Public Disclosure of Forward Contracts and Revelation of Proprietary Information

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January 20, 2002

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Acknowledgements:

We wish to acknowledge the useful comments of Paul Fischer, Steven Huddart, and especially Chandra Kanodia on an earlier version. Jennifer Kao receives financial support from Faculty of Business SAS funds for this project. All remaining deficiencies are entirely our own.

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ABSTRACT

Financial executives of firms engaged in forward contracting have raised concerns that mandated disclosure of those contracts would reveal proprietary information to rival firms. This paper considers the basis for those concerns in the framework of a duopoly in which one privately informed producer enters the forward market prior to production. In choosing its forward position, the firm considers the effects of that position on the forward price and second stage product market competition with its rival. Two regimes are considered: mandated disclosure and no disclosure. Under the former, the contracting firm faces a tension between exploiting its information advantage in the forward market and attempting to influence the production decision of its rival. On average, in equilibrium, the contracting firm gains a first-mover advantage, but at the cost of revealing its private information to its rival and extracting less expected gains from uninformed forward market participants. In contrast, with no disclosure, the contracting firm cannot influence rival firm beliefs, but extracts more expected gains from its private information in both the forward and product markets. On balance, the contracting firm prefers no disclosure. Moreover, parameterizations exist such that the rival also prefers that regime. These findings explain the opposition of respondents to draft proposals of Statement of Financial Standards No. 133.

1. Introduction

Controversy has surrounded accounting disclosure of derivative instruments for some time. With respect to forward contracts, executives of firms employing such contracts have argued that disclosure of contract terms would reveal proprietary information injurious to their competitive positions. Of late, this concern has been raised in response to the draft proposals of Statement of Financial Accounting Standards No. 133 (SFAS No. 133) entitled Accounting for Derivative Instruments and Hedging Activities. For example, in commenting on the results of a survey of over 300 financial executives by the Treasury Management Association (TMA) in 1997, Thomas Logan, Chairman of TMA, noted three major objections to more disclosure of derivatives including the following assessment of the effect on competition:

> *"Half of the respondents to the TMA survey stated that at least some of the disclosures required by the proposed FASB and SEC requirements would be proprietary information that could provide competitors with an unfair business advantage."*

The purpose of this paper is to assess the merit of these concerns and consider the larger issue of non-hedging incentives for firms to engage in forward contracts on future production. In the absence of an information asymmetry, Allaz (1992) identifies one such motive, i.e., a first-mover advantage. The basic idea is that forward contracts commit the contracting firm to more aggressive output decisions, which constructively preempt a portion of demand. Rival non-contracting firms react rationally to curtail their production, thereby conceding market share. Drawing on the insight of Bagwell (1995),[1] Hughes and Kao (1997) show that contract

[1] Bagwell (1995) has shown that even imperfect disclosure may be sufficient to eliminate the first-mover advantage in the classic Stackelberg game.

disclosure is crucial to achieving this advantage. When forward contracts are not disclosed, the contracting firm cannot influence rivals' beliefs and hence loses its first-mover advantage.

Introducing private information on the part of the contracting firm sets up a tension, not considered by Hughes and Kao (1997), between the disclosure of forward contracts as a device to implement a first-mover advantage and as a means for rivals to learn the contracting firm's information, thereby eliminating an information advantage in subsequent production decisions. Not only would the contracting firm lose its information advantage, but, similar to Gal-Or's (1987) results in her extension of the classic Stackelberg game to incorporate private information by the Stackelberg leader,[2] the prospect of influencing rival beliefs through disclosure of its forward position could cause the contracting firm to distort that position in a manner that undermines the first-mover advantage.

A further motive for a firm with private information to enter the forward market is to exploit an information advantage over other forward market participants obliged to trade for non-informational reasons. The contracting firm taking a position in the forward market is similar to that of an insider trading in the stock market. The setting here, however, is somewhat more complicated than in say Kyle's (1985) model due to the presence of a production continuation-game between the contracting firm and its rivals. While (*ex post*) disclosure of forward contracts would have no direct effect on expected gains to private information in the forward market, there could be indirect effects owing to the role of such disclosure with respect to the first-mover advantage and attempts to influence rival firm beliefs.

[2] Gal-Or (1987) shows that the only stable equilibrium in this context is one in which the contracting firm's private information is revealed in any event. However, the incentive to influence the follower's beliefs induces the leader to distort production from the level that would be optimal in the absence of this incentive. A similar effect occurs in our model, thereby diminishing the first-mover advantage that accompanies disclosure.

In this study, we characterize the consequences of disclosure by simultaneously taking into account the effects of information asymmetries in both forward markets and product markets. Specifically, we model a setting in which one of two, otherwise identical, producers of a homogeneous good receives private demand information and engages in forward contracting. Trades of other forward market participants are generated exogenously. Similar to the technique employed by Kyle (1985), a competitive broker sets forward prices to break even.[3] The principal forces facing the contracting firm are the desire to exploit its private information advantage over both the rival producer and uninformed forward market participants, and to implement a first-mover advantage over the rival producer. We consider two disclosure regimes: the contracting firm discloses or does not disclose its forward position prior to production.[4] Although risk aversion may also play a role in forward contracting decisions, we choose to abstract away from this aspect by assuming firms to be risk neutral. Incorporating a motive to hedge risks would complicate the analysis without altering our results on preferences towards disclosure in a qualitative sense.

The results of our analysis indicate that a privately informed firm engaged in forward contracting would prefer not to disclose its forward position to preserve an information advantage over rival firms in the production decisions that follow, and to better exploit its information advantage over other traders in the forward markets. While, on average, the firm gains a first-mover advantage at production stage of the game through disclosure of forward contracts, it is achieved at the cost of losing an information advantage to the rival producer. Moreover, the presence of a first-mover advantage provides the contracting firm with an

[3] The modeling choice of a Kyle-type setting is convenient, but not crucial for the informed traders to profit at the expense of uninformed traders, provided the latter have incentives to trade notwithstanding their informational disadvantage (e.g., Bhattacharya and Spiegel 1991).

incentive to distort its forward position away from the position that would be optimal if the sole purpose was to exploit its information advantage in the forward market.[5] On balance, the gains from retaining an information advantage at the production stage and eliminating a dysfunctional incentive to distort one's forward position in extracting gains from private information in the forward market outweigh the loss of a diminished first-mover advantage.

Further results indicate that, depending on the level of noise trading by other participants in the forward market, the rival firm may be better off with or without disclosure by the contracting firm. There are two opposing effects of disclosure on the rival to consider, one beneficial and the other detrimental. The former is made possible because disclosure informs the rival of the otherwise unknown level of demand, and allows it to adjust production to a more efficient level in situations where actual demand differs from the expected one. The latter occurs because, on average, the contracting firm gains a first-mover advantage with disclosure. *Ex post*, for demand realizations near the mean, the net effect of disclosure makes the rival worse off; whereas for demand realizations far from the mean, it makes the rival better off. *Ex ante*, the net effect of disclosure depends on how much the rival gains as demand varies from its mean. Substantial noise in the forward market induces the contracting firm to respond in a more contrarian way to demand in choosing its production that, in turn, enables the rival to capture the greater production efficiency benefits when extreme demand realizations are observed. With sufficient noise, the rival benefits *ex ante* from disclosure. Otherwise, disclosure harms the rival.

