Chapter 6

PUBLIC DISCLOSURE OF TRADES BY CORPORATE INSIDERS IN FINANCIAL MARKETS AND TACIT COORDINATION

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Abstract We consider the consequences of public disclosure of insider trades on trading costs and price discovery in financial markets. Similar to Cournot competition in product markets, corporate insiders with common private information have incentive to trade more aggressively than a monopolist with the same information. Since, given periodic financial corporate reporting, insiders routinely have access to information in advance of the market, it is reasonable to expect them to seek ways to limit trades and, thereby, increase profits. Public reporting of insider trades may have the unintended effect of furthering tacit coordination by allowing insiders to monitor each others trades. Moreover, even without such reporting, we show how insiders may be able to sustain coordinated behavior depending on the distribution characterizing liquidity trading. Thus, competition among corporate insiders may be less influential in price discovery than previously thought.

Keywords: Public Disclosure, Insider Trading, Tacit Coordination

Introduction

A common perception of regulation which requires public disclosure of trades by corporate insiders, well expressed by Carlton and Fischel (1983), is that "The greater the ability of market participants to identify insider trading, the more information such trading will convey." In this paper, we suggest that public disclosure of insider trades per se may actually inhibit the price discovery process by dampening competition among insiders as they seek to exploit their information advantage.

The notion that competition among insiders with common private information serves to advance price discovery is based on an analogy to Cournot behavior in product markets. As in that setting, Cournot insiders trade more aggressively on their private information than a monopolist would trade, thereby causing more of their private information to become impounded in price. However, this effect of competition presumes a static trading environment in which insiders lack the means to coordinate their demands.

It seems clear that officers, directors, and other corporate insiders routinely have information about earnings, dividend changes, contract awards, order backlogs, product approvals, appraisal values, research discoveries, litigation outcomes, and other recurring events in advance of public announcements.[1] Accordingly, a more suitable environment in which to analyze their behavior is a dynamic setting involving repeated episodes of private information arrival, opportunities to trade, and public release of that information. From a modeling standpoint this recommends characterization as a repeated game.

Our approach is based on one-period models of monopoly and Cournot competition by Kyle (1985) and Admati and Pfleiderer (1988), respectively. The extension to multiperiod play involves simple trigger strategies analogous to those of Green and Porter (1984). To capture the impact of public disclosure of insider trades, we consider scenarios in which insiders are able through such reports to perfectly monitor each others' trades or are able to only imperfectly monitor trades by observing the aggregate order flow. The former scenario involves a straightforward application of the Folk Theorem. The latter scenario is broken down into special cases wherein noise from liquidity demands has either bounded (moving) or unbounded support. Distributional assumptions range over the error class, which encompasses symmetric distributions distinguished by a shape parameter that determines kurtosis. This class includes the normal along with its limiting families, the uniform and

Laplace. Dutta and Madhavan (1997) independently consider repeated insider trading assuming the normal and apply optimal strategies described by Abreu (1988). Their results are qualitatively similar to ours in that case. By departing from optimal trigger strategies and imposing some further structure, we obtain simple and intuitive characterizations of equilibria for a variety of cases. This, in turn, allows us to portray the significant role played by the kurtosis of liquidity demands.

Holden and Subrahmanyan (1992) and Foster and Viswanathan (1993) consider the effects of competition among identically informed insiders in a context of long-lived information. They find that price discovery is accelerated in comparison to Kyle's monopolist case. Foster and Viswanathan (1996) extend the analysis to the case of heterogeneously informed insiders and show that the degree of competition depends upon the correlation structure of insiders' private signals. In contrast, we suppress the longevity of information and focus on the scope for tacit coordination as the insider trading game is repeated. The analysis is eased substantially by assuming one round of trade between public announcements, which reveal previously private information. We conjecture that allowing multiple rounds prior to each public announcement would not alter the qualitative conclusion that the coordination sustained by repeated play damps competition among insiders and impedes price discovery, especially when insiders can perfectly monitor each others' trades.

