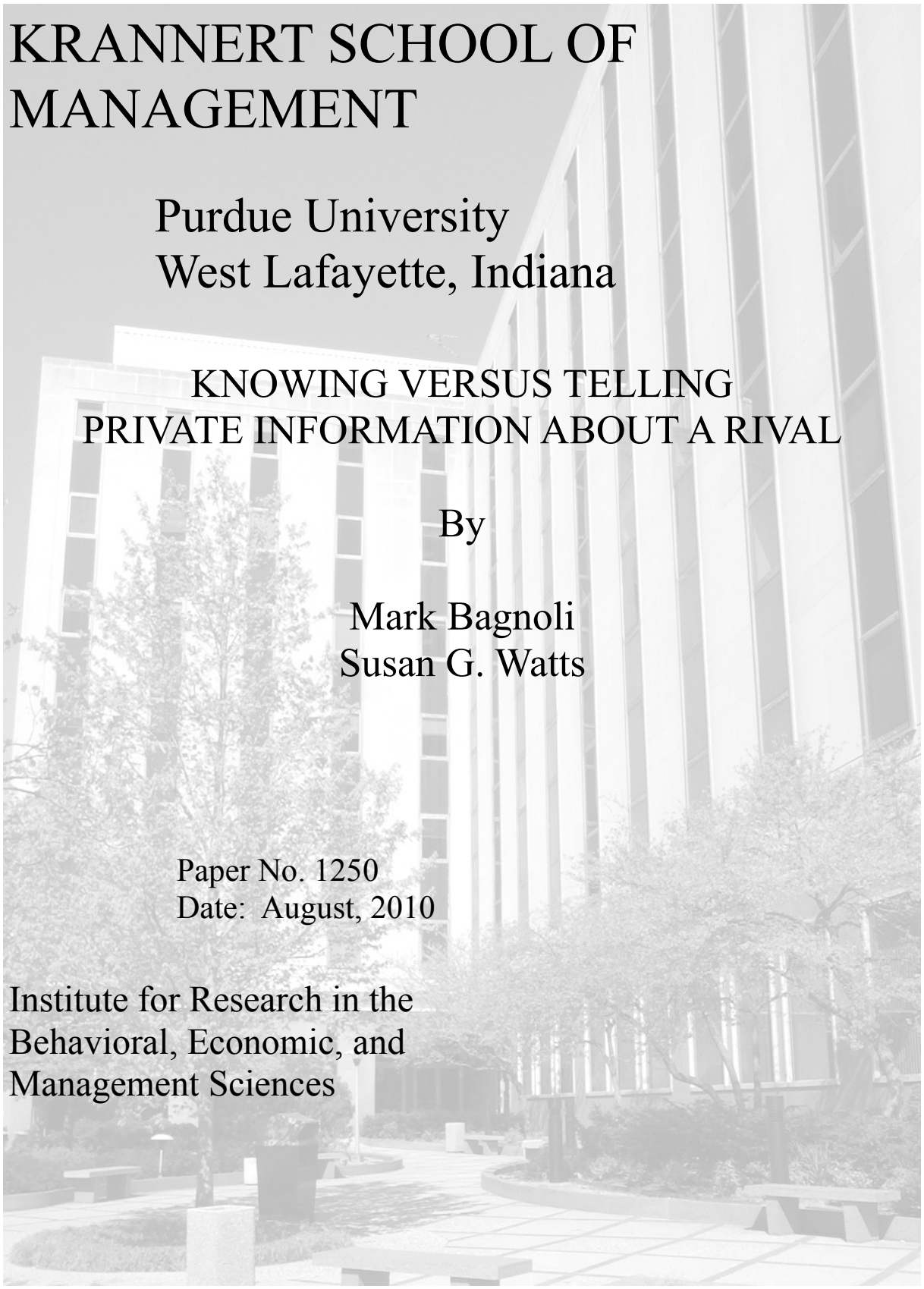

KRANNERT SCHOOL OF MANAGEMENT

Purdue University
West Lafayette, Indiana

KNOWING VERSUS TELLING PRIVATE INFORMATION ABOUT A RIVAL

By

Mark Bagnoli
Susan G. Watts

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Mark Bagnoli
and
Susan G. Watts

Krannert Graduate School of Management
Purdue University
West Lafayette, IN 47907

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Abstract: As part of a broad competitive intelligence strategy, firms expect to acquire information about their rivals' customers and production processes. In this study, we examine the firms' incentives to disclose this information. We find that firms adopt a policy of disclosing their information regardless of whether it concerns a rival's customers or production costs or whether the firms are Cournot or Bertrand competitors. Firms that have private information about their rivals tell. Their willingness to disclose private information about their rivals contrasts with the results in the literature when the firm has information about itself. This literature shows that the chosen disclosure policy depends on whether information is about the firm's own payoffs or industry demand and whether the firms' strategies are substitutes or complements.

Keywords: disclosure policy, voluntary disclosure, asymmetric information, Cournot competition, Bertrand competition

JEL Classification Codes: G1, G14, M41

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1. Introduction.

The burgeoning field of competitive intelligence (CI) is specifically focused on developing information and insight about a firm's rivals (Prescott and Miller 2001, Carr 2003, Fuld 2006, Liebowitz 2006, Fleisher and Bensoussan 2007). While much of the focus of CI is on learning and analyzing the rivals' business strategies, significant effort is expended studying the rivals' customers and production processes.

In this study, we seek to understand the firm's incentives to disclose the private information it has about its rivals. Prior literature has examined a firm's optimal disclosure policy when the firm has private information about *its own* customers or production costs.[1] In the most general analysis, Raith [1996] finds that the decision to adopt a policy of disclosure depends on whether the firms have private information that is exclusively about their own demand or costs (the private or independent values case) or exclusively about industry demand (the common values case) and whether the firm's strategies are substitutes or complements.[2] In the more familiar case, the firms adopt a policy of disclosure if they are Cournot competitors and have private information about their own production costs or are Bertrand competitors with private information about industry demand (Darrough 1993).

In contrast, our analysis of firms that have private information about their rival's customers or production costs indicates that they adopt a policy of disclosing this information regardless of whether their strategies are substitutes or complements (whether they compete as Bertrand or Cournot rivals): Firms that have private information about their rival tell. Intuitively, the difference between our results and those in the prior literature arise because in our model, disclosure decisions depend only on strategic motives. Thus, the firm's decision depends on the effect of disclosure on its rival's output or price (in expectation) and whether the effect is valuable to the disclosing firm. In the prior literature, the disclosure is about the firm's own customers or costs

[1] This is an extensive literature that examines incentives to adopt a policy of disclosing the firm's private information prior to learning it (in contrast to the segment of the disclosure literature that examines *ex post* disclosure). The key studies in the *ex ante* disclosure literature include Gal-Or [1985, 1986], Darrough [1993] and Raith [1996]. A nice survey is provided by Vives [2008]. Some recent contributions include Maleug and Tsutsui [1996] who examine *ex ante* disclosure when the firms receive signals about the slope of the market demand curve, Arya and Mittendorf [2007] who examine the effect of third party information provides on *ex ante* disclosure policy choices and Currarini and Feri [2007] who examine *ex ante* disclosure among subsets of rivals.

[2] The strategic substitutes case arises when a firm's best reply is decreasing in its rival's action (as, for example, in Cournot competition) and the strategic complements case arises when a firm's best reply is increasing in its rival's action (as, for example, in Bertrand competition). See Bulow, Geanakoplos and Klemperer [1985] for details.

and is thus directly payoff relevant to the disclosing firm. As a result, it has both an information value as well as a strategic value if disclosed. That is, the disclosing firm tailors its quantity or product price choice to this private information regardless of whether it is disclosed and, more importantly, the rival understands this.[3]

We also show that our results extend to the case when the firm is uncertain as to whether its information about its rival is, in fact, private. That is, even if there is only a chance that the firm's knowledge about its rival's customers or costs is private, it optimally adopts a policy of disclosing the information. Intuitively, even if there is only a chance that the disclosure provides the strategic benefits described above, it is worthwhile for the firm to adopt a policy of disclosure in an attempt to capture these benefits if they turn out to be available. This result is reflected in disclosure policies we observe in practice. For example, Progressive Insurance is famous for its analysis of the insurance risks posed by both its own and its rivals' customers—and for providing access to this analysis on its website by disclosing its own and some rivals' quotes for different customer profiles (Davenport and Harris 2007). Pharmaceutical companies regularly provide information on the efficacy of a drug or class of drugs that its rivals may be studying in presentations at scientific and/or professional conferences (Prescott and Miller 2001, Carr 2003, Fuld 2006, Liebowitz 2006, Fleisher and Bensoussan 2007). Similarly, oil companies often publicly discuss/disclose seismic information that relates to drilling costs in a particular location that a rival is beginning to explore or in fields where the firm and its rivals are drilling (Bower 2009). More recently, AT&T publicly discussed how smart phone usage strains data networks just as Verizon introduced the first high–end mobile phone powered by Google's Android operating system.