Uninformed forward market participants are always better off when the contracting firm discloses forward contracts. This is because the incentive to achieve a first-mover advantage and

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[4] We assume that mandated disclosure is credible due to audits and legal liability, and that non-mandated disclosure is not credible due to the absence of those devices.

the incentive to influence a rival's beliefs through the position taken in the forward market under disclosure alter the incentives of the privately informed contracting firm in the forward market, thereby lowering the expected losses of the uninformed market participants.

To appreciate the role of an information asymmetry in the forward market, we also consider a setting in which other forward market participants are informed. Although the contracting firm's information advantage in the forward market would be severely diminished by competition even if only a small number of other forward market participants were informed, we assume as a modeling convenience the limiting case where that advantage is completely dissipated. In this case, the only trade-off facing the contracting firm is between surrendering an information advantage over its rival producer through disclosure of its forward position and forgoing a first-mover advantage when that position is not disclosed. Not surprisingly, the contracting firm's disclosure decision depends crucially on the value of its private information as measured by the variance of demand. When that value is low, the contracting firm prefers a policy of disclosing forward contracts because in this case information advantage is too small to justify giving up a first-mover advantage.

To summarize, within the context of our model, the gain to the contracting firm from retaining both its information advantage over rival producers and its ability to more fully exploit the uninformed forward market participants when forward contracts are not disclosed outweighs the loss of a first-mover advantage in production decisions when those contracts are disclosed.[6]

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[5] Of course, it is also true that the presence of an information advantage in the forward market motivates the contracting firm to distort its forward position away from the optimal level obtained when exploiting a first-mover advantage were the only concern.

[6] Concavities in profit functions due to progressive taxes, agency conflicts, or risk aversion *per se* would further enhance the prospects of entering the forward market under disclosure; e.g., Froot, Scharfstein, and Stein (1993).

Only in the less plausible case where the information asymmetry does not extend to the forward market do we find conditions under which the contracting firm would prefer no disclosure.[7]

A number of studies in the accounting literature have considered the economic consequences of alternative methods of accounting for derivatives and positions hedged by these instruments. For example, DeMarzo and Duffie (1995) show that disclosure of hedge positions can affect hedge decisions in an adverse selection setting. Jorgensen (1997) models how the accounting treatment for hedges can impact on a moral hazard problem. Fischer (1999) provides conditions under which a firm can assist its employees in managing their exposure to risk through compensation when they are otherwise unable to do so due to moral hazard. Melumad, Weyns, and Ziv (1999) depict ways in which a particular accounting method employed by the firm may influence hedge positions taken by its managers. As a final example, Kanodia, Mukherji, Sapra, Venugopalan (2000) characterize the properties of futures prices as aggregators of private information in contexts where coincidental firm disclosures may also play a role. However, to the best of our knowledge, the concern expressed by managers in practice that disclosure of derivatives might disadvantageously reveal proprietary information to rival firms has not been addressed.

The remainder of the paper is organized as follows: Section 2 presents our analysis; Section 3 considers the setting wherein the only information asymmetry pertains to rival firms; and Section 4 concludes the paper.

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[7] Some executives have suggested that an accounting standard requiring disclosure of forward positions would force firms to reconsider entering the forward market. For example, in his testimony before the Securities Subcommittee of the U.S. Senate Banking Urban Affairs Committee in 1997, Thomas Wolfe, Chairman and CEO of Hershey Foods Corporation, commented that: *". . . if FASB's proposal is adopted, Hershey simply could not afford to provide its competitors with the information FASB's rule would reveal. We would have to explore other means of managing the risk of cocoa price movements. . ."* Our results suggest that such an action is unlikely. Although outputs rather than prices are the control variable in our model, Kreps and Scheinkman (1983) show quantity commitments and Bertrand price competition replicate Cournot competition.

2. Analysis

2.1 Basic Model

We assume that the industry consists of two expected profit-maximizing firms, denoted Firm 1 and Firm 2. At time 0, one of the firms, Firm 1, privately observes a demand parameter, a, and chooses a forward quantity, Q_1^f.[8] Firm 2 does not observe a, nor does it trade in the forward market. Although our analysis only considers the asymmetric case where just one firm is uninformed and participates the forward market, similar incentives would also be present in the symmetric case where both firms are privately informed and participate in the forward market. More is said about alternative assumptions in our conclusion.

For modeling purposes, we further assume that a competitive broker receives an order for this quantity, Q_1^f, intermixed with the aggregate order flow, Q_n^f, from other uninformed forward market participants whose trades are generated exogenously. The demand parameter, a, is normally distributed with mean $\bar{a} > 0$ and variance s_a^2, and the aggregate uninformed forward order, Q_n^f, is normally distributed with mean 0 and variance s_n^2. Random variables a and Q_n^f are independent. The broker is assumed to observe only the total order flow, $Q_t^f = Q_1^f + Q_n^f$ and sets the forward price as a linear function of the unexpected order flow, allowing him to break even in expectation, i.e.,

$$P^f = a - b\left(Q_t^f - E\left[Q_1^f\right]\right), \tag{1}$$

[8] Our analysis only considers the asymmetric case where one firm is privately informed. However, similar incentives for trading in the forward market would be present if both firms received private signals. Moreover, the preference for non-disclosure shown below would be strengthened by the joint desire to avoid dysfunctional strategic behavior in this case. We return to this and a further observation in our conclusion.

where a and b are endogenously determined parameters. At this stage, linearity in the pricing rule is merely conjectured, as in Kyle (1985). We will subsequently validate this conjecture by demonstrating that, in equilibrium, the market maker's posterior expectation of the future spot price is linear in the total order flow.

At time 1, Firms 1 and 2 choose their outputs from production, Q_1 and Q_2, respectively. Without loss of generality, marginal cost for both firms is assumed to be a constant c, $\overline{a} > c > 0$. In the non-disclosure regime, Firm 2 makes its production choice without observing Q_1^f (see Section 2.2). In the disclosure regime, Firm 2 observes Firm 1's forward quantity, Q_1^f, prior to making its output decision (see Section 2.3). For both regimes, Firm 2's conjectures about the demand parameter and forward position of Firm 1 are denoted as a^* and Q_1^{f*}, respectively.

At time 2, the demand parameter, a, is realized and the spot price, P, is determined by the following linear inverse demand function:

$$P = a - b\,(Q_1 + Q_2),\;\; b > 0. \qquad (2)$$

Note that Firm 1 can perfectly anticipate the spot price, P, at the time of forward market participation. This is an unnecessarily strong assumption made solely for mathematical tractability. If, instead, Firm 1 were to receive a noisy signal for a, this would merely lead to variance in P, that would increase the variance in profits, but due to symmetry, would have no effect on expected profits and thus have no effect on behavior.

Finally, at time 3, Firm 1 covers its forward position, both firms sell their production, and firm profits are realized. Figure 1 provides a time line of these events.