Our principal results are (i) mandated public disclosure of insider trading facilitates coordination by insiders in extracting monopoly rents to their private information, implying less price discovery rather than more as regulators might intend; (ii) in keeping with Fudenberg et al. (1994), moving support for liquidity demands may allow insiders to extract full monopoly rents even in the absence of public disclosure of their trades; and (iii) more platykurtic distributions of liquidity demands imply greater prospects for insiders to improve upon Cournot behavior in extracting rents. One further result establishes the ability of insiders receiving different private signals to act as a monopolist with all the signals given perfect monitoring. The most notable policy implication of these results is that private disclosure of insiders' trades might dominate public disclosure. That way, regulators can enforce restrictions on insider trading but preserve the benefits of competition among the insiders.

The remainder of this paper is organized as follows: section 1 on background relates our model to the empirical evidence; section 2 presents the basic model for a single period; section 3 analyzes the case of perfect monitoring; section 4 considers imperfect monitoring, including cases in which the Folk Theorem does or does not apply; section 5 extends the case of perfect monitoring to allow for imperfect private information; and section 6 offers some conclusions.

1. Background

Regulations governing insider trading in the U. S. include Section 16(d) of the Securities Exchange Act of 1934 which requires corporate insiders (i.e., officers, directors, and principal owners of equity securities) to file statements of their holdings and reports of changes in those holdings. the Sarbanes-Oxley Act amended Section 16(a) by accelerating the filing deadline for Section 16 insider transaction reports to two business days after the transaction occurs. These statements are public records. As well, insider trades are disclosed in the SEC News Digest daily and by commercial data services. Section 16(b) requires insiders to disgorge profits from "short-swing" trading.[2] Rule 10b-5 from Section 10 of the Act requires insiders refrain from trading on material non-public information such as an impending takeover bid.

Notwithstanding the above restrictions, there is considerable empirical evidence that insider trading is abnormally profitable. For example, Seyhun (1986 and 1992b) finds that open market purchases and sales by corporate insiders predict up to 60 percent of the variation in one-year-ahead aggregate stock returns. Similarly, Pettit and Venkatesh (1995) report a strong tendency for insiders' net purchases to be significantly above and below normal between one and two years in advance of long horizon returns that are above and below normal, respectively. Damodaran and Liu (1993) find insiders of REITs buying (selling) after they receive favorable (unfavorable) appraisal news and before its public release.

Whereas, as noted by Seyhun (1992a), insider trading litigation has evolved to discourage trade in advance of material earnings and merger announcements, insiders are rarely prosecuted for trading on other kinds of information. Even if corporate insiders cannot profit from their private information through trades covered by regulation, they may be able to profit from unregulated Over the Counter Swaps of the return on their firm's shares for the return on some other asset.[3] Moreover, even earnings releases afford scope for front-running by insiders, provided they exercise some discipline in the timing of their trades.[4] For example, Penman (1982) finds that insiders tend to buy (sell) stock before the release of earnings forecasts that caused an increase (decrease) in share price. Similarly, Elliot et al. (1984) finds decreased selling and increased buying in advance of a variety of announcements including earnings releases.

While we are unaware of large scale data analyses pointing to widespread coordinated behavior has yet to unfold, there are any number of anecdotes suggesting that the trading decisions of insiders at the same firm are not independent. In fact, it is commonplace at some companies for the same group of insiders to trade together and in the same direction. For instance, among the fifty most active issues recently listed by Corporate Ownership Watch, corporate insiders, including officers and large shareholders, at LHS Group sold roughly proportionate quantities of stock in three of the first seven months of 1998 (see Figure 6.1). In another example, EDS officers and directors collectively sold nearly a half-million shares in weeks preceding a stock price drop of 30 percent and, as reported in the *Wall Street Journal*, "Two previous rounds of insider sales were followed by stock-price reductions in the 30 percent range in 1996 and 1997."[5] The company reported "worse-than-expected" earnings approximately a month and a half later. In a case involving non-earnings information, eight executives of Curative sold shares in advance of an FDA warning letter judged by Curative's CFO not to be material and, hence, not in violation of restrictions on insider selling.[6]

Stepping back to consider the consequences of a tightening of US filing rules since the early 1980s when "many [insiders] were barely aware of the rules," one observer describes the response by insiders as moving toward more "orchestration" of their trades to "paint the insider tape." The observer goes on to suggest that only a small handful seem to engage in this activity, but that the companies of these traders "seem to stand out the most," at least with respect to insider buying.[7] Whether a desire by insiders to avoid costly competition underlies such orchestration is an open question.

