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Information Sharing in the Presence of Preemptive Incentives: Economic Consequences of Mandatory Disclosure

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Abstract. This study examines the welfare implications of a mandatory disclosure requirement in an oligopolistic market, in which firms can choose their output either before or after the resolution of demand uncertainty. Two main results are derived. First, it is shown that there exists a set of parameter values under which mandatory disclosure is ineffective in the sense that it does not induce any change in the equilibrium production. Second, for some other parameter values, imposing mandatory disclosure alters the firms' incentive structure in a way that gives rise to a Pareto loss in welfare; i.e., firms and consumers are made strictly worse off. These two results suggest that the regulatory implications derived from the information-sharing literature should be interpreted with caution.

Keywords: information sharing, preemptive incentives, mandatory disclosure, welfare analysis

It is noteworthy that for the past decades regulatory agencies, such as the SEC and the FASB, have increasingly required firms to disclose their information on top of that reported in financial statements. For example, publicly traded firms in the US and Canada are required to augment their financial statement disclosures by Management Discussion & Analysis (MD&A).[1] In MD&A, firms are required to provide forward-looking information, which includes known and anticipated trends and events associated with their operations, such as the changes in demand (sales) and factor prices (costs). Of course, disclosure requirements through MD&A are unnecessary if firms voluntarily reveal their business information through other public channels, e.g., media releases. However, it appears that firms are reluctant to do so. Chandra, Procassini, and Waymire (1998) report that—based on a search of the Dow Jones News Retrieval Service for their sample firms in the semiconductor industry during the period of May 1985 to December 1993—the average number of order-related disclosures in news articles is only 1.03 per firm-year (although such disclosures are a leading indicator of future sales revenue). Also, Mautz and May (1978) and Stevenson (1980) provide survey-based and anecdotal evidence of firms' negative attitudes toward disclosing business information. This might have motivated regulators to take actions that increase disclosure requirements, and such requirements appear to have become more stringent in recent years. For example, the SEC (1989) provided explicit guidelines on the disclosures in MD&A and it also gave warnings of *ex post* monitoring of compliance. Nevertheless, it remains largely an open question whether mandating disclosures can achieve the intended objective of improving social efficiency.[2]

The literature on information sharing has extensively analyzed the issue of whether oligopolistic firms have incentives to disclose/share their firm-specific (e.g., cost) or industry-wide (e.g., demand) private information.[3] Although the existing studies mainly focus on firms' voluntary disclosure behavior, they have important regulatory implications. For example, Darrough (1993, p. 536) observes:

> "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 disclose voluntarily."

The objective of this paper is to examine whether the regulatory implications suggested by the studies in the information-sharing literature are valid when a key assumption in those studies is relaxed. Previous studies typically assume the following sequence in a two-stage game, which is known as an *information-sharing game*. At the first stage, firms make an irreversible disclosure policy decision as to whether or not they will disclose their private demand or cost information, which will become known at a later date. At the second stage, firms receive private information and they disclose or withhold it according to their commitment made at the first stage. Firms then compete against each other (i.e., choose output or price) in an oligopoly market. Note that competition is assumed to occur *after* the arrival of the firms' information at the second stage. In reality, however, firms often make decisions *before* obtaining information.[4] Given this observation, the main question I address in this study is as follows: "Suppose that the information-sharing game is augmented in a way that firms are allowed to produce *either before or after* they are privately informed. Will the regulatory implications derived from the existing studies then remain valid?" More precisely, in a setting where firms' production timing is endogenous, I ask, "Suppose that firms do not disclose their private information in a voluntary disclosure regime. Will mandatory disclosure then be effective in the sense that it alters the firms' equilibrium production?" I also ask, "If effective, will the change induced by mandatory disclosure have a positive welfare effect?"

I derive two main results. First, there exists a set of parameter values under which firms with or without mandatory disclosure requirements produce prior to receiving information. Thus, in this case, the mandatory disclosure regulation does not induce any change in the equilibrium production; i.e., it is ineffective. Second, it is shown that, for some other parameter values, mandatory disclosure gives rise to a Pareto loss in welfare; i.e., both firms and consumers are strictly worse off. Taken together, this paper's results illustrate that the regulatory implications derived from the existing studies might not hold if firms' production timing decisions are added to information-sharing games.

To explain the above results, it is useful to first explain the key elements of my model without mandatory disclosure. I consider a symmetric Cournot duopoly market under demand uncertainty. Firms are privately—but not perfectly—informed about the market demand if they delay production until some point of time. Duopolists, however, cannot credibly commit to their production timing because it is unobservable to the other competitor. If both firms delay production until the arrival of private demand information, they decide whether or not to disclose that information (i.e., they play an information-sharing game). Thus, in game theoretic terminology, the information-sharing game in my model is a proper subgame of the entire game, which I call a *preemption game*. The unique equilibrium of the information-sharing subgame is that no firm discloses its private demand information, which is well known in the literature (see, e.g., Vives (1984), Gal-Or (1985b), Li (1985), Darrough (1993)). Prior to receiving their private demand information, firms simultaneously decide whether or not to wait for that information, i.e., they play the preemption game.

The equilibrium of the preemption game critically hinges upon the size of demand uncertainty (which is measured by the variance of the random intercept of a linear demand function) and the average market size (which is measured by the mean of the random intercept). The intuition is straightforward. Suppose that the demand uncertainty is significant while the market size is small. Then, there is a strong incentive to wait for the arrival of demand information (although it is not shared) because firms can condition their production decision upon the market demand in a more precise manner. On the other hand, suppose that the demand uncertainty is negligible while the market size is large. Then, in pursuit of a large market share, firms have an incentive to preempt their rival by committing to their output prior to the resolution of demand uncertainty (i.e., they want to be a Stackelberg leader).[5] It thus follows that the tension between those two incentives characterizes the equilibrium in the preemption game. For example, when the market size is large relative to the demand uncertainty, the preemptive incentive dominates the incentive to have flexibility in production so that both firms produce without any demand information. In this case, the firms' preemptive incentives inevitably lead to a Pareto-inferior situation. This is because if firms were able to credibly commit to delay their production, then the firms as well as consumers would be strictly better off irrespective of the magnitudes of the demand uncertainty and market size. However, there is no way for a firm to credibly convince the other firm of its production timing decision because that decision is not observable to the other firm.