[Insert Figure 1 about here]

Profit functions of Firm 1 and Firm 2 are

$$\Pi_1 = (P_f - P)Q_1^f + (P - c)Q_1, \tag{3}$$

$$\Pi_2 = (P - c)Q_2, \tag{4}$$

respectively. The first term on the right-hand-side (RHS) of (3) represents Firm 1's profits in the forward market. It is the presence of this term that distinguishes Firm 1's objective function at this stage from standard Cournot competition. We can see that since Firm 1's profit on its forward position depends on the firm's production decision through the spot price, it may have incentive to increase or decrease production by comparison to the standard Cournot solution. Production decisions for Firm 1 and Firm 2 can be determined from the following first-order conditions (FOCs):

$$\frac{\partial \Pi_1}{\partial Q_1} = a - c - b\left(2Q_1 - Q_1^f + Q_2\right) = 0,$$

$$\frac{\partial E[\Pi_2]}{\partial Q_2} = a^* - c - b(E[Q_1] + 2Q_2) = 0,$$

respectively. Since Firm 2 does not observe demand, its output choice depends on its conjecture of demand and its expectation of Firm 1's output.

As shall be demonstrated, Firm 2's conjecture of Firm 1's production will satisfy

$$Q_1^* = E[Q_1] = Q_2 + Q_1^{f*}. \tag{5}$$

Substituting Q_1 from Firm 2's FOC with (5) and solving for Q_2 lead to

$$Q_2 = \frac{a^* - c}{3b} - \frac{Q_1^{f*}}{3}. \tag{6}$$

From (6) it is apparent that to the extent that Firm 1 can influence Firm 2's beliefs about demand and Firm 1's forward position through its disclosure policy, then it can influence Firm 2's production. In particular, inducing beliefs of weaker demand or a greater forward quantity would result in lower output by Firm 2 and the prospect of Firm 1 capturing a larger market share. Note that in the absence of a forward market, Firm 2's output would correspond to the output of a standard Cournot duopolist facing uncertain demand.

Replacing Q_2 in Firm 1's FOC with (6) and solving for Q_1, we obtain

$$Q_1 = \frac{3a - a^* - 2c}{6b} + \frac{Q_1^f}{2} + \frac{Q_1^{f*}}{6}. \qquad (7)$$

Since $a^* = E(a)$ and $Q_1^{f*} = E(Q_1^f)$, it is easily checked that Firm 2's conjecture regarding Firm 1's expected production, (5), is fulfilled. Here again, the presence of a forward market distorts production by comparison to the standard Cournot solution with asymmetric information. In effect, forward contracting is means of committing to future production. Indeed, if there were no information asymmetries (Firm 2 could observe both demand and Firm 1's forward position), then as we show in Section 3 Firm 1's output would correspond to that of a Stackelberg leader.

Substituting (7) and (6) for Q_1 and Q_2 in (2), the spot price can be re-expressed as follows:

$$P = \frac{a}{2} - \frac{a^*}{6} + \frac{2c}{3} - \frac{b}{2}Q_1^f + \frac{b}{6}Q_1^{f*}. \qquad (8)$$

The spot price is increasing in demand, *a*, and decreasing in Firm 1's forward quantity, Q_1^f. The explanation for the latter is that Firm 1's forward position represents committed output that increases total production. However, to the extent that Firm 2 anticipates demand, a^*, and Firm 1's forward position, Q_1^{f*}, their effects on price are attenuated by Firm 2's strategic response to these beliefs.

This concludes the discussion of the production sub-game. We next characterize the forward-contracting sub-game for each of the disclosure regimes.

2.2 No Disclosure Regime

If Firm 1 does not disclose its forward position, Firm 2 learns nothing about either the forward market or the spot market demand parameter, a.[9] In this case, Firm 2's conjecture about a is given by the mean of the distribution, and its conjecture about Q_1^f is given by an endogenously determined constant g, i.e.,

$$a^* = \bar{a} \text{ and } Q_1^{f*} = g. \tag{9}$$

We assume in this section that Firm 2 observes neither the forward quantity nor forward price at which Firm 1 traded. It might be reasonable to expect that if the forward market is public, then the forward price would be observable, and Firm 2 could use this information to infer a noisy estimate of Firm 1's forward quantity.[10] That case (with price but not quantity observed) is significantly more complex mathematically and might be intractable. Moreover, explicit derivation of that case is unlikely to provide new insight. In effect, this case is equivalent to noisy disclosure of forward quantity and, therefore, is basically a convex combination of the two extreme cases of no disclosure and full disclosure analyzed in the paper.

With these conjectures, the production stage equilibrium, (6)-(8), can be restated as follows:

$$Q_1 = \frac{3a - \bar{a} - 2c}{6b} + \frac{Q_1^f}{2} + \frac{g}{6}, \quad Q_2 = \frac{\bar{a} - c - bg}{3b}, \tag{10}$$

$$P = \frac{a}{2} - \frac{\bar{a}}{6} + \frac{2c}{3} - \frac{b}{2} Q_1^f + \frac{b}{6} g. \tag{11}$$

[9] We point out that given Firm 2 has no information advantage, then given a no disclosure regime it has no incentive to enter the forward market.

[10] Recall that the forward price depends upon the total order flow and, therefore, includes a random portion attributable to uninformed forward market participants. Additionally, it may be incrementally costly to monitor the forward market for a firm not active as a participant.

To solve for g, observe from (1) that when $a = \overline{a}$ and $Q_1^f = E\left[Q_1^f\right] = g$, the forward price P^f equals the intercept of forward demand function, a. The market maker's breakeven condition requires that on average (and given linearity in the average case), the forward price, a, must equal the spot price, *P*, given by (11) with $a = \overline{a}$ and $Q_1^f = E\left[Q_1^f\right] = g$. Thus,

$$a = \frac{\overline{a} + 2c - bg}{3}. \tag{12}$$

Now consider Firm 1's choice of forward position. Taking the derivative of its expected profits with respect to Q_1^f, setting the resulting expression to zero,[11] and solving for Q_1^f, we obtain:

$$Q_1^f\left(2b - \frac{b}{2}\right) = \frac{\overline{a} + 2c - bg}{3} + bg - \left(\frac{a}{4} - \frac{\overline{a}}{12} + \frac{5c}{6} + \frac{b}{12}g\right) - \left(\frac{3a - \overline{a} - 2c}{12} + \frac{bg}{12}\right).$$

$$Q_1^f = \frac{\overline{a} - a + (2b - b)g}{4b - b}. \tag{13}$$

The forward quantity, Q_1^f, is decreasing in unexpected demand, $(a - \overline{a})$, since it is better to enter a forward contract to buy (go long) rather than to sell (go short) when demand is strong. We further note that the absolute forward quantity is decreasing (increasing) in the slope of the forward price function (demand curve).