We should also note that CI practitioners are encouraged to sift through financial disclosures (both mandatory and voluntary) of their firm's rivals and to attend conferences where rivals are presenting (Prescott and Miller 2001, Carr 2003, Fuld 2006, Liebowitz 2006, Fleisher and Bensoussan 2007). These activities of CI professionals offer the rival a simple means to communicate any information it may have gathered about the firm. Thus, our results suggest that information about a firm's customers or costs may be found in the mandatory and voluntary disclosures of its rivals. They also suggest that regulators need not be overly concerned about the need to substitute mandatory for voluntary disclosure of this type of information.

[3] More formally, if the firm has private information about its own customers or production costs, it can tailor its choice of output or price to this information. This makes the payoff from not disclosing larger than if the firm has private information about its rival which does not directly affect the firm's own payoffs.

Our results also have implications for the information transfer literature. This literature focuses on changes in rival firms' stock prices following announcements by a competitor (Baginski 1987, Pownall and Waymire 1989, Ramnath 2002, Gleason, Jenkins and Johnson 2008 or Kim, Lacina and Park 2008). Whether the announcement is an earnings announcement, management guidance, a restatement or some other type of financial disclosure, the idea is that if one firm reports its financial performance, that information can be used to make inferences about its rivals' financial performance. Our results suggest that in some of its disclosures, a firm may also be offering information that is directly relevant to understanding its rivals' performance—inferences may not be needed. If so, then distinguishing the different information channels may allow for a clearer understanding of any information externalities associated with financial disclosures.

Finally, to complete our analysis, we consider a firm making a disclosure choice after learning private information about its rival as opposed to making the choice *ex ante*. We find that the standard results obtain. If there are no costs to disclosure, the unique equilibrium has the firm disclosing its private information about its rival's customers or production costs regardless of the realization of that information. That is, we get the standard unraveling result (Grossman 1981, Milgrom 1981). However, if there is a cost to disclosure as in Verrecchia [1983], we find that the firm only discloses its private information if it is sufficiently good news for the disclosing firm. Interestingly, whether this disclosure is good or bad news for the rival depends on both whether the firm has private information about the rival's customers or production costs and whether the firms are Bertrand or Cournot competitors. Lastly, we show that the probability of of a voluntary disclosure depends on both whether the rival discloses and on how close substitutes the products the firms make are. Thus, our analysis suggests a new reason why there is likely to be industry clustering of voluntary disclosures and offers a new prediction that such disclosures are more likely in industries where firms sell more similar products and less likely in those industries that use differentiation strategies.

Although our analysis is most closely related to the literature on voluntary disclosure policy choice, it also complements a related literature on mandatory disclosures and earnings management. These studies endogenize the benefits of biased mandatory disclosures by examining their effects on the capital market's estimate of firm value (Fischer and Verrecchia 2000, Fischer and Stocken 2004, Stocken and Verrecchia 2004), on competition in the firm's product market (Fischer and Verrecchia 2004, Bagnoli and Watts 2010), or on contracting with the firm's manager (Arya,

Glover and Sunder 1998). Our work complements this literature by endogenizing the benefits from voluntary disclosure of private information about a rival by examining the effects of such voluntary disclosures on product market competition. Our finding that firms with this type of private information tell suggests, as mentioned above, that there is likely no need to make such disclosures mandatory. Further, even though there would be a similar short–term incentive to bias these types of disclosures as well, the fact that the disclosed information would eventually become known to the rival at a future date suggests that the arguments in Stocken [2000] could be used to show that it is unlikely that issues of bias would plague these types of disclosures.

The remainder of the study is organized as follows. Section 2 contains a description of our model of disclosure policy and describes the equilibrium policy choices. In Section 3, we extend the analysis to examine the effect of firms making disclosure choices after learning their private information about their rival, and we conclude in Section 4.

2. Model

There are a variety of situations in which a firm has private information about its rival, and these are frequently the result of specific competitive intelligence (CI) activities designed to develop intelligence about the firm's rivals. Our objective is to extend our understanding of a company's willingness to disclose private information to the case when the firm has private information about a competitor. Prior work (Gal–Or 1985, 1986, Darrough 1993, Raith 1996, summarized in Vives 2008) focuses on a company's willingness to disclose private information about itself (the so–called private or independent values case) or information that affects the payoffs of both firms (the so–called common values case). In addition to showing that the firms' disclosure policy adoption decisions depend on which type of private information the firm has, this literature also shows that the decision depends on whether the firms' strategies are substitutes or complements (generally whether the firms are Cournot or Bertrand competitors). In both the independent and common values cases, the strategic reasons for disclosure—affecting the rival's behavior in the product market—are obscured by the information effects of the disclosure. That is, the disclosure reveals value–relevant information about the firm as well as affecting the strategic choices of the firm's rival.

Our information structure fits neither the independent nor common values structure previously studied. Instead, we focus on the disclosure of private information about a rival's customers

or production costs.[4] In addition to examining the disclosure of an important type of private information, our analysis allows us to focus on strategic motives for adopting a disclosure policy separately from the information effect of the policy. That is, in the prior literature, if the firm adopts a policy of disclosure, there are strategic effects in that the disclosure alters how the firm's rival competes in the product market. There is also an information effect—the disclosing firm reveals payoff–relevant information about itself. With our information structure, if the firm discloses its private information, it provides payoff–relevant information about its rival to its rival, and this allows us to focus on the strategic motives behind the disclosure policy choice.

To highlight the importance of having private information about a rival on the choice of disclosure policy, we employ virtually the same structure for our model as used when the independent and common values cases are analyzed. In particular, we assume that there are two firms that choose a disclosure policy prior to acquiring their private information. Subsequently, they follow their chosen disclosure policy and then compete in the product market. See Figure 1 for a time line summarizing the order of events in our model. As is standard, we will analyze two versions of competition in the product market—one in which the firms are Cournot competitors and one in which they are Bertrand competitors.

More formally, let $d_i \in \{D, N\}$ represent the chosen disclosure policy where D (N) represents the choice to commit to disclose (not disclose). Each firm makes its disclosure choice without knowing the choice of its rival. Subsequently, the firms acquire their private information and then follow their chosen disclosure policies. Everything except the firms' private information is common knowledge. As a result, there are (potentially) two sources of information available to each firm. First, each firm is endowed with private information. Second, each firm may have its private information augmented by the information disclosure of its rival. We assume that, if made, the disclosure is truthful.[5] Thus, the information used when the firms compete depends on their prior choices of disclosure policy. Finally, the two firms compete in their product market by selling

[4] Private information about a rival's customers or production costs differs from the independent values case because the firm's private information is not directly payoff–relevant to the firm—if disclosed, it only has a strategic value. Similarly, it differs from the common values case because the private information does not provide a better understanding of a payoff–relevant parameter that affects *both* firms' payoffs directly.

[5] When the firm's private information is about its own customers or costs, the assumption that the disclosure is truthful is potentially problematic. In our setting, it is less troubling because it is reasonable to assume that the rival will eventually learn the information that pertains to its customers or costs that is currently only known by the firm choosing whether or not to disclose. In this case, because the information is eventually acquired, arguments in Stocken [2000] can be used to support an equilibrium in which the firms disclose truthfully if they disclose at all.

heterogeneous products. The demands for their products are:[6]

$$p_i = a_i - q_i - tq_j \qquad i = 1, 2; \quad j \neq i, \tag{1}$$

with $1 > t > 0$ to reflect the fact that the firms sell products consumers view as substitutes.[7] We also assume that each firm has constant marginal costs of production c_i and no fixed costs. Each firm competes by choosing an amount to sell (Cournot competition) or a price to charge (Bertrand competition) and each seeks to maximize expected profits conditional on their information.

The above structure is the standard one used in this literature (*e.g.*, Gal–Or 1985, 1986, Darrough 1993, Raith 1996) but our information environment is different.[8] To highlight the difference, we make the extreme assumption that firm i knows a_j and/or c_j and that firm j does not know those values unless disclosed by firm i. Assuming that firm j knows nothing about the intercept of its demand and/or marginal costs while its rival is fully informed about them is extreme and done solely to highlight the *strategic* issues of disclosure commitments. If either firm had private information about its own demand or cost structure, the strategic reasons for committing to disclosure or not would be obscured by the direct information effects of their private information (and its impact on their disclosure policy choices). We should also note that any additional, common knowledge components of the intercept or cost terms would not affect our analysis of the firms' disclosure policy choices. That is, our results would be completely unaffected by assuming that there was a common knowledge term in the firm's intercept $a_j + \alpha_j$ or costs $c_j + \kappa_j$ where α_j and κ_j are common knowledge and so we suppress them purely for notational simplicity.

Prior to learning their private information, the firms have common priors. That is, both believe that the variables are drawn from known distributions with finite means and variances. Again to highlight the effects of disclosures of private information about a rival, we further assume that all four variables (a_1, a_2, c_1 and c_2) are independent. In particular, this implies that firm i's private information is independent of firm j's private information—the distribution of a_i given

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[6] These demands can be readily derived following the analysis in Vives [1984].