Given the equilibrium of the preemption game, it is not difficult to see that the welfare implications of mandatory disclosure suggested by the studies that solely focus on the information-sharing game may no longer be valid. To see this, suppose that firms' preemptive incentives are so strong that they produce without any demand information in the voluntary disclosure regime. In this case, it can be shown that even after mandatory disclosure is imposed, firms continue producing with no demand information. As a result, the mandatory disclosure policy does not induce any change in the equilibrium production. Instead, it merely wastes enforcement costs (which might be substantial as noted by Watts and Zimmerman (1986, pp. 169–171)), thereby reducing social surplus. In fact, the information-sharing/disclosure issue completely degenerates in this case because the firms, having already made their production decisions, are indifferent between disclosing and withholding their information.[6]

On the other hand, suppose that duopolists wait for their private demand information, which is not shared in the absence of mandatory disclosure. I show that requiring firms to disclose information in this case can induce them to produce before the information arrives, thereby making everybody worse off. The economics behind this result is as follows. In the preemption game, as explained earlier, firms without mandatory disclosure decide whether to produce before or after the arrival of their demand information (which will not be disclosed). That decision is based on the trade-off relation between the incentive to preempt the rival and the incentive to make a more informed output choice. Mandatory disclosure, however, alters this trade-off relation in a way that waiting for the demand information (which now must be disclosed) becomes a less attractive option. Indeed, it is shown that there exists a set of parameter values such that mandatory disclosure induces the firms—which would have waited for their demand information in the absence of mandatory disclosure—to produce prior to the arrival of the information. As a consequence, the firms' expected profits and consumer surplus are changed from those when firms condition their output on demand information to the profits and consumer surplus when firms produce without any information. The latter payoffs are strictly lower than the former ones.

In sum, the analysis in this paper suggests that mandatory disclosure in a Cournot market under demand uncertainty can achieve its intended purpose, i.e., an improvement of social welfare, only if firms wait for their information to arrive in *both* voluntary and mandatory disclosure regimes. Moreover, given that the firms' incentive to do so depends on the industry characteristics, i.e., the demand uncertainty and market size, it follows that regulators must acquire sufficient information about those characteristics before implementing any mandatory disclosure policy. Otherwise, mandatory disclosure regulation inevitably runs the risk of reducing social welfare.[7]

This study is related to several studies in the industrial organization literature. Gal-Or (1987) and Mailath (1993) examine a firm's production sequencing decision in duopoly settings. Their models are based on signaling games, in which a privately informed firm's decision to be a Stackelberg leader (Mailath, 1993) or the leader's output choice (Gal-Or, 1987) reveals its private information. In contrast, firms in my model simultaneously decide whether to move first without having any private information—but knowing that they are going to be privately informed if they choose to move second—and thus there is no signaling issue. This paper is also closely related to Spencer and Brander (1992). In particular, the economic force behind the preemption game, i.e., the trade-off relation between flexibility and pre-commitment, is similar to that in their model. However, there is no information-sharing issue in Spencer and Brander (1992) because the demand uncertainty is publicly resolved if firms postpone their production decisions. As a result, there is no mandatory disclosure issue in their study, whereas it is the central focus of this study. Also related is a recent study by Hughes, Kao, and Mukherji (1998). In their model, firms can acquire and disclose information before choosing capital structure in the context of Brander and Lewis (1986) wherein issuing debt is a commitment device for future aggressive production. It is shown that the firms' ability to acquire and share information is beneficial because it can eliminate their mutually disadvantageous incentive to use debt as a commitment device. Although Hughes, Kao, and Mukherji's (1998) model differs from mine in terms of firms' production timing and capital structure choices, the magnitudes of the prior mean and variance of the uncertain parameter play a similar role in predicting firms' equilibrium behavior.

The rest of the paper is organized as follows. Section 1 presents a model of Cournot game under demand uncertainty. In Section 2.1, I derive the unique equilibrium of the information-sharing subgame. Section 2.2 characterizes the equilibria of the preemption game. In Section 2.3, I investigate the economic consequences of mandatory disclosure. Section 3 concludes the paper.

1. The Model

Consider a single-period product market in which two risk-neutral firms compete in quantity, i.e., a Cournot duopoly model. There are three dates indexed by $\tau = 1, 2, 3$, and the firms are subscripted by $i = 1, 2$. Denote firm i's production by q_i and let $Q \equiv q_1 + q_2$ be the industry aggregate output. The market price, p, is determined by a stochastic linear inverse demand function:

$$p = A - Q, \tag{1}$$

where A is a random demand intercept. I assume that:

$$A = a + \delta_1 + \delta_2, \tag{2}$$

where $a > 0$ is a constant and δ_i is a random variable distributed on a closed interval $[\underline{\delta}, \overline{\delta}]$ with $E[\delta_i] = 0$ and $\text{Var}[\delta_i] = \sigma^2$ for all $i = 1, 2$. I also assume that δ_1 and δ_2 are independent and $a + 4\underline{\delta} \geq 0$.[8] As will be specified below, $\delta \equiv (\delta_1, \delta_2)$ is realized at date 3 and each firm i privately observes the realized value of δ_i. For simplicity, assume that both firms have a marginal production cost of zero.

The sequence of events is as follows. At date 1, two firms play a *preemption game* in which they simultaneously decide whether or not to make a commitment to produce a certain level of quantity. Any commitment here is assumed to be an all-or-nothing decision; that is, a firm either commits to all of its output at date 1, or does not make such a commitment, in which case it can choose its output at a later date.[9] At date 2, the outcome of the preemption game is publicly observable. There are three possible outcomes. First, it might be the case that both firms commit to some quantities, say, q_1 and q_2, at date 1. In this case, given q_1 and q_2, each firm earns its profit at date 3 when δ is realized. Thus, both firms' expected payoff is the same as that of a simultaneous-move Cournot game under demand uncertainty. The second possibility is that only one firm (say, firm i) makes a commitment to produce q_i and the other firm (say, firm j) does not. In this case, the committed (non-committed) firm is a Stackelberg leader (follower) in the sense that, after observing the committed firm i's quantity q_i, the non-committed firm j produces q_j at date 3.[10] The third possible outcome of the preemption game is that no firm makes a commitment, which implies that both firms delay their production until when δ is realized. In such a case, they simultaneously make an irreversible disclosure policy decision at date 2 in anticipation of their private demand information that arrives at date 3. This is labeled an *information-sharing game*. When firm i, $i = 1, 2$, privately observes the realization of δ_i at date 3, it discloses or withholds its demand information according to its disclosure policy determined at date 2. The two firms then simultaneously choose their output. I assume that disclosed information, if any, is truthful.[11]

The game structure is common knowledge. In the analysis of the model, I only consider the case in which each firm chooses its pure strategy. Figure 1 is an extensive-form representation of the whole game, where I use the following notations for firm i's strategy, $i = 1, 2$, at each node:

$C_i \equiv$ Firm i makes a commitment to produce before the realization of the demand parameters;