Since g is the average choice of Q_1^f, it is straightforward to see that, after taking expectation of (13), the only g that satisfies the resulting expression is zero. In other words,

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$$\frac{\partial E[\Pi_1]}{\partial Q_1^f} = E\left[P_f\right] - P + \frac{\partial P_f}{\partial Q_1^f}Q_1^f + \frac{\partial P}{\partial Q_1^f}\left(Q_1 - Q_1^f\right) + (P - c)\frac{\partial Q_1}{\partial Q_1^f}$$
$$= a - b\left(Q_1^f - g\right) - \frac{1}{2}\left(\frac{a}{2} - \frac{\overline{a}}{6} + \frac{2c}{3} - \frac{b}{2}Q_1^f + \frac{b}{6}g + c\right) - bQ_1^f - \frac{b}{2}\left(\frac{3a - \overline{a} - 2c}{6b} + \frac{Q_1^f}{2} + \frac{g}{6} - Q_1^f\right) = 0. \quad .$$

based on its prior beliefs about demand, Firm 2 conjectures that Firm 1 chooses a zero forward position and Firm 1 fulfills that conjecture by doing so in expectation.

At $g = 0$, (12) and (13) become

$$a = \frac{\bar{a} + 2c}{3}, \tag{14}$$

$$Q_1^f = \frac{\bar{a} - a}{4b - b}, \tag{15}$$

where a is a function of known parameters $\bar{a}$ and c, and Q_1^f depends in part on the endogenously determined slope of the forward price function, b. The break-even requirement of the broker in the forward market implies that the forward price must equal the expected future spot price conditional on the forward order flow. That is, the slope of P^f must equal the slope of $E\left[P \middle| Q_t^f\right]$:

$$\begin{aligned} b &= -\frac{dP}{dQ_1^f}\frac{dE\left[Q_1^f \middle| Q_t^f\right]}{dQ_t^f} = -\left(\frac{\partial P}{\partial Q_1^f} + \frac{\partial P}{\partial a}\middle/\frac{\partial Q_1^f}{\partial a}\right)\frac{\mathrm{Var}\left(Q_1^f\right)}{\mathrm{Var}\left(Q_1^f\right) + s_n^2} \\ &= 2b\,\frac{s_a^2 \big/ (4b - b)^2}{s_a^2 \big/ (4b - b)^2 + s_n^2}. \end{aligned}$$

Solving for b from the above expression and recognizing that any solution needs to satisfy the second-order-condition (SOC) that requires $b > \frac{b}{4}$, we obtain the following solution:

$$b = \frac{1}{4}\left(b + \frac{s_a}{s_n}\right). \tag{16}$$

Note that b could also be derived as a linear regression slope coefficient, which equals the negative of the ratio of the covariance of the spot price and total order flow to the variance of the total order flow as in Kyle (1985), yielding the same result.

Substituting for a and b from (14) and (16), respectively, in (15) and (1) results in the following equilibrium forward quantity and expected forward price conditional on a:

$$Q_1^f = \frac{s_n}{s_a}\left(\bar{a} - a\right), \tag{17}$$

$$E\left[P^f \,|a\right] = \frac{\bar{a} + 2c}{3} - \frac{1}{4}\left(b + \frac{s_n}{s_a}\right)\left(\frac{s_n}{s_a}\left(\bar{a} - a\right)\right). \tag{18}$$

The firm goes long in the forward market (commits to buy) when demand exceeds expectations and the spot price will therefore exceed expectations. Similarly, the firm goes short (commits to sell) if demand is unexpectedly low. Trading intensity increases in the ratio of noise to signal variance, as that ratio determines how much disguise is provided by the presence of uninformed traders. Given the firm's trade, it expects a higher forward price when demand is stronger, due to the market maker inferring part of the firm's information from the order flow.

Having arrived at Q_1^f, the equilibrium outputs and equilibrium spot price for the production stage, (10) and (11), become:[12]

$$Q_1 = \frac{3\left(1 + b\frac{s_n}{s_a}\right)a - \left(1 - 3b\frac{s_n}{s_a}\right)\bar{a} - 2c}{6b}, Q_2 = \frac{\bar{a} - c}{3b}, \tag{19}$$

$$P = \frac{3\left(1 + b\frac{s_n}{s_a}\right)a - \left(1 + 3b\frac{s_n}{s_a}\right)\bar{a} + 4c}{6}. \tag{20}$$

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[12] Note that $Q_1 = \frac{3a - \bar{a} - 2c}{6b} + \frac{Q_1^f}{2} + \frac{g}{6} = \frac{3a - \bar{a} - 2c}{6b} + \frac{\frac{s_n}{s_a}(\bar{a} - a)}{2}$.

Firm 1's uncommitted output increases in demand, as would be the case absent forward contracting. The use of forward contracts increases this effect, since the forward position is negatively related to demand (to maximize forward market trading profits), and uncommitted output shifts in the opposite direction to partially offset the effect on total demand. Overall, forward trading leads to the spot price being more sensitive to demand than in the absence of forward markets. This sensitivity is to Firm 1's advantage in trying to maximize forward market trading profits, but reduces Firm 1's production profits.

Ex ante, the expected profits of Firm 1 and Firm 2 can be determined by first replacing Q_1^f, P^f, Q_1, Q_2, and P in (3) and (4) with (17)-(20) as appropriate and then taking the expectations (see the appendix for details in deriving (21)):

$$E[\Pi_1] = \frac{s_a(bs_n + s_a)}{4b} + \frac{(\bar{a}-c)^2}{9b}, \tag{21}$$

$$E[\Pi_2] = \frac{(\bar{a}-c)^2}{9b}. \tag{22}$$

The following comparative statics are immediate:

$$\frac{\partial E[\Pi_1]}{\partial s_n} = \frac{s_a}{4} > 0,\ \ \frac{\partial E[\Pi_1]}{\partial s_a} = \frac{bs_n + 2s_a}{4b} > 0,\ \ \frac{\partial E[\Pi_2]}{\partial s_n} = 0,\ \ \frac{\partial E[\Pi_2]}{\partial s_a} = 0. \tag{23}$$

Constructively, more noise in the forward market provides Firm 1 with greater disguise such that it can extract higher expected gains. These gains are partially dissipated by distortions in production. Given high (low) demand, Firm 1 has an incentive to under- or over-produce relative to the case with no forward market information asymmetry in order to manipulate the spot price. For example, by over-producing when demand is low, Firm 1 seeks to reduce the spot price at which it will cover its forward position to sell at the pre-set forward price. Although Firm 2's actual profits depend on the realizations of Q_t^f and a, its expected profits do not, because without disclosure Firm 2 learns nothing about the forward market. Clearly, if there were no information asymmetry $\left(\text{i.e.}, s_a^2 = 0\right)$ or no noise trading $\left(\text{i.e.}, s_n^2 = 0\right)$, then there would be no scope for the contracting firm to extract gains in the forward market. In either case, *ex ante*, Firm 1's expected profits are the same as those in the standard Cournot model with information asymmetry and no forward market.

2.3 Disclosure Regime

In contrast to the no disclosure regime, when Firm 1 publicly discloses its forward position, Firm 2's conjectures about the unknown spot market demand parameter will reflect that position, i.e.,

$$a^* = \bar{a} - l\,b\left(Q_1^f - g\right) \text{ and } Q_1^{f*} = Q_1^f, \tag{24}$$

where g and l are both to be determined endogenously later. As before, linearity is merely conjectured, and we will subsequently validate it.