[7] Products are substitutes if an increase in the amount sold by one firm reduces the amount sold by the other. Note that this concept differs from the idea of strategic substitutes or complements mentioned previously. The firms' decisions are strategic substitutes (complements) if a firm's best reply is increasing (decreasing) in the rival's decision. Thus, the idea of strategic substitutes and complements focuses on the strategic interaction between firms as opposed to consumers' perceptions of the products.

[8] To support the difference in information structures, we have generalized the demand functions for the firms' products to permit the firms to face different demand intercepts.

(a_j, c_j) and the distribution of c_i given (a_j, c_j) are both independent of (a_j, c_j).[9] To avoid problems with corner solutions, we assume that the smallest value of the intercept parameter for each firm exceeds the largest value that firm's marginal costs can take on.[10]

Given this structure, we turn to solving the model. As usual, we begin by solving the second–stage of the game, when the firms compete in the product market. In Section 2.1, we assume that the firms compete by choosing quantities (Cournot competition), and then in Section 2.2 we assume that they compete by choosing prices (Bertrand competition). In both cases, we examine the effect of having private information about the rival's cost and demand parameters. Our objective is to allow for a comparison to the prior literature which shows that the decision to commit to disclose depends on both the form of competition in the product market (Cournot or Bertrand) and on whether the firms have private information about their own demand or cost parameters.

2.1 Cournot Competition

Under Cournot competition, each firm chooses its profit–maximizing quantity after learning its private information and any information disclosed by its rival and after following the disclosure strategy it chose prior to learning its private information. Thus, its decisions depend on its own private information (what it knows about its rival: a_j or c_j), the disclosure strategy chosen by its rival, d_j, the information that the rival's strategy requires disclosing, and its own disclosure strategy, d_i. As a result, there are sixteen possible information sets for firm i which we will represent by ϕ_i.[11]

Thus, firm i solves $\max_{q_i} \mathrm{E}[(a_i - q_i - tq_j - c_i)q_i \mid \phi_i]$ which yields the first order condition $q_i = (1/2)\mathrm{E}[(a_i - tq_j - c_i) \mid \phi_i]$. The usual calculations yield the following Proposition that describes equilibrium quantity choices and profits in the second stage of our game.

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[9] These distributional assumptions differ from those made in the prior literature (*i.e.*, the random variables are normally distributed) and are made to simplify the analysis.

[10] Formally, we assume that $a_i \in [a_i^\ell, a_i^h]$ and $c_i \in [c_i^\ell, c_i^h]$ with $c_i^h < a_i^\ell$ for $i = 1, 2$.

[11] The sixteen possible information sets are found by crossing the alternative private information combinations $\{(a_j, a_i), (a_j, c_i), (c_j, a_i), (c_j, c_i)\}$ with the different combinations of disclosure strategies the firms chose prior to learning their private information $\{(D, D), (D, N), (N, D), (N, N)\}$.

Proposition 1: *If the firms are Cournot competitors, equilibrium quantities are*

$$q_i(D,D) = \frac{1}{(4-t^2)}\left[2a_i - ta_j - 2c_i + tc_j\right]$$
$$q_i(D,N) = \frac{1}{(4-t^2)}\left[2\mathrm{E}[a_i \mid \phi_i] - ta_j - 2\mathrm{E}[c_i \mid \phi_i] + tc_j\right]$$
$$q_i(N,D) = \frac{1}{(4-t^2)}\left[2a_i - t\mathrm{E}[a_j \mid \phi_j] - 2c_i + t\mathrm{E}[c_j \mid \phi_j]\right]$$
$$q_i(N,N) = \frac{1}{(4-t^2)}\left[2\mathrm{E}[a_i] - t\mathrm{E}[a_j] - 2\mathrm{E}[c_i] + t\mathrm{E}[c_j]\right]$$

and equilibrium profits in this stage of the game are $\pi_i^C(d_i,d_j) = [q_i(d_i,d_j)]^2$ *for* $i = 1,2; j \neq i$.

The equilibrium quantities described in Proposition 1 highlight the importance of the difference in our information structure relative to that used in the prior literature on disclosure policy choices. The only results that are the same in our model and the prior literature occur when both firms have committed to disclose because in this case, both firms become fully informed regardless of whether their private information is about their own or their rival's demand or costs. In the remaining cases, the equilibrium quantities differ from the prior literature because of the information structure that we consider. To see why, note that in our analysis, a firm only becomes perfectly informed about its own demand (cost) parameter from its rival's disclosure policy. If the firm's rival chooses not to disclose, the firm does not know its own demand (cost) parameter and thus cannot tailor its sales to the particular realization.

This is seen most clearly when neither firm commits to disclose. In this case, neither has *usable* payoff– or strategic–relevant information. To see why, note that because each firm's private information is about its rival's demand or cost parameters, without disclosure, the rival does not know these values and therefore cannot tailor its sales to the particular realizations. Since each firm knows this, it knows that its rival's quantity will not depend on these parameters, and therefore its own quantity won't depend on them either. As a result, each firm knows that its rival will make its output decision using only its priors. This differs from the results when a firm has private information about its own demand or costs because that information would be used by the firm to tailor its output choice to the particular realizations even when the decision to not disclose eliminates the strategic effects of the disclosure.

Proposition 1 also highlights a key difference from the prior literature that will be important when we consider the firms' disclosure policy decisions. In particular, the information and strategic

impacts of disclosure differ. In the standard version where the firm has private information about its own demand or costs, that information is useful independent of the disclosure decision because the firm has the ability to tailor its quantity choice to its own private information. In addition to this direct benefit, there is also a strategic effect associated with the disclosure of the firm's private information. If the firm discloses its private information, it informs its rival about its own payoffs and about how it will respond to changes in the rival's quantity choice. The important point is that the consequences of the strategic effects are measured relative to the quantity choice that the firm tailors to its private information.

In our case, the private information is not inherently useful independent of the disclosure decision: There is only a strategic effect associated with the disclosure. The firm cannot directly use its private information about its rival's customers or costs because the information doesn't directly affect the disclosing firm's payoffs. Instead, all benefits and costs from disclosure flow through the effects on the rival's quantity choice from being able to tailor that choice to the information provided by the disclosing firm.

2.2 Bertrand Competition

To compare equilibrium disclosure policies when firms are Bertrand rather than Cournot competitors, we now assume that the firms compete in the product market by choosing prices. To keep the comparison as clear as possible, we maintain the information structure, and all of the alternative prior disclosure decision possibilities are the same. The only difference is that each firm chooses its profit–maximizing price rather than its profit–maximizing quantity.

We begin by inverting the demand curves, equations (1), to obtain

$$q_i = \xi\big(a_i - ta_j - p_i + tp_j\big) \qquad i = 1, 2; \quad j \neq i, \tag{2}$$

where $\xi \equiv 1/(1 - t^2)$. The form of these demand curves highlights an issue that needs to be addressed. The descriptions of market demands contained in equations (1) differ from the descriptions in equations (2) because the intercepts in the latter depend on both a_i and a_j. This difference arises because, under Bertrand competition, when one firm lowers its product's price, sales rise for two reasons. First, the price reduction leads to new consumers entering the market and buying the firm's product. Second, the price reduction causes some consumers who were choosing to buy the rival's product to switch and buy this firm's product. Under Cournot competition, added sales only

arise from the first source—a firm that increases sales does so only by attracting new customers into the market and not by "stealing away" some of its rival's customers.

Unfortunately, this difference means that a firm's private information about a_j is no longer solely about its rival's customers. To continue to allow us to focus on the case when there is only a strategic value to disclosure without eliminating the linkage between the demand structures, we introduce an additional parameter to the demand functions, m, in equations (2) which can take on the values of one and zero. This will allow us to consider both the case when there is only strategic value to disclosure ($m = 0$) and the case when the demand functions are exactly the inverse of those used when we examined Cournot competition ($m = 1$).[12] Thus, we adjust equations (2) to become:

$$(2a) \qquad q_i = \xi\big(a_i - mta_j - p_i + tp_j\big) \qquad i = 1, 2; \quad j \neq i,$$

where, again, $\xi \equiv 1/(1 - t^2)$.

As a result, firm i solves $\max_{p_i} \mathrm{E}[\xi\big(a_i - mta_j - p_i + tp_j\big)(p_i - c_i) \mid \phi_i]$ which yields the first order condition $p_i = \frac{1}{2\xi}\mathrm{E}[(a_i - mta_j + tp_j + \xi c_i) \mid \phi_i]$. Again, we rely on the firm's information, ϕ_i, to distinguish the alternative cases and the usual calculations yield the following Proposition.