2. Basic Model

We assume a single asset is traded over a countably infinite time horizon, $\mathcal{T} = \{1, 2, ...\}$. The asset's value at time t is

$$v_t = p_0 + \sum_{s=1}^{t} \delta_s,$$

where p_0 is an initial known price and δ_t is a Bernoulli distributed innovation; i.e.,

$$\delta_t = \begin{cases} \sigma & \text{with probability } \frac{1}{2}, \text{ and} \\ -\sigma & \text{with probability } \frac{1}{2}. \end{cases}$$

The variance of δ_t is σ^2. Although the Bernoulli distribution is chosen for analytic convenience in cases with imperfect monitoring, it is not

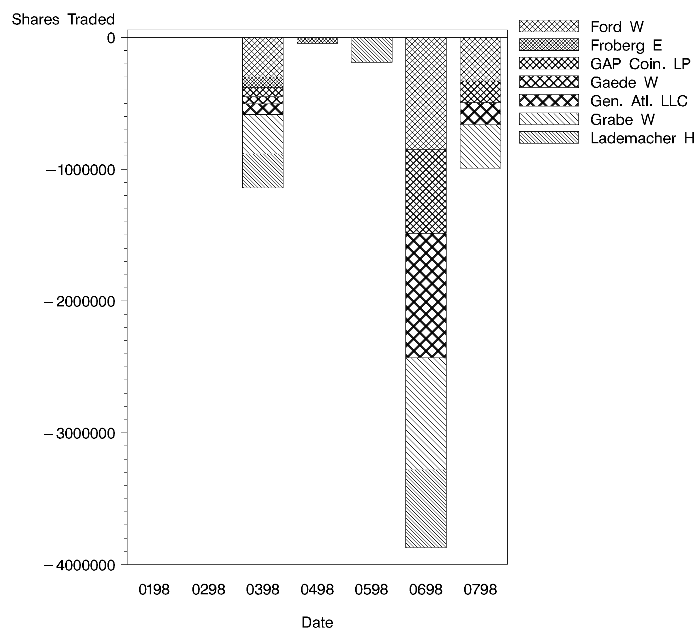

Figure 6.1. Pattern of Insider Trading. The trading activity of insiders at LHS Group for the first half of 1998. Vertical axis plots the number of shares traded. Negative figures are sales. Data are from Form 4s filed with the Securities and Exchange Commission. Trades are grouped by the month in which the form is filed. Trades by insiders of less than 40,000 shares in any month are omitted.

unrealistic. Many pieces of information that plausibly affect firm value are binary, for example, the award of a contract, a legal judgment, or a regulatory decision such as the award of a patent or the permission to market a drug.

There are N insiders each of whom receives a private signal $\theta_{jt}, j \in J = \{1, ..., N\}$, at the start of every period. Initially we assume that all insiders receive identical and perfect information, or $\theta_{jt} = \delta_t$. After trading in that period is completed, δ_t is revealed at the end of period t.[8] Insiders' trading strategies, $x_j = \{x_{jt}(\theta_{jt})\}_{t \in \mathcal{T}}$, are functions of their signals. Denote the set of such strategies X and define $X_{-j} = \{x_i\}_{i \in J, i \neq j}$. Remaining players in our game include liquidity traders whose demands, u_t, are exogenously generated and distributed uniformly on the interval

$[-b, b]$ independent of δ_t and a market maker. One could interpret the bounded support as a stylized proxy for resource constraints and other frictions that mitigate arbitrarily large positions. We relax this assumption later by assuming unbounded support for the case with imperfect monitoring. Moreover, similar to the binary support for innovations in firm value, bounded support for liquidity demands is not crucial for the case with perfect monitoring.