Given (24), the production stage equilibrium, (6)-(8), can be characterized as follows:

$$Q_1 = \frac{3a - \bar{a} - 2c + (l + 4)bQ_1^f - lgb}{6b}, \quad Q_2 = \frac{\bar{a} - l\,b\left(Q_1^f - g\right) - c - bg}{3b}, \tag{25}$$

$$P = \frac{3a - \bar{a} + 4c + (l - 2)bQ_1^f - lgb}{6}. \tag{26}$$

Again, setting $a = \bar{a}$ and $Q_1^f = E\left[Q_1^f\right] = g$ and invoking the equilibrium break-even requirement of the broker, i.e., $P^f = E\left[P \middle| Q_t^f\right]$, allow us to express the forward demand intercept as the expected spot price, as shown below:

$$a = \frac{\bar{a} + 2c - bg}{3} \tag{27}$$

Solving from Firm 1's FOC with respect to Q_1^f results in the following intermediate expression for Q_1^f (see the appendix for further details):

$$Q_1^f = \frac{(8-l)\bar{a} - 2(l+1)c + 3(l-2)a + \left[18b - \left(l^2 - 2l + 6\right)b\right]g}{36b - (l-2)^2 b}, \tag{28}$$

where, in addition to g and l, b is also an endogenous variable. Notice that b can be determined from an equilibrium relationship by setting the slope of Firm 2's conjecture about a, i.e., $-lb$, from (24) to be equal to the reciprocal of $\frac{\partial Q_1^f}{\partial a}$.[13] On the other hand, g can be solved for from the expectation of (28), after some simplification.[14] Both b and g are functions of l:

$$b = -\frac{b}{18}(l-2)(l+1). \tag{29}$$

$$g = \frac{2(\bar{a} - c)}{(4-l)b}. \tag{30}$$

The SOC requires that $0 < l < 2$, so b is positive. Clearly, g is positive as well. Thus, on average, Firm 1 takes a positive (short) forward position, committing to production and thereby gaining a first mover advantage, compelling Firm 2 to reduce production on average.

Given (30), we can restate the equilibrium production quantities and spot price, (25)-(26), in terms of l, exogenous model parameters, $\bar{a}, b,$ and c, and demand realization, a:[15]

$$Q_1 = \frac{2(l+4)\bar{a} - (2-l)(4-l)a - l(8-l)c}{3(4-l)lb}, \quad Q_2 = \frac{(a-c)(2-l)}{3b(4-l)}, \tag{31}$$

---

13 It is easy to see that $\frac{1}{\frac{\partial Q_1^f}{\partial a}} = \frac{36b - (l-2)^2 b}{3(l-2)}$ is negative since $l < 2$ and $b > 0$.

14 It is given by $g = \frac{(8-l)\bar{a} - 2(l+1)c + 3(l-2)\bar{a} + [18b - (l^2 - 2l + 6)b]g}{36b - (l-2)^2 b}$.

$$P = \frac{(l+1)(4-l)a - (l+4)\bar{a} + 2l(5-l)c}{3l(4-l)}. \tag{32}$$

(31) makes the first-mover effect transparent. The ratio of the terms containing l in the equation for Q_2 is less than 1, implying that Firm 2's production is less than it would be in standard Cournot competition with no information asymmetry. However, concomitant with incurring this second-mover penalty, Firm 2 benefits from learning a and being able to use this knowledge to adjust production to better match demand.

Using (30) in (27), a can also be expressed as a function of l:

$$a = \frac{(2-l)\bar{a} + 2(5-l)c}{3(4-l)}. \tag{33}$$

Substituting for the just derived b, g, and a in (1) and (28), we obtain the following expected forward price conditional on a and Firm 1's forward position (see the appendix for derivation of (35)):

$$E\left[P_f \,|a\right] = \frac{(2-l)\bar{a} + 2(5-l)c}{3(4-l)} + \frac{b}{18}(l-2)(l+1)\frac{\bar{a}-a}{lb}, \tag{34}$$

$$Q_1^f = \frac{(4+l)\bar{a} - 2lc - (4-l)a}{(4-l)lb}. \tag{35}$$

It is clear from the above discussion that all the endogenous model parameters and equilibrium outcomes depend on another endogenous variable, l, which is examined next. First note that, as with the no disclosure regime, the slope of the forward pricing function must equal the change in the expected spot price conditional on Q_1^f, i.e.,

---

[15] Note that $Q_1 = \frac{3a-\bar{a}-2c+(l+4)bQ_1^f - lgb}{6b} = \frac{3la - l\bar{a} - 2lc + (l+4)(\bar{a}-a) + 4lbg}{6bl} = \frac{4\bar{a}+2(l-2)a-2lc+4lb\frac{2(c-\bar{a})}{(l-4)b}}{6bl}$.

$$
\begin{aligned}
b &= -\frac{dP}{dQ_1^f}\frac{dE\left[Q_1^f \middle| Q_t^f\right]}{dQ_t^f} = -\left(\frac{\partial P}{\partial Q_1^f} + \frac{\partial P}{\partial a}\Big/\frac{\partial Q_1^f}{\partial a}\right)\frac{\mathrm{Var}\left(Q_1^f\right)}{\mathrm{Var}\left(Q_1^f\right) + s_n^2} \\
&= -\left(\frac{(l-2)b}{6} - \frac{1}{2} / \frac{1}{l b}\right)\frac{s_a^2/(l b)^2}{s_a^2/(l b)^2 + s_n^2} \qquad (36) \\
&= \frac{(l+1)b}{3}\frac{s_a^2\big/(l b)^2}{s_a^2\big/(l b)^2 + s_n^2}.
\end{aligned}
$$

Equating the RHSs of (29) and (36) and rearranging terms result in a cubic function in l :

$$
(2-l)\, l^2 b^2 s_n^2 - (l+4) s_a^2 = 0. \qquad (37)
$$

A solution to (37) exists provided that there is sufficient noise relative to the information asymmetry in the forward market, i.e., $\frac{s_a^2}{b^2 s_n^2} < 0.223427.$[16] In this case, there are two roots to (37), which cannot be ruled out by the SOC $\left(\text{i.e.,} 0 < l < 2\right).$ However, as is demonstrated in the appendix, the solution with the lower value of l yields a Pareto-dominant equilibrium over the other. When there is little noise, the forward market breaks down and trade becomes impossible.

Several comparative statics are worth noting at this point:

$$
\frac{dg}{d\,l} > 0; \quad \frac{dQ_1}{da} = \frac{l-2}{3 l b} < 0; \quad \frac{dP}{da} = \frac{l+1}{3l} > \frac{1}{2} = \frac{\partial P}{\partial a}. \qquad (38)
$$

The first result indicates that a low value of l is consistent with on average less commitment by Firm 1 to over produce in its attempt to influence Firm 2's beliefs through the disclosed position in the forward market. This implies that Firm 2 is better off than in the case when l is small since less over production by Firm 1 translates into higher spot prices and greater market share for Firm 2. The third result, that a low l creates greater sensitivity of spot price to demand, implies that low l magnifies the value of Firm 1's private information in the forward market and

[16] This value was determined numerically and represents the maximum that the ratio can achieve such that a λ satisfying the SOC solves (37).

increases its forward trading profits. This provides a rationale for the Pareto dominance of the lower value of l mentioned above.