Proposition 2: *If the firms are Bertrand competitors, equilibrium prices are*

$$\begin{aligned}
p_i(D, D) &= \frac{1}{(4 - t^2)}\big[(2 - mt^2)a_i + t(1 - 2m)a_j + 2c_i + tc_j\big] \\
p_i(D, N) &= \frac{1}{(4 - t^2)}\big[(2 - mt^2)\mathrm{E}[a_i \mid \phi_i] + t(1 - 2m)a_j + 2\mathrm{E}[c_i \mid \phi_i] + tc_j\big] \\
p_i(N, D) &= \frac{1}{(4 - t^2)}\Big[(2 - mt^2)a_i + (t/2)((4 - t^2)ma_j \\
&\qquad + (2 - mt)\mathrm{E}[a_j \mid \phi_j]) + 2c_i + t\mathrm{E}[c_j \mid \phi_j]\Big] \\
p_i(N, N) &= \frac{1}{(4 - t^2)}\big[(2 - mt^2)\mathrm{E}[a_i] - (t/2)((4 - t^2)ma_j \\
&\qquad - (2 - mt^2)\mathrm{E}[a_j]) + 2E[c_i] + t\mathrm{E}[c_j]\big]
\end{aligned}$$

and equilibrium profits in this stage of the game are $\pi_i^B(d_i, d_j) = (\frac{1}{\xi})\big(p_i(d_i, d_j) - \mathrm{E}[c_i \mid \phi_i]\big)^2$ *for* $i = 1, 2; j \neq i$.

[12] Note that assuming that $m = 0$ does not change the fact that the firms' strategies are complements when the compete on price.

As before, differences between our results and the prior literature arise when there are differences in the information the firms have when choosing prices. In particular, when the demand intercepts depend on both firms' private information ($m = 1$), we are essentially in the common values case examined previously and obtain similar results.[13] In contrast, when the firms only have strategic reasons for disclosure (their private information is purely about their rival's customers or costs, $m = 0$), differences arise except when both firms have chosen to disclose their private information. As in the Cournot case, if they both disclose, then both firms have complete information about the market and the two firms' costs and so the results are (essentially) the same as in the prior literature.

However, when one or both firms choose not to disclose their private information, differences in equilibrium prices arise. Similar to the Cournot case, the reason is that when firms have private information about their rival, there is only a strategic value to disclosure. The firm's private information is not directly payoff–relevant. This is most apparent when one considers $p_i(N, N)$ which depends on neither firm's private information. If neither has chosen to disclose its private information, neither provides its rival with payoff–relevant information and so the rival's action (price) cannot depend on the non–disclosed information. Since the rival's action doesn't depend on the firm's private information and the firm's payoff doesn't directly depend on its private information, the firm's action (price) doesn't depend on the information either. Thus, equilibrium price choices obtained under our information structure when $m = 0$ differ from equilibrium prices obtained under the information structure used in the prior literature.

Having determined equilibrium quantities or prices in the second stage of the game, we turn to the first stage and examine under what conditions the firms choose to commit to disclose.

2.3 Disclosure Choices

The equilibrium quantities and prices described in Propositions 1 and 2 describe equilibrium behavior conditional on the firms having learned their private information and conditional on following the alternative disclosure policy choices that they may have made. To determine the conditions under which the firms voluntarily commit to disclose their private information once they learn it, we must examine their *ex ante* disclosure incentives.[14] Because we use the equilibrium

[13] Again, we note that the only differences arise because we generalize the demand structure to allow the two firms to face demands with different intercepts.

[14] In the extensions section, we discuss voluntary disclosure choices when they are made after the firm learns its

choices described in Propositions 1 and 2, we can describe the subgame perfect Nash equilibrium of our two–stage game as the equilibrium of the associated normal form game whose payoffs are the expected profits computed for each commitment decision.[15]

		Firm 2	
		D	N
Firm 1	D	$\mathrm{E}[\pi_1^k(D,D)], \mathrm{E}[\pi_2^k(D,D)]$	$\mathrm{E}[\pi_1^k(D,N)], \mathrm{E}[\pi_2^k(N,D)]$
	N	$\mathrm{E}[\pi_1^k(N,D)], \mathrm{E}[\pi_2^k(D,N)]$	$\mathrm{E}[\pi_1^k(N,N)], \mathrm{E}[\pi_2^k(N,N)]$

Comparisons of expected profits will depend on the *ex ante* variance of the demand or cost parameters because profits are proportional to the square of sales (Proposition 1) or the square of the firm's mark–up (Proposition 2). This is why we needed to assume that the random variables had finite variances. Given this, the main result of our analysis is presented in Theorem 1.

Theorem 1: (a) *When the firms' private information is purely about its rival ($m = 0$), then regardless of whether the firms have private information about demand or costs, and regardless of whether they are Bertrand or Cournot competitors, in the unique equilibrium, both firms adopt the policy of disclosing their private information.*

(b) *When $m = 1$, the firm's private information is about its rival's market demand and the firms are Bertrand competitors, in the unique equilibrium, neither firm adopts the policy of disclosing its private information.*

Theorem 1 highlights the importance of the information structure to the firms' equilibrium disclosure policy choices. In particular, prior literature (Gal-Or 1985, 1986, Darrough 1993, Raith 1996, Vives 2008) informs us that when firms have private information about their own payoffs, their disclosure policy choice depends on whether they have private information about their customers or their costs and whether they compete by choosing prices or quantities. Darrough [1993] shows that firms opt to disclose if they have private information about their own costs and are Cournot competitors or if they have private information about their own customers and are Bertrand competitors. They opt to not disclose if they have private information about their own costs and are Bertrand competitors or private information about their own customers and are

private information.

[15] We use $k = C, B$ to designate whether the firms are Cournot or Bertrand competitors.

Cournot competitors.[16] In contrast, in our model, each firm has payoff–relevant information about its rival and, so long as the information is solely about its rival's payoffs, the unique equilibrium involves each firm adopting the policy of disclosing its private information. While having information that is payoff–relevant to the firm's rival is a key feature of the common values set–up, our setting differs from the common values setting because, in our setting, the private information is not directly payoff–relevant to the firm itself.

The difference in results has three important implications. First, for policy makers who are concerned about the need to substitute mandatory for voluntary disclosure, the suggested trade–off between the benefits of disclosure and the costs associated with being placed at a competitive disadvantage relative to one's rivals seems to be unimportant when considering disclosure of private information about one's rival. That is, while prior literature has shown that there are cases in which regulators desiring disclosure are likely to have to intervene, for example, in the details of the information included in the firm's MD&A, intervention is not required if the firm has private information about its rival. The firm will voluntarily commit to providing this information to the market.

A consequence of this is that our analysis offers an additional explanation for information transfers—changes in rival firms' stock prices following an announcement by a competitor.[17] The literature that studies this phenomenon basically takes the view that disclosures by a firm about its financial performance can be used by the market to make inferences about the financial performance of the firm's rivals. Our results suggest the possibility that the disclosing firm is also directly providing information about the financial performance of its rivals. As a result, it may be useful to analyze the two disclosure channels separately to attain a clearer understanding of the information externalities associated with financial disclosures.

Second, our analysis suggests that many of the issues believed to be central to the firm's decision to adopt a disclosure policy are specific to disclosure of private information about itself. As

[16] These results are generalized in Raith [1996] who shows that the disclosure policy choice depends on the nature of the firms' private information (common values or independent values), the correlation in the firms' private information and whether the firms' strategies are substitutes or complements.

[17] There is an extensive empirical literature on information transfer. For example, Ramnath [2002] studies stock price reactions around earnings announcements; Bagniski [1987] and Kim, Lacina and Park [2008] focus on reactions around management guidance; Pownall and Waymire [1989] and the discussion by Dietrich [1989] focus on the interaction between earnings information transfer and management guidance; and Gleason, Jenkins and Johnson [2008] focus on reactions around accounting restatements.

mentioned previously, when the private information is about the firm's own payoffs, the decision to adopt a policy of disclosure depends on whether the firms' strategies are substitutes or complements and whether the private information is of the independent values form or the common values form. None of these issues are important when the firm's private information is solely about its rival's customers or production costs.

Intuitively, the difference arises because of differences in the payoffs to adopting a policy of not disclosing the firm's private information. In our case, the firm's private information is about its rival's customers or production costs and cannot be used to tailor the firm's own price or quantity because it is information about the rival. It can be used only if the firm adopts a policy of disclosure. In contrast, when the firm has private information about its own customers or production costs, it is able to tailor its price of quantity choice to that information whether or not it adopts a policy of disclosure. Thus, the payoff from adopting a policy of not disclosing depends on whether the firm has private information about its rival or itself.

More specifically, this payoff is smaller in expectation when the firm has private information about its rival because firm profits are convex in the value of the demand intercept and in the firm's costs of production. Convexity ensures that the expected payoff from the firm knowing that it can tailor its output (price) to its private information when acquired exceeds the expected payoff from the firm knowing that it cannot and simply setting its output (price) based on its expectation of its demand and/or cost parameters. Thus when comparing the advantages of adopting a policy of disclosure to a policy of not disclosing, the payoff associated with not disclosing is greater when the firm's output or price choice can be tailored to its private information. As a result, it less likely that the firm adopts a policy of disclosing its private information when it is about the firm's own customers or production costs. This difference plays an important role in explaining the difference in the firm's willingness to adopt a policy of disclosure when it has private information about its rival rather than itself.

Third, the disclosure policy choices are surprisingly robust. In equilibrium, the firms adopt a policy of disclosure if (1) they both have private information about their rival's customers, (2) they both have private information about their rival's production costs, or (3) one has private information about their rival's customers while the other has private information about the rival's production costs.