Given the market orders of all traders, the net order flow, y_t, is given by

$$y_t = \sum_{j=1}^{N} x_{jt} + u_t.$$

Conditional on the observed order flow, the market maker sets price equal to the expected value of the asset. The breakeven price, p_t, is

$$p_t = p_t(y_t, v_{t-1}) = E[v_t \mid y_t, v_{t-1}] = \begin{cases} v_{t-1} + \sigma, & \text{if} \quad y_t > \bar{y}, \\ v_{t-1}, & \text{if} \quad -\bar{y} < y_t < \bar{y}, \\ v_{t-1} - \sigma, & \text{if} \quad y_t < -\bar{y} \end{cases} \quad (1)$$

where $\bar{y} = b + \sum_{j \in J} x_{jt}(-\sigma)$ and $-\bar{y} = -b + \sum_{j \in J} x_{jt}(\sigma)$ are the critical thresholds such that, in equilibrium, more extreme aggregate order flows reveal insiders' private information, σ (respectively, $-\sigma$). Thus, if $y \in [-\bar{y}, \bar{y}]$ then the market maker infers an insider's information is σ or $-\sigma$ with equal probability and hence does not adjust the price from its initial value. Outside this range, the market maker infers δ from the order flow and set price equal to v. [9] Figure 6.2 depicts the order of events in a representative trading round. Figure 6.3 depicts the distributions of order flow, conditioned on the insiders' information.

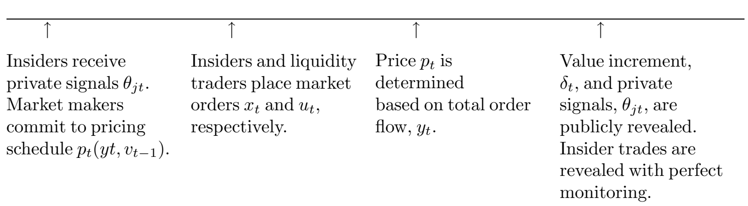

Figure 6.2. Timeline for Period t

The objective of each risk-neutral insider is to maximize the net present value of expected profits over time horizon $\mathcal{T}$. The one-period

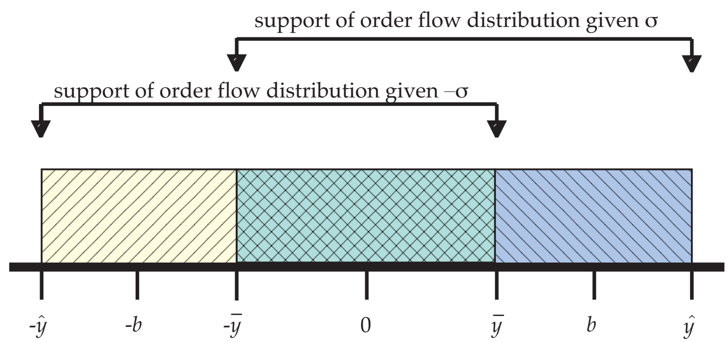

Figure 6.3. Conditional Distributions of Orderflow. This figure plots the distribution of the order flow conditional on insiders receiving (i) signal $-\sigma$, in which case the order flow is distributed uniformly on $[-\hat{y}, \bar{y}]$ or, (ii) signal σ, in which case the order flow is distributed uniformly on $[-\bar{y}, \hat{y}]$. The two distributions overlap in the cross-hatched region. For any realized order flow in the cross-hatched region, the market maker correctly assesses that it is equally likely that the insiders information about fundamental value is σ or $-\sigma$. Hence, there is no revision in the price of the stock. If the order flow is less than $-\bar{y}$, then the insiders information is that the stock is overvalued, and the market maker reduces the current period price by σ. If the order flow exceeds $\bar{y}$, then the insiders information is that the stock is undervalued, and the market maker increases the current period price by σ.

discount factor is $\gamma \in (0, 1)$. An equilibrium has the insiders choosing the expected profit maximizing demand given price, and the market maker choosing the breakeven (in expectation) price. These conditions are given below:

For all $j \in J$ and $t \in \mathcal{T}$, for all realizations of θ_{js} and any $\hat{x}_{js}$,

$$\sum_{s=t}^{\infty} \gamma^{s-t} E\left[\pi_s\left(x_{js}(\theta_{js}) \mid \bar{y}, X_{-j}\right)\right] \geq \sum_{s=t}^{\infty} \gamma^{s-t} E\left[\pi_s\left(\hat{x}_{js}(\theta_{js}) \mid \bar{y}, X_{-j}\right)\right], \quad (2)$$

where $E[\pi_s(x_{js}(\theta_{js}) \mid \bar{y}, X_{-j})] \equiv E\left[x_{js}(\theta_{js})\left(v_s - p_s\right)\right]$.