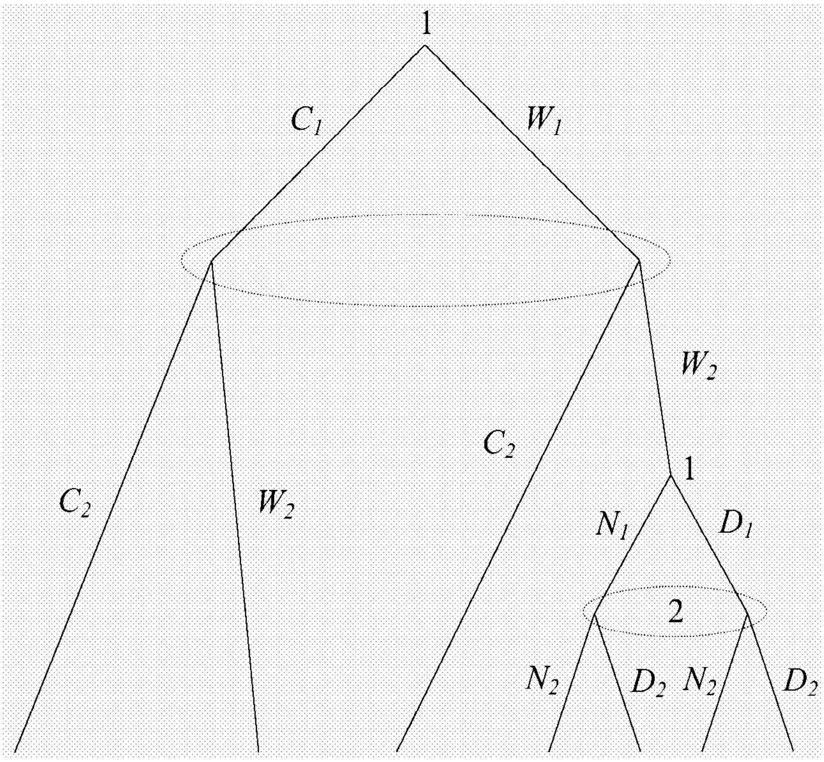

Figure 1. Extensive-form game tree.

$W_i \equiv$ Firm i waits for the realization of the demand parameters by delaying its production;

$D_i \equiv$ In the case of (W_1, W_2), firm i makes a commitment to disclose its private information;

$N_i \equiv$ In the case of (W_1, W_2), firm i makes a commitment not to disclose its private information.

In the game tree, one can think of firms' production as taking place at the end nodes reached by each strategy profile. For example, at the end node reached by (C_1, C_2), both firms play a Cournot output game under demand uncertainty, i.e., both produce at date 1. At the end nodes reached by (C_1, W_2) or (W_1, C_2), one firm produces at date 1 whereas the other firm produces at date 3, i.e., they play a Stackelberg game. The remaining end nodes are reached if, and only if, both firms delay their production until date 3, i.e., play (W_1, W_2). Each of those end nodes, however, differs in terms of information structure. For example, at the end node reached by (W_1, W_2) and (N_1, N_2), only firm i knows δ_i for all $i = 1, 2$. At the end node reached by (W_1, W_2) and (N_1, D_2), firm 1 knows both δ_1 and δ_2 whereas firm 2 knows only δ_2. On the other hand, at the end node reached by (W_1, W_2) and (D_1, D_2), firms have symmetric information about $\delta = (\delta_1, \delta_2)$. Dotted ellipses indicate that one firm does not observe the other firm's strategy in both the preemption and information-sharing games.

2. Analysis

2.1. Information-Sharing Game

As depicted in Figure 1, the information-sharing game (at the southeast corner of the game tree) and firms' subsequent production constitute a proper subgame of the entire game. This subgame—reached by strategy profile $\boldsymbol{W} \equiv (W_1, W_2)$—is played if, and only if, both firms delay production until when the random demand shock δ is realized. It is well known in the literature (e.g., Vives (1984), Gal-Or (1985b), Li (1985), Darrough (1993)) that both firms' non-disclosure of private demand information, $\boldsymbol{N} \equiv (N_1, N_2)$, is the unique equilibrium. Formally:

Proposition 1 *The unique subgame perfect equilibrium of the information-sharing game reached by* $\boldsymbol{W}$ *is* $\boldsymbol{N}$. *The Bayesian-Nash equilibrium quantity and expected profit of firm* $i = 1, 2$, *are given by:*

$$q_i^*(\delta_i \mid \boldsymbol{WN}) = \frac{1}{3}a + \frac{1}{2}\delta_i; \tag{3}$$

$$E[\pi_i^* \mid \boldsymbol{WN}] = E[(q_i^*(\delta_i \mid \boldsymbol{WN}))^2] = \frac{1}{9}a^2 + \frac{1}{4}\sigma^2. \tag{4}$$

In addition, given that $Q^*(\delta \mid \boldsymbol{WN}) = q_1^*(\delta_1 \mid \boldsymbol{WN}) + q_2^*(\delta_2 \mid \boldsymbol{WN})$ *is the industry aggregate output, expected consumer surplus is given by:*

$$E[CS^* \mid \boldsymbol{WN}] = \frac{1}{2}E[(Q^*(\delta \mid \boldsymbol{WN}))^2] = \frac{2}{9}a^2 + \frac{1}{4}\sigma^2. \tag{5}$$

The proof is omitted because the results are well known. In Proposition 1, $\boldsymbol{WN}$ indicates that both firms wait for δ to be realized (i.e., play $\boldsymbol{W}$) and do not disclose their private demand information (i.e., play $\boldsymbol{N}$). The economics behind Proposition 1 is well summarized in Darrough (1993, pp. 541–543). Of particular note is that, for any given combination of disclosure strategies in the information-sharing game, a firm's expected profit increases with the variability of its equilibrium quantity. It turns out that the equilibrium quantity is more volatile in the case of non-disclosure (i.e., $\boldsymbol{N}$) than in the full disclosure case (i.e., (D_1, D_2)) or in the unilateral disclosure cases (i.e., (D_1, N_2) or (N_1, D_2)). To see why the firms are better off by withholding their demand information, suppose that firm i privately observes a large δ_i. This, *ceteris paribus*, induces firm i to increase its production. Firm i can increase its output more when it does not reveal its favorable demand information, compared to a setting where it reveals such information. The reason is that disclosing a favorable δ_i motivates firm j to increase its quantity, which in turn provides an incentive for firm i to reduce its quantity. The fact that quantities are strategic substitutes (in the sense of Bulow, Geanakoplos, and Klemperer (1985)) is crucial here. In contrast, firm j's reaction is limited in the case of non-disclosure. Thus, *ex ante*, firm i enjoys more variability in its equilibrium output when it does not disclose its private demand information than when it does.

2.2. *Preemption Game*

Given that non-disclosure of private demand information is the unique subgame perfect equilibrium of the information-sharing game in the voluntary disclosure regime, I go one step backward to derive the Nash equilibrium of the entire game. Since the firms' expected payoffs in the subgame reached by (W_1, W_2) are given in Proposition 1, it remains to derive the firms' expected payoffs at the end nodes reached by strategy profiles (C_1, C_2), (C_1, W_2), and (W_1, C_2)—see Figure 1.