The second result in (38) that, at the margin, higher demand induces Firm 1 to lower its production is surprising. With disclosure, Firm 2 learns a from Firm 1's disclosed forward position. As demand increases, Firm 2 increases its output. Firm 1 reacts to Firm 2's increased output by reducing its own output. At the same time, Firm 1 has an incentive to enhance its expected profits in the forward market by manipulating the spot price, which again leads to lower production by Firm 1, in response to strong demand. The last result in (38) implies that the presence of the forward market increases the sensitivity of the spot price to demand and is a consequence of Firm 1's manipulation of the spot price through subsequent production. Since l is increasing in $\frac{s_a^2}{b^2 s_n^2}$, greater noise in the forward market intensifies this effect.

Given (31), (32), (34), and (35), the *ex ante* total profits of Firm 1 and Firm 2 become:

$$\begin{aligned} E[\Pi_1] &= E\left[\left(P_f - P\right)Q_1^f\right] + E\left[(P-c)Q_1\right] \\ &= \frac{(l+1)(2-l)bs_n^2}{18} + \frac{(2-l)(8-l)(\bar{a}-c)^2}{9(4-l)^2 b} - \frac{(l+1)(2-l)s_a^2}{9l^2 b} \qquad (39) \\ &= \frac{(2-l)(8-l)(\bar{a}-c)^2}{9(4-l)^2 b} + \frac{(l+1)s_a^2}{6lb}, \end{aligned}$$

$$E[\Pi_2] = E\left[\frac{(P-c)^2}{b}\right] = \frac{(l+1)^2 s_a^2}{9l^2 b} + \frac{(2-l)^2(\bar{a}-c)^2}{9(4-l)^2 b}, \qquad (40)$$

respectively. The first (second) term after the first equality sign of (39) is Firm 1’s expected profits from the forward market (production). Again, both firms’ expected profits depend on l, or equivalently, on the variance of both noise trades and the demand parameter in the spot market (i.e., s_n^2 and s_a^2). It is useful to consider the behavior of these expected firm profits as the variance of noise trades in the forward market, s_n^2, increases to infinity. For Firm 1, the limit approaches $\frac{(\bar{a}-c)^2}{9b}+\frac{s_a s_n}{6\sqrt{2}}$; whereas that for Firm 2 is $\frac{bs_n^2}{18}+\frac{(\bar{a}-c)^2}{36b}$. The former result implies that, as noise trading becomes large, Firm 1's expected profits increase approximately linearly with the standard deviation of noise trades. Firm 2, on the other hand, can benefit without bound from disclosure by Firm 1, when trades in the forward market become increasingly noisier.

2.4 Comparison of Disclosure Regimes

Having characterized the expected profits for Firm 1 and Firm 2 under no disclosure and disclosure regimes, we are now in a position to examine the effect of disclosure on both firms and other uninformed forward market participants.

First consider Firm 1. The difference in expected profits across disclosure regimes is as follows:

$$E\left[\Pi_1 \middle| \text{Disclosure}\right]-E\left[\Pi_1 \middle| \text{No Disclosure}\right] \tag{41}$$

$$<\left[\frac{(\bar{a}-c)^2}{9b}+\frac{s_a s_n}{6\sqrt{2}}\right]-\left[\frac{s_a(bs_n+s_a)}{4b}+\frac{(\bar{a}-c)^2}{9b}\right]=\frac{2bs_a s_n-3\sqrt{2}s_a(bs_n+s_a)}{12\sqrt{2}b}<0,$$

where the expression within the first square bracket denotes the upper bound under disclosure as $s_n^2 \to \infty$, and that within the second square bracket is the RHS of (21) under no disclosure. Since the difference is negative given Firm 1’s limiting expected profit function under disclosure, it must continue to hold with any finite level of noise trading. Thus, we have our first proposition:

Proposition 1 *Firm 1 strictly prefers no disclosure of forward contracts to disclosure of such contracts.*

Proposition 1 provides a rationale for the claim made by producers that they would suffer competitive injury due to the revelation of proprietary information to rival firms if the FASB's proposed forward contract disclosure requirement were to become law. These claims are subtle in that a privately informed firm not only prefers to deny rival firms' access to its private information, but also desires to avoid incentives that could undermine its ability to extract gains from such information in the forward market.

Turning next to Firm 2, the difference in expected profits is as follows:

$$
\begin{aligned}
&E\left[\Pi_2 \,\middle|\, \text{Disclosure}\right] - E\left[\Pi_2 \,\middle|\, \text{No Disclosure}\right] \\
&= \left[\frac{(l+1)^2 s_a^2}{9l^2 b} + \frac{(2-l)^2(\bar{a}-c)^2}{9(4-l)^2 b}\right] - \left[\frac{(\bar{a}-c)^2}{9b}\right], \\
&= \frac{4(3-l)}{9(4-l)^2 b}\left[\frac{(l+1)(2-l)(4-l)^2}{4(3-l)(l+4)} b^2 s_n^2 - (\bar{a}-c)^2\right],
\end{aligned}
\qquad (42)
$$

where the expected profits in the two regimes are given by the RHS of (40) and (22), and (37) is substituted into the equation to remove s_a^2. The sign of the above difference in expected profits depends on the terms in brackets. Because the ratio involving l within the brackets is narrowly bounded (recall $0 < \lambda < 2$) and does not vary substantially as l changes,[17] the principal determinants of whether disclosure increases expected profits of Firm 2 are the remaining terms. An increase in the slope of the demand function, *b*, increases the attractiveness of disclosure because errors in estimating demand are more costly when the demand curve is steep. More noise in the forward market, s_n^2, also makes disclosure more attractive since it induces Firm 1 to undermine its effort to obtain a first-mover advantage, sacrificing product market profits to pursue forward market profits. Stronger mean demand or lower unit costs, hence an increase in $(\overline{a}-c)$, representing stronger inherent profit opportunities in the product market, makes disclosure less appealing since Firm 1 gains a first-mover advantage that erodes a fraction of the base profits of Firm 2. Combining these effects, it is clear from (42) that for sufficiently small *b* or s_n^2 or sufficiently large $(\overline{a}-c)$, the last term dominates and disclosure harms Firm 2, while for sufficiently large *b* or s_n^2 or sufficiently small $(\overline{a}-c)$, the first term dominates and disclosure benefits Firm 2. The above discussion leads to the following proposition:

Proposition 2 *Conditions (as described above) exist such that both Firm 1 and Firm 2 strictly prefer no disclosure of forward contracts to disclosure of such contracts.*

This proposition offers a plausible explanation for why the industry as a whole opposes to disclosure even though, *ceteris paribus*, firms that do not enter the forward market would benefit from having access to the private information of contracting firms.