Consider the one-shot game, $T = \{1\}$. Here, insider j seeks to maximize the single-period expected profits conditional on his private information and his conjectures about the strategic choices of other insiders and the market maker. Suppose the insider's signal is $\theta_{j1} = \sigma$.[10] Then, suppressing time subscripts when no confusion can result and writing $x_{j1}(\sigma)$ as simply x_j, expected profits are:

$$
\begin{aligned}
& E[\pi_j\,(x_j(\sigma) \mid \bar{y}, X_{-j})] \\
= \; & E[x_j(v_1 - p_1) \mid \bar{y}, X_{-j}] \\
= \; & x_j(v_1 - p_0 - \sigma)\Pr(p_1 = p_0 + \sigma) + x_j(v_1 - p_0)\Pr(p_1 = p_0) \\
& + x_j(v_1 - p_0 + \sigma)\Pr(p_1 = p_0 - \sigma), \qquad (3) \\
= \; & \sigma x_j \Pr(p_1 = p_0) \\
= \; & \sigma x_j \Pr(-\bar{y} \leq y_1 \leq \bar{y}) \\
= \; & \sigma x_j \int_{-\bar{y}}^{\bar{y}} \frac{1}{2b} du \\
= \; & \sigma x_j \left(1 - \frac{x_j + \sum_{\substack{i \neq j \\ i \in N}} x_i}{b} \right).
\end{aligned}
$$

In (3), the first term in the sum is zero because the market maker adjusts price to equal the expected value of the firm, so insiders cannot profit. The third term in the sum is zero because, conditional on $\theta_{jt} = \sigma$, insiders buy, and thus order flow cannot fall in the range where the market maker lowers the stock price. An equilibrium in this case is a set of strategies for the insiders and the market maker such that

$$E\left[\pi_j\,(x_j(\sigma) \mid \bar{y}, X_{-j})\right] \geq E\left[\pi_j\,(\hat{x}_j(\sigma) \mid \bar{y}, X_{-j})\right],$$

for all $\hat{x}_j, j \in J = \{1, 2, ..., N\}$, and $\bar{y}$ satisfies (1). It follows from Admati and Pfleiderer (1988) that an equilibrium has

$$x_j = x^c = \frac{b}{N+1}, \quad \text{for } j \in J,$$

$$\bar{y} = \bar{y}^c = \frac{b}{N+1}, \quad \text{and}$$

$$E(\pi_j(x_j)) = E(\pi^c) = \frac{b\sigma}{(N+1)^2}, \quad \text{for } j \in J,$$

where we use the superscript c to denote Cournot behavior. When $N = 1$, the solution collapses to Kyle's (1985) monopolist case, denoted with superscript k:

$$
\begin{aligned}
x^k &= \frac{b}{2}, \\
\bar{y}^k &= \frac{b}{2}, \quad \text{and} \\
E(\pi^k) &= \frac{b\sigma}{4}.
\end{aligned}
$$

Were each insider to trade quantity x^k/N, the expected profits of each would be

$$\frac{E(\pi^k)}{N} = \frac{b\sigma}{4N} > \frac{b\sigma}{(N+1)^2}, \quad N \geq 2.$$

Thus, there are benefits to coordination, provided self-enforcing strategies can be found such that insiders cooperate in setting their demands at least some of the time.

3. Perfect Monitoring

We begin our analysis of the repeated insider trading game with a setting in which insiders report their trades following each trading round and those reports are publicly disclosed.

