm 1, firm 2 will choose its price as:

$$P_2 = \frac{a(1-t)}{2-t}.$$

With a private signal, x_1, firm 1 chooses its price, if it decides not to send any message, as:

$$P_1^{ND} = \frac{1-t}{2-t}\left[a + \frac{2-t}{2}E(\Delta a|x_1)\right].$$

If it decides to disclose, firm 1's price will be:

$$P_1^D = \frac{1-t}{2-t}\left[a + tE(\Delta a|\hat{x}_1) + \frac{2-t}{2}E(\Delta a|x_1)\right].$$

Thus, $P_1^D \geq P_1^{ND}$ for $x_1 \geq 0$.

2. *Cournot/Cost Case.* Without firm 1's disclosure, firm 2 will choose $Q_2 = a/[b(2+t)]$. Absent disclosure, firm 1 chooses:

$$Q_1^{ND} = \frac{1}{(2+t)}\left[a - \frac{2+t}{2}E(\Delta c|z_1)\right],$$

whereas with disclosure it will produce:

$$Q_1^D = \frac{1}{(2+t)}\left[a - \frac{2+t}{2}E(\Delta c|z_1) - \frac{t^2}{2(2+t)}E(\Delta c|\hat{z}_1)\right].$$

It is clear that $Q_1^D \geq Q_1^{ND}$ for $z_1 \leq 0$.

3. *Bertrand/Cost Case.* Firm 1 chooses its (net) price without disclosure as:

$$P_1^{ND} = \frac{1-t}{2-t}\left[a - \frac{2-t}{1-t}E(\Delta c|z_1)\right],$$

while with disclosure, its price will be:

$$P_1^D = \frac{1-t}{2-t}\left[a + \frac{t^2}{2(2+t)(1-t)}E(\Delta c|\hat{z}_1) - \frac{2-t}{2(1-t)}E(\Delta c|z_1)\right].$$

Thus, $P_1^{ND} \geq P_1^D$ for $z_1 \leq 0$.

Proof of Proposition 7

When $\gamma=1$, the expected profit of firm i is:

$$E\Pi_i=\frac{1}{(2-t)^2(1+t)}\left[a+\frac{t}{(2+t)(1-t)}\bar{z}_j+\frac{t^2}{2(2+t)(1-t)}(\bar{z}_i-z_i)-\frac{2-t^2}{(2+t)(1-t)}z_i\right]^2,$$

which gives,

$$E\Pi_i^{ND}-E\Pi_i^{D}=\frac{t^2}{(4-t^2)(1-t^2)}(\bar{z}_i-z_i)\left[\frac{t^2}{4(2+t)(1-t)}\bar{z}_i-a+\frac{8-3t^2}{4(2+t)(1-t)}z_i\right],$$

where $\bar{z}_i=E(z_i|z_i\in Z_i^{ND})$ and $\bar{z}=0$ (when $\gamma=0$ and $\bar{z}\neq 0$) (when $\gamma=1$). The difference in expected profits is nonpositive in the interval in the proposition. When $\gamma=0$, let $\bar{z}_i=0$ and solve for z_i.

To prove that firms prefer to precommit themselves to nondisclosure in Bertrand with cost uncertainty, let $\pi_i(\gamma)$ be the probability that $x_i\in X_i^{ND}(\gamma)$ for $i\neq j=1,2$. Then expected profit of i under a no-precommitment regime is [multiplied by $b(2-t)^2(1+t)$]:

$$\begin{aligned}E\Pi_i^{NC}=E\Bigg(&\pi_j\left[a+\frac{t}{(2+t)(1-t)}\bar{z}_j-\frac{2-t^2}{(2+t)(1-t)}z_i\right]^2\\&+(1-\pi_j)E_{z_j}\left\{\left[a+\frac{t}{(2+t)(1-t)}\bar{z}_j-\frac{2-t^2}{(2+t)(1-t)}z_i\right]^2|z_j\in Z_j^{D}\right\}\Bigg)\\&+\pi_i\frac{8-3t^4}{4(2+t)^2(1-t)^2}\mathrm{Var}(z_i\,|\,z_i\in Z_j^{ND}).\end{aligned}$$

whereas expected profit under a precommitment (to no disclosure) regime is:

$$E\Pi_i^{C}=E\left\{\left[a-\frac{2-t^2}{(2+t)(1-t)}z_i\right]^2\right\}+\frac{8-3t^4}{4(2+t)^2(1-t)^2}\sigma_c^2.$$

This implies

$$\begin{aligned}E\Pi_i^{C}\geq E\Pi_i^{NC}\Leftrightarrow&\frac{8-3t^4}{4(2+t)^2(1-t)^2}[\sigma_c^2-\pi_i\mathrm{Var}(z_i|z_i\in Z_i^{ND})]\\&\geq\frac{t^2}{(2+t)^2(1-t)^2}[\sigma_c^2-\pi_j\mathrm{Var}(z_j\,|\,z_j\in Z_j^{ND})],\\&=\frac{t^2}{(2+t)^2(1-t)^2}[\sigma_c^2-\pi_i\mathrm{Var}(z_i|z_i\in Z_i^{ND})],\end{aligned}$$

where the last equality follows from symmetry. This boils down to a condition $8-3t^4\geq 4t^2$, which holds for any value of $0\leq t\leq 1$.