We should also note an interesting feature of the firms' disclosure policy decisions that becomes clear when examining the proof of Theorem 1:

Corollary 1: *Optimal disclosure policy choices do not depend on either how precise the firm's private information is nor on how similar the products the firms sell are (the value of t).*

Finally, we note that our results when $m = 1$ differ from the prior literature (Darrough 1993). Recall that when $m = 1$, each firm's private information about the rival's customers is payoff relevant to both firms because, if firm i lowers its price, its sales rise for two reasons. First, more consumers are willing to buy the firm's product, and second some of the rival's customers switch and now buy from firm i. Thus, information about its rival's customers is directly payoff relevant to firm i. This does not, however, produce the common values structure analyzed by Darrough [1993] and Raith [1996]. In their models, larger realizations of one firm's private information is associated with increased demand for both firms. When firms have private information about their rival's customers (and $m = 1$), a larger realization of the firm's private information is associated with increased demand for the firm's rival but decreased demand for the informed firm. This difference is why when firms have private information about industry demand and are Bertrand competitors, they adopt a policy of disclosing their private information whereas, in our model, when firms have private information about the rival's customers, $m = 1$ and they are Bertrand competitors, they adopt a policy of not disclosing their private information.

Our analysis, while most closely related to literature on the choice of voluntary disclosure policy, complements the theoretical literature on earnings management. In that literature, the benefits of biased mandatory disclosures are endogenized by examining their effects on the capital market's estimate of firm value (Fischer and Verrecchia 2000, Fischer and Stocken 2004, Stocken and Verrecchia 2004), on competition in the firm's product market (Fischer and Verrecchia 2004, Bagnoli and Watts 2010), or on contracting with the firm's manager (Arya, Glover and Sunder 1998). In addition to the showing that there are benefits to managing earnings, this literature also shows that it arises in equilibrium only if the agents observing the earnings reports are unable to fully undo any introduced bias. Our analysis complements this literature in two ways. First, we show that product market competition also provides incentives to disclose private information about a firm's rival. In fact, we show that the incentives are stronger than they are when the firm's private information is about its own customers or production costs. Second, because any disclosure about a rival's customers or production costs is likely verifiable by that rival in the future,

the arguments in Stocken [2000] could be adapted to show that it is unlikely that these disclosures would be biased. Thus, when the firm's private information is about its rival's customers or costs, it is expected to be disclosed and disclosed without introducing bias.

3. Extensions

In this section, we consider two extensions to our analysis. First, we consider the effect of allowing a firm to be uncertain as to whether or not the information it has acquired about the rival is, in fact, private. Second, we consider a version of our model in which the firms make disclosure decisions after they have learned their private information and thus are not committing to a disclosure policy.

3.1 Uncertainty about the private nature of the firms' information

While firms can invest in competitive intelligence gathering that produces information about a rival's customers and/or production costs, it is much more difficult for the firm to be sure that the information uncovered is unknown to the rival. In the previous section, the analysis assumes that the information uncovered is, in fact, private information. In this subsection, we extend our analysis to include the possibility that the firm's information is already known to the rival.

We maintain all of the assumptions made previously but augment them by assuming that the firm's information is private with probability $\rho_i > 0$. For any disclosure choice by the firm's rival (d_j), firm i's payoff from adopting a policy of disclosure is

$$\rho_i \mathrm{E}_i^k[\pi_i(D, d_j)] + (1 - \rho_i)\mathrm{E}_i^k[\pi_i(D, d_j)],$$

and firm i's payoff from adopting a policy of not disclosing is

$$\rho_i \mathrm{E}_i^k[\pi_i(N, d_j)] + (1 - \rho_i)\mathrm{E}_i^k[\pi_i(D, d_j)].$$

Since the second terms in the two expressions are the same, comparing them is equivalent to comparing $\mathrm{E}_i^k[\pi_i(D, d_j)]$ and $\mathrm{E}_i^k[\pi_i(N, d_j)]$. Since this is exactly the comparison behind the proof of Theorem 1, we have shown

Proposition 3: *When the firm's information is purely about its rival ($m = 0$), as long as there is a positive probability that this information is private ($\rho_i > 0$), then regardless of whether the firms have private information about demand or costs, and regardless of whether they are Bertrand or Cournot competitors, in the unique equilibrium, both firms adopt the policy of disclosing their private information.*

Intuitively, the firm's disclosure choice is based only on the possibility that its information is, in fact, private. Consequently, we obtain the same result as before: As long as there is a chance that the firm's information is private, it adopts a policy of disclosing its information about its rival's customers or production costs regardless of whether strategies are substitutes or complements (*i.e.*, whether the firms are Bertrand or Cournot competitors in their product markets). Firms that *may* have private information about their rival tell.

3.2 Ex Post Disclosure

To allow for easier comparisons between the analyses of *ex ante* and *ex post* disclosure, we maintain all of the assumptions about product market competition made previously but focus only on the case when $m = 0$, when the firm's private information is solely about its rival's customers or production costs. Figure 2 provides a time line of events.

Since disclosure models of this type are analyzed separately for each firm, we proceed by analyzing a firm's disclosure choice given a choice by its rival. Our first result confirms that in our setting, the standard unraveling result holds (Grossman 1981, Milgrom 1981) much as it does when the firms have private information about their own payoffs (Christensen and Feltham 2002). That is, without costs of disclosure or uncertainty about whether the firm actually does have any information at all, the unique equilibrium is to voluntarily disclose the firm's private information regardless of its type or realization.

Lemma 1: *Assume that firms make voluntary disclosure choices after learning their private information. If there are no costs to disclosure and no uncertainty about whether the firm has any information at all, the unique voluntary disclosure equilibrium involves the firm disclosing its private information regardless of whether it has private information about its rival's customers or production costs, regardless of whether the firms' strategies are substitutes or complements, and regardless of whether its rival does or does not disclose its private information.*

Verrecchia [1983] shows that the unraveling result disappears if there is a cost of disclosure that is not prohibitive and Dye [1985] shows that it disappears if the market is uncertain that the disclosing firm actually has private information. In either case, the firm is assumed to have private information about its own payoffs and the common result is that the firm voluntarily discloses its private information if it is sufficiently good news.[18] The following Theorem shows that this result extends to the case when the firm has private information about its rival's customers or

[18] Recently, Arya, Frimor and Mittendorf [2010] have shown that the unraveling result can also disappear if the disclosing firm competes in multiple product markets.

production costs. To simplify the analysis, we assume that there is a positive but not prohibitive cost to disclosure, κ, and that the distributions reflecting the firms' priors are log–concave so as to ensure that conditional expectations are monotone.[19]

Theorem 2: *Assume that firms make voluntary disclosure choices after learning their private information. If costs of disclosure are not prohibitive, the firm voluntarily discloses its private information if it is sufficiently good news for the firm regardless of whether it has private information about its rival's customers or production costs, regardless of whether the firms' strategies are substitutes or complements, and regardless of whether its rival does or does not disclose its private information.*

The result described in Theorem 2 is consistent with prior voluntary disclosure models of this type (Verrecchia 2001, Dye 2001) in that the disclosing firm voluntarily discloses good news. What is interesting about our result is that good news for the disclosing firm may or may not be good news for its rival. To see why, consider the case of a Cournot competitor with private information about its rival's production costs. Good news for the disclosing firm is represented by larger than expected production costs for its rival—which is bad news for the rival. Similarly, if the firm's private information is about the rival's customers, good news for the disclosing firm is represented by a smaller demand for the rival's product, which is again bad news for the rival. However, if the firm is a Bertrand competitor with private information about its rival's customers, good news for the disclosing firm is represented by greater demand for the rival's product—which is also good news for the rival.

Corollary 2: *Assume that firms make voluntary disclosure choices after learning their private information. If costs of disclosure are not prohibitive and the firms are Bertrand competitors, the probability that the firm chooses to voluntarily disclose its private information about its rival is increasing in how close substitutes the firms' products are (how large t is). If the firm's are Cournot competitors, the result holds so long as the firms' markets are sufficiently similar.*[20]

Intuitively, the more similar the firms' products are, the greater is the strategic benefit associated with providing information the firm has about its rival's customers or costs. The strategic benefits from disclosing a firm's private information to its rival is that the rival responds to the new information in a manner that ultimately benefits the disclosing firm. For example, if it is disclosed that the rival's costs are higher than it expected, the rival reduces the amount it wishes to sell (or increases the price it wishes to charge if the firms are Bertrand competitors) thereby

[19] See Bagnoli and Bergstrom [2005] for examples of distributions that are log–concave.

[20] "Sufficiently similar" means that $\mathrm{E}[a_i - c_i \mid d_j]/(a_j - c_j) > t(4+t^2)/(4+3t^2)$.

increasing the disclosing firm's profits. The impact of the disclosure is greater the more closely the firms' products substitute for one another. As a result, set of values the firm wishes to disclose increases and so the probability of a voluntary disclosure rises.