Consider the strategy in which each insider chooses x^k/N in every period unless the publicly-revealed trades from the previous round indicate that an insider has defected. The incentive to defect in the first period is characterized by the following optimization:

$$\begin{aligned} & \max_{x_j} E\left[\pi_j\left(x_j(\sigma) \mid \bar{y}, X_{-j} = \{b/2N\}_{i\in J, i\neq j}\right)\right] \\ = \quad & \max_{x_j} \sigma x_j \left(1 - \frac{x_j + (N-1)b/2N}{b}\right), \end{aligned}$$

where, again, we write $x_j(\sigma)$ as simply x_j. It follows from the first-order condition that

$$x_j = \frac{b(N+1)}{4N}.$$

Expected first-period profit given defection is, therefore,

$$E(\pi^d) = \frac{b\sigma(N+1)^2}{16N^2},$$

and the expected first-period gain from defection is

$$E(\pi^d) - \frac{E(\pi^k)}{N} = b\sigma\frac{(N-1)^2}{16N^2}. \tag{4}$$

If a defection occurs, then by self-enforcing preplay agreement insiders choose the Cournot demands for all future periods. The present value of expected future losses from playing the Cournot solution rather than the Kyle solution is

$$\sum_{t=1}^{\infty} \gamma^t \left(\frac{E(\pi^k)}{N} - E(\pi^c)\right) = \frac{\gamma}{1-\gamma} b\sigma\frac{(N-1)^2}{4N(N+1)^2}. \tag{5}$$

Comparing the above with the present value of the expected gain and losses from defection, it is evident that the credible threat to play Cournot in future periods is sufficient to sustain an equilibrium in which insiders collectively behave as a single Kyle monopolist in the current and all future periods for all γ such that the right-hand side of (4) is less than that of (5) or, upon rearranging terms,

$$\gamma > \frac{(N+1)^2}{(N+1)^2 + 4N}, \quad \text{for } N \geq 2. \tag{6}$$

PROPOSITION 1 *Assume public reporting of insider trades, perfect private information, and uniformly distributed liquidity demands. For any number of insiders, $N \geq 2$, and a sufficiently large discount factor, γ, there exists an equilibrium to the infinitely-repeated insider trading game such that aggregate insider demand and expected insider profits in each period correspond to the Kyle monopolist solution.*

PROOF: For all $N \geq 2$, (6) implies $\gamma \in (0, 1)$. Accordingly, a γ can be found such that $x_{jt} = x^k/N$ is a best response to $x_{it} = x^k/N$, for all $i \in J, i \neq j$, and $p_t = E(v_t \mid y_t, v_{t-1})$ defined by (1) for all $t \in T$. Thus, both conditions for an equilibrium are met.

4. Imperfect Monitoring

In this section, we assume insiders' trades are not publicly reported *ex post*. In this case, aggregate order flow serves as the only signal that may be used to implement coordinated strategies among corporate insiders, all of whom receive perfect private information.

4.1 Bounded (Moving) Support

Recall that the order flow is comprised of both insiders' demands and the random demands from uninformed traders. We define trigger strategies as a pair of critical values, $(-\hat{y}, \hat{y})$, of the order flow conditioned on the realization of the private signal that is publicly observed *ex post*. Set $\hat{y}$ equal to the upper end of the support of the order flow distribution given aggregate insider demand corresponding to the Kyle monopolist solution. Correspondingly, set $-\hat{y}$ equal to the lower end of the support of the order flow distribution given the Kyle solution.[11]

Since choosing the Cournot demands, x^c, along with the price $p_t = E(v_t \mid y_t, v_{t-1})$, is a subgame perfect equilibrium for all $t \in \mathcal{T}$, cooperative strategies in the repeated game exploit the threat of Cournot play to enforce a Pareto-preferred (by insiders) equilibrium. For the remainder of this section, we suppress the time subscript, t. Below, we consider the case $\delta = \sigma$. The case $\delta = -\sigma$ is symmetric. Consider a candidate equilibrium in which each insider's choice of quantity traded is x^k/N, $\hat{y} = b + x^k$, and $T = \infty$. It is sufficient for this to be an equilibrium that no insider has incentive to defect unilaterally from this quantity choice given the threat of Cournot play forever in the event the defection is detected. An insider who contemplates increasing the quantity he trades by d increases his profits by $d\sigma$ per unit traded in the event the market maker does not update the price given the order flow, but he also decreases the probability the price is not updated by $d/(2b)$ and increases the probability he is detected and punished with Cournot play forever by $d/(2b)$. The optimal defection is

$$\begin{aligned}\arg\max_{d} \qquad & \sigma\left(\frac{x^k}{N}+d\right)\left(1-\frac{x^k/N+d+(N-1)x^k/N}{b}\right)\\ & -\sigma\left(\frac{x^k}{N}\right)\left(1-\frac{x^k/N+(N-1)x^k/N}{b}\right)\\ & -\frac{\gamma}{1-\gamma}\left(\frac{E(\pi^k)}{N}-E(\pi^c)\right)\left(\frac{d}{2b}\right).\end{aligned}$$