First, consider the end node reached by (C_1, C_2). Recall that in this case two firms commit themselves to produce at date 1 with no demand information, thereby playing a Cournot output game under demand uncertainly. Given the structure of the model, it is easy to verify that firm i's equilibrium quantity and expected profit, $i = 1, 2$, and expected consumer surplus are:

$$q_i^*(\boldsymbol{C}) = \frac{1}{3}a, \qquad E[\pi_i^* \mid \boldsymbol{C}] = \frac{1}{9}a^2, \qquad E[CS^* \mid \boldsymbol{C}] = \frac{2}{9}a^2, \tag{6}$$

where $\boldsymbol{C} \equiv (C_1, C_2)$ indicates that both firms commit to their production at date 1.

Second, consider the end node reached by (C_1, W_2). In this case, firm 1 plays the role of a Stackelberg leader by committing to an output at date 1. After observing firm 1's committed quantity, firm 2—as a Stackelberg follower—makes production timing and volume decisions. The former decision refers to whether to produce at date 2 or 3. Given that firm 1 has already made an output choice q_1, it is clear that firm 2 has no incentive to produce at date 2 without knowing δ_2; by delaying production until date 3, firm 2 can use its demand information δ_2 in making its output choice q_2. In addition, note that there is an information-sharing issue at date 3. This is because even though firm 1 has already committed to q_1, it might reveal its demand information δ_1 to firm 2. It can be shown that, whether firm 1 reveals δ_1 to firm 2 or not, firm 1's expected profit is the same but firm 2's expected profit is strictly greater when it has information about both δ_1 and δ_2. Firm 2's higher expected profit under full information is not surprising given that more precise demand information allows it to make a more flexible production decision. On the other hand, firm 1 is indifferent because its optimal quantity at date 1 is based on firm 2's average quantity at date 3, which is the same whether δ_1 is revealed or not. In the subsequent analysis, I assume that if a firm is indifferent between disclosing and withholding its private information, it acts to enhance the industry aggregate expected profit by disclosing its private information at date 3.

The above discussion establishes that, given q_1, firm 2 produces at date 3 with full information about $\delta = (\delta_1, \delta_2)$. That is, after observing q_1 and δ, firm 2 solves:

$$\max_{q_2} \pi_2(q_1, q_2, \delta) = (A - q_1 - q_2)q_2.$$

On the other hand, firm 1's optimal quantity choice at date 1 is a solution to:

$$\max_{q_1} E[\pi_1] = (E[A] - q_1 - E[q_2^*(q_1, \delta)])q_1,$$

where $q_2^*(\cdot)$ is firm 2's best response and expectation is taken over δ. It is straightforward to check that the equilibrium outputs and firms' expected payoffs are:

$$q_1^*(\boldsymbol{L}) = \frac{1}{2}a \quad \text{and} \quad q_2^*(q_1, \delta \mid \boldsymbol{F}) = \frac{1}{4}a + \frac{\delta_1 + \delta_2}{2}; \tag{7}$$

$$E[\pi_1^* \mid \boldsymbol{L}] = \frac{1}{8}a^2 \quad \text{and} \quad E[\pi_2^* \mid \boldsymbol{F}] = \frac{1}{16}a^2 + \frac{1}{2}\sigma^2, \tag{8}$$

where $\boldsymbol{L}$ ($\boldsymbol{F}$) denotes that firm 1 (2) is the Stackelberg leader (follower).

It remains to consider the end node reached by (W_1, C_2). However, by symmetry, the analysis for this case is the same as that for the previous case, except that firm 2 (1) is the Stackelberg leader (follower). Observe that the Stackelberg leader's expected profit is not always greater than that of the follower, which is in contrast to the certainty case.[12] To be specific, (8) shows that if firm 1 were *entitled* to choose a leader's or follower's position, it would opt for the leader's position if, and only if, $a^2 \geq 8\sigma^2$.[13] In other words, preempting the rival firm is beneficial if the market size (measured by $E[A] = a$) is large relative to the demand uncertainty (measured by $\text{Var}[A] = 2\sigma^2$). Otherwise, the second-mover's benefit from having more precise demand information is dominant over the benefit from having a larger market share on average. The next proposition, however, shows that a Stackelberg leader-follower relation does not arise in my model where the firms' sequencing decisions are endogenous (i.e., no firm is entitled to move first or second).

Proposition 2

(i) If $\sigma^2 \leq \frac{a^2}{18}$, then both firms produce prior to the arrival of their demand information; i.e., the unique dominant strategy equilibrium is $\boldsymbol{C} = (C_1, C_2)$.

(ii) If $\sigma^2 \geq \frac{7a^2}{72}$, then both firms delay their production until when their demand information arrives; i.e., the unique dominant strategy equilibrium is $\boldsymbol{W} = (W_1, W_2)$.

(iii) If $\frac{a^2}{18} < \sigma^2 < \frac{7a^2}{72}$, then the equilibrium is either $\boldsymbol{C}$ or $\boldsymbol{W}$.[14]

Proof: See Appendix. ■

Table 1 is a normal-form representation of the preemption game, in which each firm i makes its commit-or-wait decision (i.e., C_i or W_i) without observing the same decision by firm j. The two firms' expected payoffs in each cell are taken from (4), (6), and (8). Note that, following $\boldsymbol{W} = (W_1, W_2)$, the two firms subsequently play the information-sharing game in which non-disclosure, $\boldsymbol{N} = (N_1, N_2)$, prevails.

Proposition 2 establishes that there exists a range of parameter values, under which both firms produce prior to the arrival of their demand information. For these parameter values, there is no point in firms' sharing or withholding their private information; i.e., the information-sharing issue completely degenerates. Such degeneracy occurs when firms' preemptive incentives are dominant. Specifically, note that when a firm chooses its strategy in the preemption game, there is a tension between its incentive to preempt the rival in order to take a large market share and its incentive to wait for better demand information. When the market size, a, is large relative to the demand uncertainty, σ^2, the incentive to be

Table 1. Normal-form representation of the preemption game.

	C_2	W_2
C_1	$\frac{1}{9}a^2$; $\frac{1}{9}a^2$	$\frac{1}{8}a^2$; $\frac{1}{16}a^2 + \frac{1}{2}\sigma^2$
W_1	$\frac{1}{16}a^2 + \frac{1}{2}\sigma^2$; $\frac{1}{8}a^2$	$\frac{1}{9}a^2 + \frac{1}{4}\sigma^2$; $\frac{1}{9}a^2 + \frac{1}{4}\sigma^2$

In each cell, the entry in the northwest (southeast) corner denotes firm 1's (2's) equilibrium expected payoff.

a Stackelberg leader is dominant over the incentive to have flexibility in the output choice. However, as shown in Proposition 2, neither (C_1, W_2) nor (W_1, C_2) prevails in equilibrium for any given parameter values. In other words, a Stackelberg leader-follower relation does not arise. Instead, both firms always share the market equally. This is due to the symmetry of the incentive structure such that if one firm has an incentive to produce before receiving its demand information, the other firm also has the same incentive. In the same vein, if one firm delays its production, so does the other firm.