Finally, the breakeven condition of the broker implies a zero-sum game. Since Firm 1 strictly prefers not to disclosure its forward position to better exploit the uninformed forward market participants, the interest of these participants is clearly opposite to that of the privately informed contracting firm. This is summarized below:

Proposition 3 *Uninformed forward market participants strictly prefer disclosure of forward contracts to no disclosure of such contracts.*

3. Informed Forward Market Participants

---

[17] Recall that SOC requires $0 < l < 2$. Furthermore, only the lower root would ever be chosen, so in fact, l will always be less than 1.2749. At l = 0, the l ratio in (42) is 2/3; at l = 1.2749, the ratio is 1/3.

It is well known that in the Kyle-type (1985) settings, the expected gains to private information quickly dissipate as the number of informed traders increases. An interesting question to consider is whether circumstances exist under which Firm 1 would be better off with disclosure when we assume that other market participants are informed. In this case, forward price is based on the private information shared with these traders and their rational expectations regarding future production. To ease the analysis, we consider the extreme and, admittedly, implausible case where all forward market participants are informed and where disclosure includes the forward price as well as the forward quantity pertaining to the contracting firm.[18]

In the present setting, disclosure by Firm 1 eliminates the information asymmetry with Firm 2. Expected profits are therefore the same as that of the leader's in the Stackelberg game without information asymmetries:[19]

$$E\left[\Pi_1\right] = \frac{\left(\bar{a} - c\right)^2 + s_a^2}{8b}. \tag{43}$$

In the absence of disclosure, Firm 1's expected profits given no information asymmetry in the forward market are similar to (21), except that the variance of the noise trading s_n^2 is now zero:

$$E\left[\Pi_1\right] = \frac{s_a^2}{4b} + \frac{\left(\bar{a} - c\right)^2}{9b}. \tag{44}$$

Comparing (43) with (44) results in the following difference:

[18] By comparison, in the setting analyzed in the preceding section, the forward price had no incremental information beyond that contained in the disclosed forward position.

[19] Given symmetric information at the production stage, Allaz (1992) has shown that in equilibrium $Q_1^f = \frac{a-c}{4b}$, $Q_1 = \frac{a-c}{2b}$ and $Q_2 = \frac{a-c}{4b}$, i.e., the solution to the Stackelberg game. Substituting in the profit function for Firm 1 and simplifying results in the expected profit shown below.

$$
\begin{aligned}
&E\left[\Pi_1 \middle| \text{Disclosure; Informed}\right] - E\left[\Pi_1 \middle| \text{No Disclosure; Informed}\right] \\
&= \left[\frac{(\bar{a}-c)^2 + s_a^2}{8b}\right] - \left[\frac{(\bar{a}-c)^2}{9b} + \frac{s_a^2}{4b}\right] \\
&= \frac{(\bar{a}-c)^2 - 9s_a^2}{72b} \geq (\leq)\, 0 \;\forall\; s_a^2 \leq (\geq) \frac{(\bar{a}-c)^2}{9}.
\end{aligned}
\tag{45}
$$

It is clear from (45) that disclosure is preferred to no disclosure when the "value" of private information is low (i.e., s_a^2 is small) because in this case there is less to be gained from information advantage than from a first-mover advantage. Conversely, when the value of Firm 1's private information is high (i.e., s_a^2 is large), its concern for surrendering information advantage outweighs the desire to achieve a first-mover advantage such that Firm 1 would prefer not to disclose. This is summarized in the next proposition:

Proposition 4 *When other forward market participants are informed, there exists a positive critical value for variance of demand parameter, s_a^2, above (below) which Firm 1 strictly prefers no disclosure (disclosure) of forward contracts.*

A final question we pose is, given that Firm 1 is required to disclose both forward price and forward quantity (recall price is redundant in sub-section 2.3), whether it is better off when other traders in the forward market are informed, than when they are not informed. The difference in expected profits between these two cases as s_n^2 becomes large is approximately:[20]

$$
\begin{aligned}
&E\left[\Pi_1 \middle| \text{Disclosure; Informed}\right] - E\left[\Pi_1 \middle| \text{Disclosure; Uninformed}\right] \\
&\approx \left[\frac{(\bar{a}-c)^2 + s_a^2}{8b}\right] - \left[\frac{(\bar{a}-c)^2}{9b} + \frac{s_a s_n}{6\sqrt{2}}\right].
\end{aligned}
\tag{46}
$$

[20] They are given by (43) and Firm 1's limiting expected profit function under disclosure discussed in Section 2.3, respectively.

Firm 1 prefers to have other forward market participants privy to its private information about demand parameter a when (46) is strictly positive. For a suitable value of b, the last term within the second bracket can be made arbitrarily small by reducing the noise trading or information asymmetry parameters without violating the earlier requirement that $\frac{s_a^2}{b^2 s_n^2} < 0.223427$. The following proposition is immediate:

Proposition 5 *In a regime where both forward quantity and forward price are disclosed, conditions exist such that Firm 1 strictly prefers trading with informed forward market participants than with uniformed participants.*

An implication from Proposition 5 is that, for firms operating in a regime that requires disclosure, an information advantage over uninformed trades in the forward market could prove to be a curse, rather than a blessing. This is because the incentive to exploit such an advantage could induce the privately informed firm to over-commit to future production in order to influence its rival's beliefs, so much so that the resulting losses in profits from production *per se* overwhelm the gains in the forward market.

4. Conclusion

In this study, we considered the implications of mandating disclosure of forward contracts by privately informed contracting firms engaged in product market competition. Our results provide support for the opposition of financial executives toward mandating disclosure of forward contracts. In particular, these results suggest that the incentives to preserve an information advantage over rivals in production decisions and to maximize expected gains from trading on private information in the forward market outweigh the first-mover advantage achieved from revealing commitments to sell in advance of production. As a consequence, privately informed contracting firms would prefer a policy of no disclosure. Only in the less likely case where these firms do not enjoy information advantage over other forward market participants, we were able to identify conditions under which they are better off with mandated disclosure than without. We also provide conditions under which non-privately informed rivals would likewise prefer non-disclosure.

An especially interesting insight on the consequences of having a production stage follow trading in the forward market with asymmetric information is that a privately informed contracting firm has an incentive to distort production so as to manipulate the future spot price after forward contracts are in place. This occurs because of its desire to extract further gains from forward contracts at the expense of uninformed participants in the forward market. Disclosure of forward contracts re-enforces this incentive to distort. Under this regime, rival producers increase their production upon observing higher demand realizations. Accordingly, the best response by the contracting firm in this case is to curtail its own production.

It is natural to ask how our results might be affected if we assumed that both firms had private information and traded in the forward market. First, we note that symmetry in these respects would not eliminate the incentives of firms to exploit uninformed traders in the forward market and to influence the behavior of their rival in choosing their outputs. As well, we surmise that since jointly aggressive production in seeking a first-mover advantage is mutually dysfunctional (analogous to a "prisoner's dilemma"), preferences for non-disclosure would be strengthened rather than diminished.