The first line of this expression is the expected profit in the first period for an insider who defects from the equilibrium to trade $x^k/N + d$ for some $d > 0$. The second line is the expected profit that an insider would earn in the current period if he did not defect. Hence, the difference of these terms is the payoff to defection in the current period. The third line is expected present value of the reduction in future profits from Cournot rather than monopolistic choices of quantities traded, multiplied by the probability of this outcome.

This expression is strictly concave in d and hence has a unique maximum. The maximizing value of d, from the first-order condition is

$$d = \frac{b(N-1)}{4N}\left(1-\frac{\gamma}{1-\gamma}\cdot\frac{N-1}{4(N+1)^2}\right).$$

A defection is worthwhile in this equilibrium only if $d > 0$. The discount factor can always be chosen large enough to discourage defection. The critical value of the discount factor is

$$\gamma = \frac{4(N+1)^2}{4(N+1)^2+N-1} > \frac{(N+1)^2}{(N+1)^2+4N} \quad N \geq 2.$$

The right-hand side of the above inequality is the critical value of the discount rate in the case of perfect monitoring. As we would anticipate given a positive probability that a defection is not detected under imperfect monitoring, the critical discount factor in this case is strictly greater than the critical discount factor with perfect monitoring.

Accordingly, we have shown the following proposition and corollary.

PROPOSITION 2 *Assume no public reporting of insider trades, perfect private information, and uniformly distributed liquidity demands. For any number of insiders, $N \geq 2$, and a sufficiently large discount factor, γ, there exists an equilibrium to the infinitely-repeated insider trading game such that aggregate insider demand and expected insider profits in each period correspond to the Kyle monopolist solution.*

COROLLARY 1 *Under the same assumptions as those in Proposition 2, the critical discount factor for implementing the Kyle monopolist solution, as an equilibrium in every period of the infinitely-repeated insider trading game, through the trigger strategy defined by critical values $(-\hat{y}, \hat{y})$, is strictly greater than the critical discount factor for implementing the Kyle monopoly solution in the case of publicly reported insider trades.*

The moving support plays an obvious role in driving the above results. We interpret bounds on liquidity demands as a stylized reflection of market frictions which preclude unlimited buying and selling by unmodeled liquidity traders. Interestingly, the critical discount factor for this case does not depend on the bounds of this distribution implying robustness with respect to the parameterization.

4.2 Unbounded Support

We now assume that the distribution of liquidity demands extends over the entire real line. This condition implies that defection is never detected with certainty. By assuming normality one might appeal to the optimal strategies of Abreu (1988) (e.g. Dutta and Madhavan, 1997). Instead, we gain some flexibility in choosing distributions by retaining simple trigger strategies and assuming that market makers commit to linear pricing schedules, $p(y_t, v_{t-1}) = \lambda y_t + v_{t-1}$.[12] The ability to demonstrate how the shape of distributions contributes to implementability of coordinated play outweighs the disadvantages of imposing this structure.[13]

We consider the error distribution class for which the Laplace, normal, and uniform are special cases. These three distributions are distinguished by the values of a shape parameter, which governs the degree of kurtosis. Generally speaking, we show that the more platykurtic (i.e., closer to uniform) the distribution, the easier it is to sustain coordination. Coordination is easier to sustain because the sensitivity of our

Green and Porter-type trigger strategy to a true defection (rather than a spurious liquidity demand shock) becomes greater implying a higher likelihood of triggering a penalty only if a defection has occurs.