Given the basic incentive structure, the intuition behind Proposition 2 is straightforward. In Part (i), firms play $\boldsymbol{C} = (C_1, C_2)$ because the parameters are such that both firms' incentive to be a Stackelberg leader is so strong as to give up the benefit from a more informed output choice. As explained above, the attempt to take a larger market share is not successful in that both firms end up with an equal market share. In fact, observe that firms in this case are exactly trapped in a prisoner's dilemma. From Table 1, it is clear that if firms were able to make a credible commitment to delay their production (i.e., play $\boldsymbol{W} = (W_1, W_2)$), then both would be strictly better off. However, there is no way for firm i to credibly convince firm j of its production timing because, given that its production timing decision is unobservable to firm j, preempting firm j is firm i's dominant strategy. Also, the expected consumer surpluses in (6) and (5) show that firms' preemptive incentives impose a negative externality on consumers as well. On the other hand, if the demand uncertainty is large relative to the market size so that the condition in Part (ii) of Proposition 2 is satisfied, then the incentive to wait for the demand information dominates the incentive to preempt the opponent, which results in equilibrium $\boldsymbol{W}$.

Now consider the case in which the demand uncertainty is intermediate in that the condition in Part (iii) of Proposition 2 holds. Two pure strategy equilibria are possible here, depending on whether a firm commits or waits. That is, if firm i chooses C_i, firm j has no incentive to choose W_j for all $i, j = 1, 2$ and $i \neq j$, whereas if firm i chooses W_i, firm j has no incentive to choose C_j. Given that $\boldsymbol{W}$ is a Pareto-dominant equilibrium over $\boldsymbol{C}$, the two firms in this case have a coordination problem. In the subsequent analysis, relying on Schelling's (1960) theory of focal points, I assume that firms have pre-play communication channels, through which they coordinate their strategies in favor of the Pareto-dominant equilibrium, $\boldsymbol{W}$.[15] Given this assumption, Parts (ii) and (iii) in Proposition 2 can be combined into a single statement. Moreover, recall that when $\boldsymbol{W}$ is played in the preemption game, the non-disclosure equilibrium $\boldsymbol{N} = (N_1, N_2)$ subsequently prevails in the information-sharing game. Thus, the equilibrium of the entire game in the voluntary disclosure regime can be summarized as follows:

$$\text{If } \sigma^2 \leq \frac{a^2}{18}, \quad \text{then the equilibrium is } \boldsymbol{C}; \tag{9}$$

$$\text{If } \sigma^2 > \frac{a^2}{18}, \quad \text{then the equilibrium is } \boldsymbol{WN}. \tag{10}$$

2.3. Economic Consequences of Mandatory Disclosure

When each firm is free to choose whether or not to share its private demand information with its rival, the equilibrium of the entire game critically hinges upon the industry demand characteristics, i.e., the market size a and demand uncertainty σ^2. In this section, I turn to the paper's main focus, which is to investigate the welfare consequences of mandatory disclosure.

Before proceeding to the analysis, it is useful to first discuss the economic consequences of mandatory disclosure, *assuming* that both firms always wait for their demand information to arrive (i.e., they always play $\boldsymbol{W}$ in the preemption game at date 1). This is equivalent to assuming that firms play *only* the information-sharing game. Given this assumption, suppose that firms are required to disclose their private demand information in the information-sharing game (although they will not do so if not required). Then, it can be checked that each firm's expected payoff and expected consumer surplus are:

$$E[\pi_i^* \mid \boldsymbol{WD}] = \frac{1}{9}a^2 + \frac{2}{9}\sigma^2 \text{ for } i = 1, 2; \tag{11}$$

$$E[CS^* \mid \boldsymbol{WD}] = \frac{2}{9}a^2 + \frac{4}{9}\sigma^2, \tag{12}$$

where $\boldsymbol{WD}$ denotes that both firms must wait ($\boldsymbol{W}$) for δ to be realized and they must disclose ($\boldsymbol{D}$) their demand information in the information-sharing game. A comparison of (11) and (4) shows that $E[\pi_i^* \mid \boldsymbol{WD}] < E[\pi_i^* \mid \boldsymbol{WN}]$. Similarly, comparing (12) and (5) reveals that $E[CS^* \mid \boldsymbol{WD}] > E[CS^* \mid \boldsymbol{WN}]$. It thus follows that consumers will support mandatory disclosure, whereas the firms will be against it. On the other hand, regulators might consider social surplus as a basis of enforcing mandatory disclosure. Using (4), (5), (11), and (12), one can verify that expected social surplus, defined by

$$E[SS^* \mid \cdot] \equiv E[\pi_1^* \mid \cdot] + E[\pi_2^* \mid \cdot] + E[CS^* \mid \cdot],$$

is greater under full disclosure than under non-disclosure, i.e., $E[SS^* \mid \boldsymbol{WD}] > E[SS^* \mid \boldsymbol{WN}]$. Thus, to the extent that the objective of a regulatory policy is to improve social surplus, regulators have a rationale for imposing mandatory disclosure on firms.

The aforementioned welfare effects of mandatory disclosure are similar to those in the existing studies (e.g., see Vives (1990), Darrough (1993)), which solely focus on the information-sharing game. Nevertheless, as emphasized above, a crucial presumption is that firms wait for their demand information to arrive, and thus, they play the information-sharing game *both* in the voluntary and mandatory disclosure regimes. However, when the preemption game that precedes the information-sharing game is considered, the analysis in the previous section has shown that the latter game might not be even played in the voluntary disclosure regime if the market size is large relative to the demand uncertainty—see (9). Thus, unless regulatory agencies can enforce firms' production timing, two questions arise. The first is: "When firms play ***C*** in the absence of the disclosure requirement, can mandatory disclosure induce them to play ***W***?" The second question is: "When firms play ***W*** in the voluntary disclosure regime, will mandatory disclosure induce them to continue playing ***W***?" An immediate observation is that if the answers to the above questions are "No," then the welfare implications of mandatory disclosure discussed in the previous paragraph, and hence, those in the information-sharing literature are no longer valid. As will be shown below, the answers critically depend on the industry characteristics (i.e., the market size and demand uncertainty) and in fact for some parameter values mandatory disclosure makes both the firms and consumers strictly worse off.