Another possibility is that both firms engage in forward contracting, but only one firm has private information. Given no disclosure, there is no change in our results because the only incentive for the non-privately informed firm to engage in forward contracting is to achieve a first-mover advantage and doing so requires disclosure. Given disclosure, unlike the privately informed firm, the non-privately informed firm's forward position is undistorted by an incentive to exploit other uninformed market participants, implying a larger market share on average.[21] Accordingly, the non-privately (privately) informed firm is better (worse) off under disclosure than depicted in our analysis, all else held constant.

[21] The non-privately informed firm is always selling in the forward market implying that sometimes it trades in the same direction as the informed and other times the reverse is true. On average, it breaks even in the forward market.

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FIGURE 1

TIME LINE

t = 0	t = 1	t = 2	t = 3
Firm 1 receives private demand signal a and chooses quantity Q_1^f to be bought or sold forward at price P^f.	Depending on the disclosure regime, Firm 2 may or may not observe Q_1^f. Firms 1 and 2 choose total outputs Q_1 and Q_2, respectively.	The demand parameter a is realized and the spot price P determined.	Firm 1 covers its forward position; $Q = Q_1 + Q_2$ is sold at the spot price P; and profits are realized.

Appendix

Derivation of Equation (21)

From (3), Firm 1's expected profits can be stated as follows:

$E[\Pi_1] = E\left\{\left[E[P_f \mid a] - P(a)\right]Q_1^f(a)\right\} + E\left\{\left[P(a) - c\right]Q_1(a)\right\}$, where

$\left[E[P_f \mid a] - P(a)\right]Q_1^f(a)$

$$= \left[\frac{3\left(1+b\frac{s_n}{s_a}\right)a + \left(1-3b\frac{s_n}{s_a}\right)\bar{a} + 8c}{12} - \frac{3\left(1+b\frac{s_n}{s_a}\right)a - \left(1+3b\frac{s_n}{s_a}\right)\bar{a} + 4c}{6}\right]\frac{s_n}{s_a}(\bar{a} - a)$$

$$= \frac{\frac{s_n}{s_a}\left(1+b\frac{s_n}{s_a}\right)(\bar{a} - a)^2}{4}$$ and

$$[P(a) - c]Q_1 = \frac{3\left(1+b\frac{s_n}{s_a}\right)a - \left(1+3b\frac{s_n}{s_a}\right)\bar{a} - 2c}{6}\,\frac{3\left(1-b\frac{s_n}{s_a}\right)a - \left(1-3b\frac{s_n}{s_a}\right)\bar{a} - 2c}{6b}.$$

Taking expectations,

$E\left\{\left[E[P_f \mid a] - P(a)\right]Q_1^f(a)\right\} = \dfrac{s_a s_n\left(1+b\frac{s_n}{s_a}\right)}{4}$, and $E\left\{[P(a) - c]Q\right\} = \dfrac{s_a^2 - b^2 s_n^2}{4b} + \dfrac{(\bar{a} - c)^2}{9b}$.

Hence,

$$E[\Pi_1] = \frac{s_a s_n\left(1+b\frac{s_n}{s_a}\right)}{4} + \frac{s_a^2 - b^2 s_n^2}{4b} + \frac{(\bar{a} - c)^2}{9b} = \frac{s_a(bs_n + s_a)}{4b} + \frac{(\bar{a} - c)^2}{9b}.$$

Derivation of Equation (28)

Firm 1's FOC for the choice of forward position is

$$
\begin{aligned}
\frac{\partial E\left[\Pi_1\right]}{\partial Q_1^f} &= E\left[P_f\right] - P + \frac{\partial P_f}{\partial Q_1^f} Q_1^f + \frac{\partial P}{\partial Q_1^f}\left(Q_1 - Q_1^f\right) + \frac{\partial Q_1}{\partial Q_1^f}\left(P - c\right) \\
&= a - b\left(Q_1^f - g\right) - P - bQ_1^f + \frac{(l-2)b}{6}\left(Q_1 - Q_1^f\right) + \frac{l+4}{6}\left(P - c\right) \\
&= \frac{\bar{a} + 2c - bg}{3} - b\,(2Q_1^f - g) + \frac{(l-2)}{6}\left[P - c + b(Q_1 - Q_1^f)\right] - c \\
&= \frac{\bar{a} - c - bg}{3} - b\,(2Q_1^f - g) + \frac{(l-2)\left[3a - \bar{a} - 2c + (l-2)bQ_1^f - lgb\right]}{18} \\
&= Q_1^f\left(2b - \frac{(l-2)^2 b}{18}\right) = \frac{6\bar{a} - 6c - 6bg + 18bg + (l-2)\left[3a - \bar{a} - 2c - lgb\right]}{18} \\
\therefore Q_1^f &= \frac{(8-l)\bar{a} - 2(l+1)c + 3(l-2)a + [18b - (l^2 - 2l + 6)b]g}{36b - (l-2)^2 b}.
\end{aligned}
$$

Derivation of Equation (35)

$$
\begin{aligned}
Q_1^f &= \frac{(8-l)\bar{a} - 2(l+1)c + 3(l-2)a + \left[18b - \left(l^2 - 2l + 6\right)b\right]g}{36b - (l-2)^2 b} \quad \text{(from (28))} \\
&= \frac{(8-l)\bar{a} - 2(l+1)c + 3(l-2)a - (2l^2 - 3l + 4)b\,\dfrac{2(c-\bar{a})}{(l-4)b}}{-3(l-2)lb} \quad \text{(using (29) – (30))}, \\
&= \frac{(l-8)(l-4)\bar{a} + 2(l+1)(l-4)c - 3(l-2)(l-4)a + (4l^2 - 6l + 8)(c - \bar{a})}{3(l-2)(l-4)lb} \\
&= \frac{(4+l)\bar{a} - 2lc - (4-l)a}{(4-l)lb}.
\end{aligned}
$$

Proof that the Solution with the Lower Value of l Yields a Pareto-dominant Equilibrium

$$
\begin{aligned}
\frac{dE[\Pi_1]}{dl} &= \frac{2(\bar{a}-c)^2}{9b}\left[\frac{l-5}{(4-l)^2} + \frac{(2-l)(8-l)}{(4-l)^3}\right] + \frac{s_a^2}{6b}\left[\frac{1}{l} - \frac{l+1}{l^2}\right] \text{(from (39))} \\
&= -\frac{2(\bar{a}-c)^2(4+l)}{9b(4-l)^3} - \frac{s_a^2}{6l^2 b} < 0.
\end{aligned}
$$

$$
\begin{aligned}
\frac{dE[\Pi_2]}{dl} &= \frac{2s_a^2}{9b}\left[\frac{l+1}{l^2} - \frac{(l+1)^2}{l^3}\right] + \frac{2(\bar{a}-c)^2}{9b}\left[\frac{(2-l)^2}{(4-l)^3} - \frac{2-l}{(4-l)^2}\right] \text{(from (40))} \\
&= -\frac{2(l+1)s_a^2}{9l^3 b} - \frac{4(2-l)(\bar{a}-c)^2}{9(4-l)^3 b} < 0 \text{ (Recall that SOC requires } 0 < l < 2\text{)}.
\end{aligned}
$$