Corollary 2 also offers an interesting empirical prediction. It suggests that the probability of a voluntary disclosure is greater for firms that sell more similar products. Thus, firms that sell products that are difficult to differentiate from one another are more likely to offer voluntary disclosure of information about their rival than firms that compete but sell more easily differentiated products. Since some firms compete using differentiation strategies while others adopt a cost leadership strategy, Corollary 2 suggests that there will be less voluntary disclosure among the first set of firms and more among the second.

4. Conclusions

Businesses are putting ever greater emphasis on competitive intelligence (CI): the process of developing information and insight about their rivals with the objective of identifying strategic advantages (Carr 2003, Fuld 2006, Liebowitz 2006, Fleisher and Bensoussan 2007). As part of the CI process, a firm is likely to acquire private information about its rivals' customers and/or production processes. Our objective is to understand the firm's incentives to disclose this type of private information.

Prior work (Gal–Or 1985, 1986, Darrough 1993, Raith 1996) focuses on disclosure policies when firms have private information about their own customers or production costs (the independent values case) or information about industry demand (the common values case), not private information about their rivals. This literature shows that the decision to adopt a policy of disclosing this information depends on the nature of the private information (whether it pertains to the firm's own customers or costs or whether pertains to industry demand) and whether the firms are Cournot or Bertrand competitors (Darrough 1993).[21]

In contrast, we find that when firms have private information about their rivals, they adopt a policy of disclosing that information regardless of the nature of that information (whether it pertains to the rival's customers or costs) and whether the firms are Cournot or Bertrand competitors.

[21] These results have been generalized and extended in Raith [1996] who shows that the decision depends on whether the private information is of the independent– or common–values form (the information only directly affects the disclosing firm's payoff or is information about a parameter that affects both firms' payoffs in a common way) and whether the firms' strategies are substitutes or complements.

Firms that have private information about a rival tell. Intuitively, the reason for this is that in our setting, the disclosure depends solely on the strategic benefits and costs of disclosing. In the setting studied in the prior literature (firms have private information about their own payoffs), each firm uses its private information to tailor its output or price choice to that private information *independent of the disclosure decision*, and the firm's rival understands this. Thus, there is an additional "information effect" associated with the disclosure in the prior literature that is absent when the private information is about the firm's rival.

Our result that each firm adopts a policy of disclosing any private information it has about a rival indicates that there is unlikely to be a need to substitute mandatory for voluntary disclosure of this type of information. Each firm has sufficient incentives to include such information about its rivals in its public disclosures. It also has implications for the information transfer literature. The idea in this literature is that one firm's financial disclosures can be used to make inferences about the performance or financial well–being of its rivals (Baginski 1987, Pownall and Waymire 1989, Ramnath 2002, Gleason, Jenkins and Johnson 2008 or Kim, Lacina and Park 2008). Our study indicates that information the disclosing firm has about a rival will also be included in its disclosures. If so, then distinguishing the different information included in a disclosure may allow for a clearer understanding of any information externalities associated with the disclosure.

Finally, we complete the analysis of a firm's incentives to disclose by considering its *ex post* disclosure choice. Absent inhibitions (costs or additional uncertainty), the standard unraveling result—that the firm discloses every realization of its private information—obtains. If, instead, there are costs of disclosure the firm only discloses if its private information is sufficiently good news for the disclosing firm. Interestingly, whether this disclosure is good or bad news for the rival depends on both whether the firm has private information about the rival's customers or production costs and whether the firms are Bertrand or Cournot competitors. We further show that the decision to only disclose its private information if it is sufficiently good news for the disclosing firm does not depend on whether or not the rival does or does not disclose its private information. However, the probability of a voluntary disclosure does depend on both whether the rival discloses and the degree to which the firms' products are substitutes.

5. Appendix

Proposition 1: *If the firms are Cournot competitors, equilibrium quantities are*

$$q_i(D,D) = \frac{1}{(4-t^2)}\big[2a_i - ta_j - 2c_i + tc_j\big]$$
$$q_i(D,N) = \frac{1}{(4-t^2)}\big[2\mathrm{E}[a_i \mid \phi_i] - ta_j - 2\mathrm{E}[c_i \mid \phi_i] + tc_j\big]$$
$$q_i(N,D) = \frac{1}{(4-t^2)}\Big[2a_i - t\mathrm{E}[a_j \mid \phi_j] - 2c_i + t\mathrm{E}[c_j \mid \phi_j]\Big]$$
$$q_i(N,N) = \frac{1}{(4-t^2)}\Big[2\mathrm{E}[a_i] - t\mathrm{E}[a_j] - 2\mathrm{E}[c_i] + t\mathrm{E}[c_j]\Big]$$

and equilibrium profits in this stage of the game are $\pi_i^C(d_i,d_j) = [q_i(d_i,d_j)]^2$ *for* $i = 1,2; j \neq i$.

Proof: Firm i solves $\max_{q_i} \mathrm{E}[(a_i - q_i - tq_j - c_i)q_i \mid \phi_i]$ which yields the first order condition $q_i = (1/2)\mathrm{E}[(a_i - tq_j - c_i) \mid \phi_i]$. Each of the cases differ in that the firms' information sets are different. For example, if both have committed to disclose, then both know a_i, a_j, c_i and c_j. In other words, the firms play a game of complete information and we obtain the standard result for $q_i(D,D)$. If firm i has committed to disclose but firm j has not, then firm i does not learn a_i and/or c_i. As a result, firm i's first order condition becomes $q_i = (1/2)(\mathrm{E}[a_i \mid \phi_i] - t\mathrm{E}[q_j \mid \phi_i] - \mathrm{E}[c_i \mid \phi_i])$. In contrast, firm j knows all four parameters—two because they are its private information and two because firm i has committed to disclose its private information. As a result, its first order condition becomes $q_j = (1/2)(a_j - tq_i - c_j)$. Solving these equations produces $q_i(D,N)$ and, by symmetry $q_i(N,D)$. The final case, when both firms commit not to disclose, the first order conditions are $q_i = (1/2)\mathrm{E}[a_i - tq_j - c_i] \quad i = 1,2; j \neq i$. The reason is that neither firm's private information is useful in determining their equilibrium outputs. Solving this pair of equations yields $q_i(N,N)$. In each case, substituting the equilibrium quantities into the firm's objective function produces the expression for profits given in the Proposition. ∎

Proposition 2: *If the firms are Bertrand competitors, equilibrium prices are*

$$p_i(D,D) = \frac{1}{(4-t^2)}\big[(2-mt^2)a_i + t(1-2m)a_j + 2c_i + tc_j\big]$$
$$p_i(D,N) = \frac{1}{(4-t^2)}\big[(2-mt^2)\mathrm{E}[a_i \mid \phi_i] + t(1-2m)a_j + 2\mathrm{E}[c_i \mid \phi_i] + tc_j\big]$$
$$p_i(N,D) = \frac{1}{(4-t^2)}\Big[(2-mt^2)a_i + (t/2)((4-t^2)ma_j + (2-mt)\mathrm{E}[a_j \mid \phi_j]) + 2c_i + t\mathrm{E}[c_j \mid \phi_j]\Big]$$
$$p_i(N,N) = \frac{1}{(4-t^2)}\big[(2-mt^2)\mathrm{E}[a_i] - (t/2)((4-t^2)ma_j - (2-mt^2)\mathrm{E}[a_j]) + 2E[c_i] + t\mathrm{E}[c_j]\big]$$

and equilibrium profits in this stage of the game are $\pi_i^B(d_i,d_j) = (\frac{1}{\xi})\big(p_i(d_i,d_j) - \mathrm{E}[c_i \mid \phi_i]\big)^2$ *for* $i = 1,2; j \neq i$.

Proof: Firm i solves $\max_{p_i} \mathrm{E}[\xi\big(a_i - mta_j - p_i + tp_j\big)(p_i - c_i) \mid \phi_i]$ which yields the first order condition $p_i = \frac{1}{2\xi}\mathrm{E}[(a_i - mta_j + tp_j + \xi c_i) \mid \phi_i]$. Again, each of the cases differ in that the firms' information sets are different. As before, if both have committed to disclose, both know all parameters and therefore play a game of complete information which yields the standard result for $p_i(D, D)$. If firm i has committed to disclose but firm j has not, then firm i does not learn a_i and/or c_i. As a result, firm i's first order condition becomes $p_i = \frac{1}{2\xi}(\mathrm{E}[a_i \mid \phi_i] - mta_j + t\mathrm{E}[p_j \mid \phi_i] + \xi\mathrm{E}[c_i \mid \phi_i])$. In contrast, firm j knows all four parameters—two because they are its private information and two because firm i has committed to disclose its private information. As a result, its first order condition becomes $p_i = \frac{1}{2\xi}(a_i - mta_j + tp_j + \xi c_i)$. Solving these equations produces $p_i(D, N)$ and, by symmetry $p_i(N, D)$. The final case, when both firms commit not to disclose, the first order conditions are $p_i = \frac{1}{2\xi}\big(\mathrm{E}[a_i + tp_j + \xi c_i] - mta_j\big)$. Solving this pair of equations yields $p_i(N, N)$. In each case, substituting the equilibrium quantities into the firm's objective function produces the expression for profits given in the Proposition. ∎

Theorem 1: (a) *When the firms' private information is purely about its rival ($m = 0$), then regardless of whether the firms have private information about demand or costs, and regardless of whether they are Bertrand or Cournot competitors, in the unique equilibrium, both firms adopt the policy of disclosing their private information.*

(b) *When $m = 1$, the firm's private information is about its rival's market demand and the firms are Bertrand competitors, in the unique equilibrium, neither firm adopts the policy of disclosing its private information.*

Proof: Our proof strategy is to show that $\mathrm{E}[\pi_i^k(D, N)] > \mathrm{E}[\pi_i^k(N, N)]$ and then that $\mathrm{E}[\pi_i^k(D, D)] > \mathrm{E}[\pi_i^k(N, D)]$ to show that the unique subgame perfect Nash equilibrium is for both firms to commit to disclose and then follow the equilibrium quantity (price) described in Proposition 1 (2) for $k = C, B$.