To answer the questions raised above, now suppose that firms are required to disclose their demand information at date 3 but they are no longer restricted to play ***W*** at date 1. Note that the disclosure requirement alters the firms' expected payoffs when they both wait for their information to arrive. In particular, the equilibrium payoffs in the cell of the strategy profile (W_1, W_2) in Table 1 are now changed to the ones given by (11). This translates into a change in the trade-off relation between making a production commitment without demand information and waiting for the information. To be more precise, by conducting an analysis similar to that in Section 2.2, one can verify that the equilibrium of the entire game in the mandatory disclosure regime is:

$$\text{If } \sigma^2 \leq \frac{a^2}{16}, \text{ then the equilibrium is } \boldsymbol{C}; \tag{13}$$

$$\text{If } \sigma^2 > \frac{a^2}{16}, \text{ then the equilibrium is } \boldsymbol{WD}. \tag{14}$$

Observe that (13) and (14) are directly comparable with (9) and (10), which characterize the equilibria in the voluntary disclosure regime.

The economic consequences of mandatory disclosure can be examined for three mutually disjoint parameter spaces. First, consider the case in which $\sigma^2 \leq \frac{a^2}{18}$. In this case, as stated in (9), ***C*** prevails in equilibrium without mandatory disclosure. Since $\frac{a^2}{18} < \frac{a^2}{16}$, it directly follows from (13) that firms will continue playing ***C*** in equilibrium with mandatory disclosure. As a result, the disclosure regulation in this case will be completely ineffective in the sense that it does not induce any change in equilibrium allocation, and thus, the firms' expected payoffs and consumer surplus remain unchanged. The firms, of course, can satisfy the regulatory disclosure requirement by disclosing their information at date 3, which is *after* their output decisions are made. In that sense, the mandatory disclosure regulation is not viable.

Second, consider the case in which $\sigma^2 \in \left(\frac{a^2}{18}, \frac{a^2}{16}\right]$. As stated in (10), firms in the voluntary disclosure regime choose to wait for their private demand information and they withhold it (i.e., play ***WN***). However, according to (13), mandatory disclosure induces both firms to play ***C***. Put differently, the firms that would have played ***WN*** in the absence of the disclosure requirement choose to play ***C*** in the presence of mandatory disclosure. Indeed, a comparison of (9) and (13) shows that mandatory disclosure expands the set of parameters that induce both firms to produce prior to knowing their demand information. The reason for why mandatory disclosure induces firms to change their equilibrium behavior from ***WN*** to ***C*** in this case can be explained as follows. From (4) and (11), we can see that the firms' expected payoffs are higher in ***WN*** equilibrium (i.e., both wait for their information that is withheld in equilibrium) than those in ***WD*** equilibrium (i.e., both wait for their information that must be disclosed due to the regulation). Given that the firms' expected payoffs in the case of ***C*** are independent of the disclosure regulation, it follows that when the firms are forced to reveal their private demand information, delaying production becomes a less attractive option. Consequently, the firms have a stronger incentive to make a commitment to their production at date 1 in the mandatory disclosure regime, although doing so is to their mutual disadvantage.

Turning to the welfare consequences in this case, recall that when there is no disclosure requirement, the firms' expected payoffs are given by (4); i.e.,

$$E[\pi_i^* \mid \boldsymbol{WN}] = \frac{1}{9}a^2\frac{1}{4}\sigma^2 \text{ for all } i = 1, 2.$$

On the other hand, if the mandatory disclosure policy is enforced, ***C*** becomes the equilibrium so that the firms' expected payoffs are those given by (6); i.e.,

$$E[\pi_i^* \mid \boldsymbol{C}] = \frac{1}{9}a^2 \text{ for all } i = 1, 2.$$

Thus, firms are made strictly worse off. On the other hand, consumer surpluses with and without mandatory disclosure are respectively given by (6) and (5); i.e.,

$$E[CS^* \mid \boldsymbol{WN}] = \frac{2}{9}a^2 + \frac{1}{4}\sigma^2 \quad \text{and} \quad E[CS^* \mid \boldsymbol{C}] = \frac{2}{9}a^2.$$

Hence, consumers are also made strictly worse off. In summary, when the demand parameters satisfy $\sigma^2 \in \left(\frac{a^2}{18}, \frac{a^2}{16}\right]$, mandatory disclosure alters firms' incentive structure in the preemption game in a way that the firms, which would have delayed their production in the voluntary disclosure regime, are induced to produce with no demand information. This results in a Pareto loss in welfare.

Finally, consider the case in which $\sigma^2 > \frac{a^2}{16}$. From (10) and (14), it follows that firms wait for their demand information to arrive in both disclosure regimes. Firms delay their production irrespective of the disclosure regimes in this case because when the demand uncertainty is large relative to the market size, their incentive to make a more informed output decision is dominant. It is only in this case that imposing mandatory disclosure has the welfare effects stated at the beginning of this section. That is, it increases consumer surplus but decreases the firms' expected profits with the former effect more than offsetting the latter. Thus far, I have proved the following proposition, which summarizes the welfare implications of mandatory disclosure.

Proposition 3 *Suppose that regulators mandate firms to disclose their private demand information.*

(i) *If* $\sigma^2 \leq \frac{a^2}{18}$, *then there is no change in the firms' equilibrium production and thus social welfare remains unchanged.*

(ii) *If* $\sigma^2 \in \left(\frac{a^2}{18}, \frac{a^2}{16}\right]$, *then both the firms and consumers are made strictly worse off.*

(iii) *If* $\sigma^2 > \frac{a^2}{16}$, *then the firms are strictly worse off while consumers are strictly better off. The increase in consumer surplus is greater than the decrease in firms' expected payoffs.*

As any regulatory policy, enforcing mandatory disclosure necessitates regulatory agencies to incur non-trivial costs (see chapter 7 of Watts and Zimmerman (1986)). Hence, in the presence of enforcement costs, Proposition 3 actually shows that mandatory disclosure will reduce social welfare (net of the enforcement costs) when the industry demand parameters, (σ^2, a), belong to a set $\Theta \equiv \{(\sigma^2, a) \in \Re^2_+ \mid \sigma^2 \leq \frac{a^2}{16}\}$.[16] Note that such a negative consequence is more likely to occur (i.e., Θ expands) when the market size is large and the demand uncertainty is small. Thus, one policy implication of Proposition 3 is that, before implementing mandatory disclosure regulation in an industry, it is worthwhile for regulatory bodies to spend resources to acquire information about the industry demand parameters, (σ^2, a), upon which the welfare effect of mandatory disclosure critically depends. Without precise information about those parameters, mandating disclosure inevitably runs the risk of lowering social surplus.