References

Bulow, J. I., J. D. Geanakoplos, and P. D. Klemperer. 1985. Multimarket oligopoly: Strategic substitutes and complements. *Journal of Political Economy* 93: 488–511.

Clarke, R. N. 1983. Collusion and incentives for information sharing. *Bell Journal of Economics* 14 (Autumn): 383–94.

Clinch, G., and R. E. Verrecchia. 1991. Information sharing in oligopoly with no precommitment. Working paper, Wharton School, University of Pennsylvania.

Darrough, M. N., and N. M. Stoughton. 1990. Financial disclosure policy in an entry game. *Journal of Accounting & Economics* 12 (January): 219–43.

Dontoh, A 1990. Voluntary disclosure. *Journal of Accounting, Auditing & Finance* 4 (Fall): 480–511.

Dye, R. 1986. Proprietary and nonproprietary disclosures. *Journal of Business* 59: 331–66.

Feltham, G. A., and J. Z. Xie. 1992. Voluntary financial disclosure in an entry game with continua of types. *Contemporary Accounting Research* 9 (Fall): 46–80.
———, F. B. Gigler, and J. S. Hughes. 1992. The effects of line of business reporting on competition in oligopoly setting. *Contemporary Accounting Research* 9 (Fall): 1–23.
Foster, G. 1986. Financial Statement Analysis. Englewood Cliffs, NJ: Prentice-Hall.
Frank, R. H. 1991. *Microeconomics and Behavior*. New York: McGraw-Hill.
Fried, D. 1984. Incentives for information production and disclosure in a duopolistic environment. *Quarterly Journal of Economics* 99 (May): 367–81.
Gal-Or, E. 1985. Information sharing in oligopoly. *Econometrica* 53 (March): 329–43.
———. 1986. Information transmission—Cournot and Bertrand equilibria. *Review of Economic Studies* 53: 85–92.
Gertner, R., R. Gibbons, and D. Sharfstein. 1988. Simultaneous signalling to the capital and product markets. *Rand Journal of Economics* 19: 173–90.
Gigler, F. B. 1992. Self-enforcing public disclosures. Working paper, University of Chicago.
Grossman, S. 1981. The information role of warranties private disclosure about product quality. *Journal of Law and Economics* 24: 461–83.
Hughes, J. S., and J. Kao. 1991. Economic implication of alternative accounting rules for research and development costs. *Contemporary Accounting Research* 8 (Fall): 152–69.
Jung, W. O., and Y. K. Kwon. 1988. Disclosures when the market is unsure of information endowment of managers. *Journal of Accounting Research* 26: 146–53.
Kirby, A. 1988. Trade associations as information exchange mechanisms. *Rand Journal of Economics* 19 (Spring): 138–46.
———. 1990. Optimal information exchange. Working paper, University of California, Berkeley.
Klemperer, P., and M. Meyer. 1986. Price competition vs. quantity competition: The role of uncertainty. *Rand Journal of Economics* 17 (Winter): 618–38.
Milgrom, P. 1981. Good news and bad news: Representation theorems and application. *Bell Journal of Economics* 12: 380–91.
Novshek, W., and H. Sonnenschein. 1982. Fulfilled expectations Cournot duopoly with information acquisition and release. *Bell Journal of Economics* 13: 214–18.
Okuno-Fujiwara, M., A. Postlewaite, and K. Suzumura. 1990. Strategic information revelation. *Review of Economic Studies* 57: 25–47.
Sankar, M. 1992. Corporate voluntary disclosure of predecision information. Ph.D. dissertation. University of British Columbia, Vancouver.
Shapiro, C. 1986. Exchange of cost information in oligopoly. *Review of Economic Studies* 53: 433–46.
Verrecchia, R. 1983. Discretionary disclosure. *Journal of Accounting & Economics* 5 (December): 179–94.
———. 1990a. Endogenous proprietary costs through firm interdependence. *Journal of Accounting & Economics* 12 (January): 245–50.
———. 1990b. Information quality and discretionary disclosure. *Journal of Accounting & Economics 12* (March): 365–80.
Vives, X. 1984. Duopoly information equilibrium: Cournot and Bertrand. *Journal of Economic Theory* 34: 71–94.
———. 1990. Trade association disclosure rules, incentives to share information, and welfare. *Rand Journal of Economics* 21 (Autumn): 409-30.
Wagenhofer, A. 1990. Voluntary disclosure with a strategic opponent. *Journal of Accounting & Economics* 12 (March): 341–63.