Case 1: Cournot Competition. Direct computations show that $\mathrm{E}[\pi_i^C(D, N)] - \mathrm{E}[\pi_i^C(N, N)] = \mathrm{E}[\pi_i^C(D, D)] - \mathrm{E}[\pi_i^C(N, D)] = (t/(4 - t^2))^2\big(\mathrm{Var}[a_j] + \mathrm{Var}[c_j]\big)$. Both differences in expected profits are positive because both variances are positive and so is $(t/(4 - t^2))^2$. Thus, the unique subgame perfect Nash equilibrium when firms are Cournot competitors is to adopt the policy of disclosing their private information regardless of whether the firm has private information about demand or cost (or both).

Case 2: Bertrand Competition when $m = 0$. Direct computations show that $\mathrm{E}[\pi_i^B(D, N)] - \mathrm{E}[\pi_i^B(N, N)] = \mathrm{E}[\pi_i^B(D, D)] - \mathrm{E}[\pi_i^B(N, D)] = (t/(4 - t^2))^2\big(\mathrm{Var}[a_j] + \mathrm{Var}[c_j]\big)$. Both differences in expected profits are positive because both variances are positive and so is $(t/(4 - t^2))^2$. Thus, the unique subgame perfect Nash equilibrium when firms are Bertrand competitors is to adopt the policy of disclosing their private information regardless of whether the firm has private information about demand or cost (or both).

Case 3: Bertrand Competition when $m = 1$. Since the value of m has no effect on the firms' disclosure decisions when they have private information about their rival's costs, both firms adopt the policy of disclosing their private information when they have private information about their rival's costs. (This is readily verified by direct computation.) Turning to the case when the firms have private information about their rival's demand, direct computations show that $\mathrm{E}[\pi_i^B(D, N)] - \mathrm{E}[\pi_i^B(N, N)] = \mathrm{E}[\pi_i^B(D, D)] - \mathrm{E}[\pi_i^B(N, D)] = -(t/(4 - t^2))^2\big(\mathrm{Var}[a_j]\big)$. Since the coefficient on the $\mathrm{Var}[a_j]$, the unique subgame perfect Nash equilibrium when both firms are Bertrand competitors and have private information about their rival's demand is to adopt the policy of not disclosing their private information. ∎

Lemma 1: *Assume that firms make voluntary disclosure choices after learning their private information. If there are no costs to disclosure and no uncertainty about whether the firm has any information at all, the unique voluntary disclosure equilibrium involves the firm disclosing its private information regardless of whether it has private information about its rival's customers or production costs, regardless of whether the firms' strategies are substitutes or complements, and regardless of whether its rival does or does not disclose its private information.*

Proof: Let $x_i \in \{a_j, c_j\}$ represent the realization of firm i's private information, $\mathcal{D}$ be the set of x_i that firm i chooses to disclose and let $\mathcal{N}$ be the set of x_i that firm i chooses not to disclose.

Case 1: Cournot Competition. Proposition 1 describes firm i's equilibrium quantity choice and equilibrium profits both when it discloses x_i and when it does not in two distinct environments—when firm j disclosed its private information and when firm j did not. In particular, firm i's payoff from disclosing when j did not (with a slight abuse of notation) is $\pi_i^C(x_i \in \mathcal{D}\,; y) \equiv \pi_i^C(D, y)$ where $y = N, D$. Similarly, if firm i does not disclose, let $\pi_i^C(x_i \in \mathcal{N}\,; y) \equiv \pi_i^C(N, y)$ where again $y = N, D$. Note that the latter payoff is independent of the value of x_i while the former are decreasing in a_j and increasing in c_j for $y = N, D$.

The monotonicity of $\pi_i^C(x_i \in \mathcal{D}\,; y)$ in x_i for $y = N, D$ ensures that $\mathcal{D}$ and $\mathcal{N}$ are, in equilibrium, intervals. To see why, suppose not. If $x_i = a_j$, then there are values of a_j such that $a_1 > a_2$ with $a_1 \in \mathcal{D}$, $a_2 \in \mathcal{N}$. Since $a_1 \in \mathcal{D}$ means that $\pi_i^C(a_1 \in \mathcal{D}\,; y) > \pi_i^C(a_1 \in \mathcal{N}\,; y)$ and $a_2 \in \mathcal{N}$ means that $\pi_i^C(a_2 \in \mathcal{D}\,; y) < \pi_i^C(a_2 \in \mathcal{N}\,; y)$ for $y = N, D$. However, since $\pi_i^C(a_j \in \mathcal{D}\,; y)$ is monotonically decreasing in a_j, this produces a contradiction and so both $\mathcal{D}$ and $\mathcal{N}$ are intervals. Next, let the critical value that separates $\mathcal{D}$ and $\mathcal{N}$ be a_j^*. In equilibrium, this critical value would be defined as the solution to $\pi_i^C(a_j^*; y) = \mathrm{E}[\pi_i^C(a_j; y) \mid a_j \in [a_j^*, a_j^h]]$. However, the monotonicity of $\pi_i^C(a_j \in \mathcal{D}\,; y)$ ensures that $\pi_i^C(a_j^*; y) > \mathrm{E}[\pi_i^C(a_j; y) \mid a_j \in [a_j^*, a_j^h]]$ for any a_j^* (except when $a_j^* = a_j^\ell$, in which case they are equal). As a result, the unique equilibrium has the firm voluntarily disclosing every realization of its private information. (A similar argument using the fact that $\pi_i^C(c_j \in \mathcal{D}\,; y)$ is monotonically increasing in c_j ensures that both $\mathcal{D}$ and $\mathcal{N}$ are intervals when the firm's private information is about its rival's production costs and that the unique equilibrium has the firm voluntarily disclosing every realization of its private information in this case too.)

Case 2: Bertrand Competition. Proposition 2 describes firm i's equilibrium price choice and equilibrium profits when it discloses x_i and when it does not in two distinct environments—when firm j disclosed its private information and when firm j did not. Analogous reasoning to that in Case 1 but noting that firm i's payoffs from disclosure are both increasing in the realized values of a_j and c_j completes the proof. ∎

Theorem 2: *Assume that firms make voluntary disclosure choices after learning their private information. If costs of disclosure are not prohibitive, the firm voluntarily discloses its private information if it is sufficiently good news for the firm regardless of whether it has private information about its rival's customers or production costs, regardless of whether the firms' strategies are substitutes or complements and regardless of whether its rival does or does not disclose its private information.*

Proof: Focusing first on the case when the firms are Cournot competitors and firm i has private information about its rival's customers, a_j, we can make use of the proof of Lemma 1 to show that the critical value separating $\mathcal{D}$ and $\mathcal{N}$, a_j^* satisfies

$$\pi_i^C(a_j^*; y) - \kappa = \mathrm{E}[\pi_i^C(a_j; y) \mid a_j \in [a_j^*, a_j^h]]. \tag{A1}$$

where we have included the cost of disclosure. Log–concavity of the distribution of a_j ensures that $\pi_i^C(a_j^*; y) - \mathrm{E}[\pi_i^C(a_j; y) \mid a_j \in [a_j^*, a_j^h]]$ is monotonically decreasing in a_j^* ensuring that there is a

unique solution to (A1) as long as the cost of disclosure, κ, is not prohibitive. Similarly reasoning shows that there is a unique interior critical value for the remaining cases. ∎

Corollary 2: *Assume that firms make voluntary disclosure choices after learning their private information. If costs of disclosure are not prohibitive and the firms are Bertrand competitors, the probability that the firm chooses to voluntarily disclose its private information about its rival is increasing in how close substitutes the firms' products are (how large t is). If the firm's are Cournot competitors, the result holds so long as the firms' markets are sufficiently similar.*[22]