3. Summary and Concluding Remarks

I have studied a game in which duopoly firms can produce either before or after they are privately informed about demand parameters. This game, labeled a preemption game, augments a standard information-sharing game under demand uncertainty in a way that the latter game is a proper subgame of the former game. In particular, the information-sharing game is played if, and only if, both firms delay production until when their demand information is available. In this framework, it is shown that firms' preemptive incentives might be so strong as to induce them to produce without any information. Such equilibrium behavior, which is to the firms' mutual disadvantage, is unavoidable when the market size is large relative to the demand uncertainty so that the incentive to be a Stackelberg leader is dominant over the incentive to make a more informed output decision. The analysis then demonstrates that regulatory implications suggested by the studies in the information-sharing literature need to be interpreted with caution. Specifically, it is shown that imposing a disclosure requirement might merely waste enforcement costs, or doing so might lead to a Pareto-inferior equilibrium allocation.

Even though it appears difficult to obtain public data for firms' production timing, one might empirically test the paper's results as follows. Consider a group of industries for which it is reasonable to assume linear demand functions (as applied in this study). For each industry, estimate the mean and variance of the demand intercept for a certain period of time. Then, each industry can be rank-ordered on the basis of the estimated mean of the demand intercept scaled by the estimated standard deviation of it. By definition, a highly ranked industry on average has a larger market size and exhibits more stable demand structure relative to a lower-rank industry. The paper's result that firms will produce after obtaining more precise demand information when the demand uncertainty is large relative to market size implies that, *ceteris paribus*, the firms' output in lower-rank industries will exhibit more volatility than the output of firms in highly ranked industries. Assuming that the demand parameters are persistent over time, the next step is to compute the average of the mean-adjusted quantity squared across the firms in each industry for a different period of time, and rank the industries based on this new measure. Then, a Spearman rank correlation coefficient might be an appropriate statistic to test whether the rank of industries based on the former measure is negatively associated with that based on the latter measure. In a similar vein, by comparing the average volatility of the output in an industry over two periods, which differ in terms of strength of regulatory disclosure requirements, one might test whether mandatory disclosure induces firms to give up their benefit from a more informed output decision.[17]

As any analytical study, this paper relies on several important assumptions. First, like most studies in the information-sharing literature, firms in my model are assumed to maximize their expected profits, i.e., they are risk neutral. However, as pointed out by Kao and Hughes (1993), firms' production and disclosure decisions are to a large extent delegated to managers whose wealth is often tied to the firms' profit. In such a case, risk aversion is another factor that enters into the trade-off relation between the preemptive incentive and the incentive to wait for more precise information. Intuitively, a manager is more likely to opt for delaying production when s/he is more risk averse. This follows from the fact that the amount of risk imposed on the manager is smaller when s/he delays production to make a more informed output decision than when s/he commits to production without information to preempt the rival.

Second, firms in my model compete in quantity and their private information is about uncertain industry demand, which is not disclosed in the absence of mandatory disclosure. However, it is well known in the literature that firms' equilibrium disclosure behavior is sensitive to model specifications. For example, it depends on whether firms compete in quantity or price as well as whether the information pertains to industry-wide (i.e., common) or firm-specific (i.e., private) value—see Vives (1990) for a survey of the results in the information-sharing games. Of particular note is that when firms compete in price and they have firm-specific private information (e.g., production costs), non-disclosure equilibrium prevails in the information-sharing game. Therefore, it would be interesting to see how the results in the present study will change if one assumes Bertrand (instead of Cournot) competition and private cost (instead of demand) information. I speculate that, in such a setting, firms' incentives to preempt their rival by committing to a price without cost information will be weakened. This is because, given that prices are strategic complements, there is a second-mover's advantage. I leave a formal analysis of this setting to future research.

Third, the model in this paper does not consider potential entrants into the market. Instead, it focuses on the efficiency implications of mandatory disclosure when firms have strategic considerations of their competitors who are already in the market. In contrast, a recent study by Hwang and Kirby (2000) examines the strategic effect of incumbent firms' disclosure of private cost information on a potential entrant's entry decision and its economic consequences. A key insight from their study is that, since the potential entrant's entry decision is a function of both the incumbents' cost disclosures and the entrant's (undisclosed) cost parameter, the incumbents can infer more precisely the entrant's private cost from its entry decision when the incumbents disclose their costs more accurately. Such an informational benefit motivates, for some parameter values, the incumbents to disclose their cost information in spite of disclosure-induced entry. I believe that if one introduces a potential entrant into my model (assuming that the entrant has private cost information), then there would be an additional trade-off relation similar to that identified by Hwang and Kirby (2000) even though incumbent firms' private information pertains to the industry demand in my model.

Finally, it is worth emphasizing that although my study focuses on the economic consequences of a mandatory disclosure requirement in the context of a duopoly product market, the conceptual framework offered in this study can be applied to other settings. For example, consider disclosures about environmental liabilities, over which firms have considerable discretion. Motivated by the paucity of disclosures, the SEC increased its oversight of firms' environmental liability disclosures over the period of 1991 to 1993. Barth, McNichols, and Wilson (1997) provide empirical evidence that the SEC's increased enforcement effort had a significant impact on firms' disclosure decisions. In this setting, it might be interesting to examine—in the spirit of the question addressed in this paper—whether the increased disclosure requirements and enforcement effort on environmental liabilities alter firms' incentive to undertake environmentally sensitive projects at the beginning. If so, such an indirect impact on the firms' project choice and its consequential welfare implications might deserve more attention than firms' disclosure behavior *per se*.

Appendix

Proof of Proposition 2: Table 1 is a normal-form representation of the preemption game and it summarizes two firms' equilibrium expected payoffs given in (4), (6), and (8). I verify that given the conditions stated in Proposition 2, no firm has an incentive to deviate from the stated strategy profile. For Part (i), assume $\sigma^2 \le \frac{a^2}{18}$. Suppose that firm 1 chooses C_1. Given C_1, C_2 is firm 2's best response if, and only if,

$$\frac{a^2}{9} \ge \frac{a^2}{16} + \frac{\sigma^2}{2} \Leftrightarrow \sigma^2 \le \frac{7a^2}{72}.$$

On other hand, if firm 1 chooses W_1, C_2 is optimal for firm 2 if, and only if,

$$\frac{a^2}{8} \ge \frac{a^2}{9} + \frac{\sigma^2}{4} \Leftrightarrow \sigma^2 \le \frac{a^2}{18}.$$

Since $\frac{7a^2}{72} > \frac{a^2}{18}$ for all $a > 0$ and we assume $\sigma^2 \le \frac{a^2}{18}$ here, C_2 is firm 2's dominant strategy. By symmetry, C_1 is also firm 1's dominant strategy. Taken together, it follows that $\boldsymbol{C} = (C_1, C_2)$ is the unique dominant strategy equilibrium in this case.

Following the same procedure as in Part (i), it can be verified that W_i is firm i's dominant strategy for all $i = 1, 2$, if $\sigma^2 \geq \frac{7a^2}{72}$. Thus, $\boldsymbol{W} = (W_1, W_2)$ is the unique dominant strategy equilibrium in this case, which proves Part (ii).

Finally, suppose that $\frac{a^2}{18} < \sigma^2 < \frac{7a^2}{72}$. If firm 1 chooses C_1, firm 2's best response is C_2 since $\sigma^2 < \frac{7a^2}{72}$ (see the proof of Part (i)). By symmetry, firm 1's best response to C_2 is C_1 as well. Thus, $\boldsymbol{C}$ is an equilibrium. Similarly, it is easy to see that $\boldsymbol{W}$ is also an equilibrium in this case since $\sigma^2 > \frac{a^2}{18}$. This proves Part (iii). ■

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Notes

1. See Bryan (1997) and Clarkson, Kao, and Richardson (1994) for the institutional details of MD&A requirement in the US and Canada, respectively. For an exhaustive list of the types of disclosures in MD&A, see Bryan (1997).
2. See chapter 7 of Watts and Zimmerman (1986) and chapter 7 of Beaver (1998).
3. Throughout this paper I use "sharing" and "disclosing" information interchangeably, assuming that information sharing occurs in a non-exclusionary fashion, e.g., via public disclosures. Studies on this subject include Ponssard (1979), Novshek and Sonnenshein (1982), Clarke (1983), Vives (1984, 1990), Gal-Or (1985b, 1986), Li (1985), Shapiro (1986), Hughes and Kao (1991, 1994), Feltham, Gigler, and Hughes (1992), and Darrough (1993), Kao and Hughes (1993), Raith (1996), Hughes, Kao, Mukherji (1998), among others.
4. In a strategic setting, making a decision prior to the arrival of information has the effect of a commitment, which is an important part of real business strategies. For example, in growing industries, firms often launch projects (e.g., increase plant capacity) in advance of the resolution of demand uncertainty even though doing so involves the risk of an *ex post* over-commitment. Another example of firms' commitment to their future production is to write forward contracts. To the extent that it is costly to renege upon contracts, forward contracts can be a credible commitment device. Of course, the question is under what circumstances firms will make such a commitment, which will be analyzed in this paper.
5. The fact that firms compete in quantities, which are strategic substitutes, is responsible for such a preemptive incentive (see Bulow, Geanakoplos, and Klemperer (1985), Gal-Or (1985a)).
6. In this regard, an observation by Elliott and Jacobson (1994, p. 85) is noteworthy: "The key factor in determining whether (disclosed) information ... creates competitive disadvantage is *timing*. ... Disclosure can be competitively disadvantageous or competitively *meaningless* depending on when disclosure is made" (emphasis added).
7. Although this paper's focus is on the social efficiency implications of a mandatory disclosure policy in a duopoly product market setting, the conceptual framework offered in this study can be applied to other settings of disclosure regulation, such as firms' disclosures about environmental liabilities. See Section 3 for a more detailed discussion on this matter.
8. Allowing δ_1 and δ_2 to be stochastically dependent does not change the paper's main results in a qualitative sense. The restriction on the space of a and $\underline{\delta}$ is to ensure that the firms' equilibrium outputs are non-negative for any realization of (δ_1, δ_2).
9. In this sense, I follow Spencer and Brander (1992) and Daughety and Reinganum (1994), ruling out the possibility of a partial commitment, in which case the committed firm might produce more at a later date.

Although the full commitment assumption is not entirely realistic, it allows me to focus on the paper's main question (i.e., the welfare consequences of mandatory disclosure) without complicating the analysis too much.

10. Note that although firm j can produce at date 2, it has no incentive to do so. By delaying its production until date 3, firm j can condition its output decision on its private demand information, δ_j, which improves production efficiency. To be more precise, as will be discussed in Section 2.2, firm j's output decision at date 3 is actually based upon both δ_j and δ_i, which is because the committed firm i in this case will disclose its private demand information to firm j.
11. Although the irreversibility of disclosure policy and truthful disclosure assumptions are commonly adopted in the information-sharing literature, they are crucial. Without the former assumption, unraveling dictates full disclosure equilibrium (see, e.g., Grossman (1981), Milgrom (1981)). Without the latter assumption, Ziv (1993) shows that no meaningful disclosure can take place in a standard information-sharing game. He then introduces a costly signaling mechanism, through which a truthful information-sharing equilibrium is sustained.
12. Gal-Or (1985a) shows that when two identical firms compete in quantity in a complete information setting, there is a first-mover's advantage. Subsequently, she demonstrates that the first-mover's advantage might disappear in an incomplete information setting (see Gal-Or (1987)). However, her latter study is different from mine in that the main force driving her result is that the follower can infer the leader's private information via the leader's output choice in fully separating equilibria. On the other hand, the first mover in my model has no private information, and thus, there is no signaling issue. Moreover, Gal-Or (1987) takes the firms' information endowment as given, whereas the firms in my model endogenously choose their information endowment by deciding whether to wait for their private information to arrive or to make a commitment with no private information.
13. Given the paper's earlier assumption $a + 4\underline{\delta} \geq 0$ (see Section 1), note that if the distribution of δ_i, $i = 1, 2$, is symmetric (which implies that $\overline{\delta} = -\underline{\delta}$), then we must have $a^2 \geq 16\sigma^2$ (since $\sigma^2 = E[\delta_i^2] \leq \overline{\delta}^2$). Hence, $a^2 \geq 8\sigma^2$ holds always. Of course, if the distribution of δ is asymmetric, $a^2 < 8\sigma^2$ can hold even when $a + 4\underline{\delta} \geq 0$. I am grateful to the referee for bringing this point to my attention.
14. In Part (iii), note that by symmetry there exists a mixed strategy equilibrium in which each firm plays "commit" or "wait" with a positive probability. However, as mentioned earlier, I restrict the analysis to the firm's pure strategy.
15. However, such coordination is impossible in Part (i) because, for all $i, j = 1, 2$ and $i \neq j$, no matter what strategy firm j chooses, firm i always has an incentive to choose C_i.
16. Furthermore, the positive impact of mandatory disclosure on social welfare in the case of $\sigma^2 > \frac{a^2}{16}$ (as stated in Part (iii) of Proposition 3) must be weighed against the enforcement costs.
17. The above discussions, of course, have to be further refined in order to control the factors that potentially have confounding effects. That is, for the industries during the period concerned, one needs to carefully take into account factors such as trends and cyclical changes in market demand, changes in firms' inventory, new entry and exit of firms, technology development that significantly changes firms' cost structure, regulatory actions other than disclosure, etc. See Jin (1996) for more detailed discussions of this issue. As an alternative to an empirical test, one might consider an experimental test, in which case the potentially confounding factors can be controlled more effectively. See Cason (1994) for more details.

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