Proof: Case 1, Cournot Competition: If the firm's private information is about the rival's customers (a_j), then its profits from disclosure are $\pi_i^C(D, d_j) = \big(q_i(D, d_j)\big)^2$ (Proposition 1) and the critical value defining the largest value of a_j that is disclosed, say A_j, satisfies $H(A_j; t, d_j) \equiv \pi_i^C(A_j; d_j) - \mathrm{E}[\pi_i^C(a_j; d_j) \mid a_j \in [A_j, a_j^h]] = \kappa$ (Theorem 2). Since $\partial A_j/\partial t > 0$ if $\partial H/\partial t > 0$, we need to compute $\partial \pi_i^C/\partial t$ and $\partial^2 \pi_i^C/\partial t \partial a_j$. Direct computation yields:

$$\frac{\partial \pi_i^C}{\partial t} = 2q_i(D, d_j)\frac{\partial q_i(D, d_j)}{\partial t} = 2q_i\left(\frac{1}{4-t^2}\right)^2\Big[4t\mathrm{E}[a_i - c_i \mid d_j] - (4+t^2)(a_j - c_j)\Big]$$

$$\frac{\partial^2 \pi_i^C}{\partial t \partial a_j} = 2\frac{\partial q_i}{\partial a_j}\frac{\partial q_i}{\partial t} + 2q_i\frac{\partial^2 q_i}{\partial t \partial a_j} = 4\left(\frac{1}{4-t^2}\right)^2\Big[-(4+3t^2)\mathrm{E}[a_i - c_i \mid d_j] + t(4+t^2)(a_j - c_j)\Big].$$

If $-(4+3t^2)\mathrm{E}[a_i - c_i \mid d_j] + t(4+t^2)(a_j - c_j) < 0$ then both are negative, H increases in t and so does A_j. Since the set of a_j the firm discloses $[a_j^\ell, A_j]$, the probability of disclosure increases in t. Analogous calculations yields the same result if the firm's private information is c_j instead.

Case 2, Bertrand Competition: Since we are assuming that $m = 0$, without loss of generality we can take the firms' demand curves to be $q_i = a_i - p_i + tp_j$ which implies that $\pi_i^B(D, d_j) = (p_i - \mathrm{E}[c_i \mid d_j])^2$. If the firm's private information is about the rival's customers, then the critical value defining the smallest value of a_j that is disclosed, say A_j, satisfies $G(A_j; t, d_j) \equiv \pi_i^C(A_j; d_j) - \mathrm{E}[\pi_i^C(a_j; d_j) \mid a_j \in [A_j, a_j^h]] = \kappa$ (Theorem 2). Again, $\partial A_j/\partial t > 0$ if $\partial G/\partial t > 0$, we need to compute $\partial \pi_i^B/\partial t$ and $\partial^2 \pi_i^B/\partial t \partial a_j$. Direct computation yields:

$$\frac{\partial \pi_i^B}{\partial t} = 2(p_i - \mathrm{E}[c_i \mid d_j])\frac{\partial p_i}{\partial t} = 2t\left(\frac{1}{4-t^2}\right)^2\Big[2\mathrm{E}[a_i - c_i \mid d_j] + t(a_j - c_j)\Big]$$

$$\frac{\partial^2 \pi_i^B}{\partial t \partial a_j} = \left(\frac{1}{4-t^2)}\right)^2(2t)(4+t^2).$$

In this case, both are positive and so G increases in t. Thus, the critical value (A_j) declines and so the probability of disclosure increases. Analogous calculations yield the same result if the firm's private information is c_j instead. ∎

[22] "Sufficiently similar" means that $\mathrm{E}[a_i - c_i \mid d_j]/(a_j - c_j) > t(4+t^2)/(4+3t^2)$.

6. References.

Arya, A., H. Frimor and B. Mittendorf, 2010. "Discretionary Disclosure of Proprietary Information in a Multi–Segment Firm," *Management Science*, vol. 56 (4), 645–658.

Arya, A., J. Glover and S. Sunder, 1998. "Earnings Management and the Revelation Principle," *Review of Accounting Studies*, vol. 3 (1–2), 7–34.

Arya, A. and B. Mittendorf, 2007. "The Interaction Among Disclosure, Competition Between Firms and Analyst Following," *Journal of Accounting & Economics*, vol. 43 (2–3), 321–339.

Baginski, S., 1987. "Intraindustry Transfers Associated with Management Forecasts of Earnings," *Journal of Accounting Research*, vol. 25 (2), 196–216.

Bagnoli, M. and T. Bergstrom. 2005. "Log–Concave Probability and its Applications," *Economic Theory*, vol. 26 (2), 445-469.

Bagnoli, M. and S. Watts, 2010. "Oligopoly, Earnings Management and Disclosure," *The Accounting Review*, vol. 85 (4), 1191–1214.

Bower, T., 2009. *Oil: Money, Politics and Power in the 21st Century*, Grand Central Publishing, New York, NY.

Bulow, J., J. Geanakoplos and P. Klemperer, 1985. "Multimarket Oligopoly: Strategic Substitutes and Complements," *Journal of Political Economy*, vol. 93 (3), 488–511.

Carr, M. 2003. *Super Searchers on Competitive Intelligence*, Cyberage Books, Medford, NJ.

Christensen, P. and G. Feltham, 2002. *Economics of Accounting: Information in Markets*, Springer, New York, NY.

Currarini, S. and F. Feri, 2007. "Bilateral Information Sharing in Oligopoly," University of Venice working paper.

Darrough, M., 1993. "Disclosure Policy and Competition: Cournot vs. Bertrand," *The Accounting Review*, vol. 68 (3), 534–561.

Davenport, T. and J. Harris, 2007. *Competing on Analytics*, Harvard Business School Press, Boston, MA.

Dietrich, J., 1989. "Discussion of Voluntary Disclosure Choice and Earnings Transfer," *Journal of Accounting Research*, vol. 27 (Supplement), 106–110.

Dye, R., 1985. "Disclosure of Nonproprietary Information," *Journal of Accounting Research*, vol. 23 (1), 123–145.

Fischer, P. and P. Stocken, 2004. "Effect of Investor Speculation on Earnings Management," *Journal of Accounting Research*, vol. 42 (5), 843–870.

Fischer, P. and R. Verrecchia, 2000. "Reporting Bias," *The Accounting Review*, vol. 75 (2), 229–245.

Fischer, P. and R. Verrecchia, 2004. "Disclosure Bias," *Journal of Accounting & Economics*, vol. 38 (3), 233–250.

Fleisher, C. and B. Bensoussan, 2007. *Business and Competitive Analysis*, FT Press, Upper Saddles River, NJ.

Fuld, L., 2006. *The Secret Language of Competitive Intelligence*, Crown Business, New York, NY.

Gal–Or, E., 1985. "Information Sharing in Oligopoly," *Econometrica*, vol. 53 (2), 329–344.

Gal–Or, E., 1986. "Information Transmission—Cournot and Bertrand Equilibria" *Review of Economic Studies*, vol. 53 (1), 85–92.

Gleason, C., N. Jenkins, and W. Johnson, 2008. "The Contagion Effects of Accounting Restatements," *The Accounting Review*. vol. 83 (1), 83–110.

Grossman, S., 1981. "The Role of Warranties and Private Disclosure about Product Quality," *Journal of Law and Economics*, vol. 24 (3), 461–483.

Kim, Y., M. Lacina and M. Park, 2008. "Positive and Negative Information Transfers from Management Forecasts," *Journal of Accounting Research*, vol. 46 (4), 885–908.

Liebowitz, J., 2006. *Strategic Intelligence*, Auerbach Publications, New York, NY.

Maleug, D. and S. Tsutsui, 1996. "Duopoly Information Exchange: The Case of Unknown Slope," *International Journal of Industrial Organization*, vol. 14 (1), 119–136.

Milgrom, P., 1981. "Good News and Bad News: Representation Theorems and Applications," *Bell Journal of Economics*, vol. 12 (2), 380–391.

Pownall, G. and G. Waymire, 1989. "Voluntary Disclosure Choice and Earnings Information Transfer," *Journal of Accounting Research*, vol. 27 (Supplement), 85–105.

Prescott, J. and S. Miller, 2001. *Proven Strategies in Competitive Intelligence: Lessons From the Trenches*, John Wiley and Sons, New York, NY.

Raith, M., 1996. "A General Model of Information Sharing in Oligopoly," *Journal of Economic Theory*, vol. 71 (2), 260–288.

Ramnath, S., 2002. "Investor and Analyst Reactions to Earnings Announcements of Related Firms: An Empirical Analysis," *Journal of Accounting Research*, vol. 40 (5), 1351–1376.

Stocken, P., 2000. "Credibility of Voluntary Disclosure," *Rand Journal of Economics*, vol. 31 (2), 359–374.

Stocken, P. and R. Verrecchia, 2004. "Financial Reporting System Choice and Disclosure Management," *The Accounting Review*, vol. 79 (4), 1181–1203.

Verrecchia, R., 1983. "Discretionary Disclosure," *Journal of Accounting & Economics*, vol. 5 (1), 179–194.

Vives, X., 1984. "Duopoly Information Equilibrium: Cournot and Bertrand," *Journal of Economic Theory*, vol. 34 (1), 71–94.

Vives, X., 2008. "Information Sharing Among Firms," *The New Palgrave Dictionary of Economics Online*, S. Durlauf and L. Blume editors, 2nd Edition.
(http://www.dictionaryofeconomics.com/dictionary)