Suppose the insiders' information is $\theta_{jt} = \sigma$.[14] Again, we suppress the time subscript, t. In the first period and any later cooperative period an insider's problem is:

$$\max_{xj} W_j$$

where

$$\begin{aligned} W_j &= E\left[\pi_j(\sigma) \mid \lambda, X_{-j}\right] + F(\hat{y} \mid \sigma, X)\gamma W_j \\ &\quad + (1 - F(\hat{y} \mid \sigma, X))\left(\sum_{s=1}^{T-1} \gamma^s E[\pi^c] + \gamma^T W_j\right), \quad (7) \\ E\left[\pi_j(x_j(\sigma) \mid \lambda, X_{-j})\right] &= E\left[x_j\left(\sigma - \lambda\left(\sum_{i\in J} x_i + u\right)\right)\right], \\ E[\pi^c] &= \frac{\sigma\sigma_u}{(N+1)\sqrt{N}}, \end{aligned}$$

and the function $F(\hat{y} \mid \sigma, X)$ is the cumulative distribution function (CDF) of the order flow, y, evaluated at the critical value $\hat{y}$.[15] The CDF is conditioned on private information $\delta = \sigma$ and insiders choosing demands X. Specifically, for the error distribution

$$F(y \mid \sigma, X) = \int_{-\infty}^{y} \frac{\exp \frac{-\left|z - \sum_{j=1}^{N} x_j\right|^{\frac{2}{\alpha}}}{2\sigma_u^2}}{\sqrt{\sigma_u} 2^{1+\frac{\alpha}{2}} \Gamma(1+\frac{\alpha}{2})} dz. \quad (8)$$

The first term on the right-hand side of (7) is the profit insider j expects in the current period given the quantities traded by the other insiders. The probability that insiders will continue to play cooperatively is $F(\hat{y} \mid \sigma, X)$, where X denotes $\{s_i\}_{i\in J}$. The second term is the present value of insider j's future profits given the order flow, y, is less extreme than the critical value $\hat{y}$ times the probability that order flow is less extreme than the critical value. The third term is the present value of insider j's future profits given the order flow is more extreme than $\hat{y}$ times the probability that order flow exceeds the critical value. The probability that the order flow will be greater than the critical value $\hat{y}$ given δ equals σ is $1 - F(\hat{y} \mid \sigma, X)$, in which event a penalty phase of duration $T - 1$ begins, followed by a return to cooperative play.

Recursive equation (7) can be solved for W_j:

$$\begin{aligned} W_j &= \frac{E(\pi^c)}{1-\gamma} + \frac{E\left[\pi_j(\sigma) \mid \lambda, X_{-j}\right] - E(\pi^c)}{1-\gamma^T - (\gamma-\gamma^T)F(\hat{y} \mid \sigma, X)} \\ &= \frac{E(\pi^c)}{1-\gamma} + \frac{E\left[\pi_j(\sigma) \mid \lambda, X_{-j}\right] - E(\pi^c)}{1-\gamma + (\gamma-\gamma^T)F(-\hat{y} \mid -\sigma, X)} \end{aligned} \tag{9}$$

where, by symmetry, $F(\hat{y} \mid \sigma, X) = 1 - F(-\hat{y} \mid -\sigma, X)$. The right-hand side of (9) is easy to interpret. The first term is the present value of expected profits assuming Cournot behavior over an indefinite time horizon, and the second term is the present value of the expected gains to cooperative behavior taking into account penalty phases during which insiders do not play cooperatively. If the probability of entering a penalty phase is large, then the second term will be small, consistent with less frequent cooperative behavior.

The first-order conditions are met if $\partial W_j/\partial x_j = 0$ for all $j \in J$, which implies

$$\frac{\partial E\left[\pi_j(\sigma) \mid \lambda, X_{-j}\right]}{\partial x_j(\sigma)} = \frac{E\left[\pi_j(\sigma) \mid \lambda, X_{-j}\right] - E[\pi^c]}{\frac{1-\gamma}{\gamma-\gamma^T} + F(-\hat{y} \mid -\sigma, X)} \cdot \frac{\partial F(-\hat{y} \mid -\sigma, X)}{\partial x_j(\sigma)} \tag{10}$$

for all $j \in J$.

Linearity of prices and Bernoulli private information imply insider demands can be written in the form $x_j(\theta) = \beta_j \theta$, which is familiar from Kyle (1985). Invoking symmetry in choices of β_j (i.e., $\beta_1 = \beta_2 = \ldots = \beta_N = \beta$) and a choice of λ that yields zero expected profits for the market maker leads to

$$\frac{\partial E\left[\pi_j(\sigma) \mid \lambda, X_{-j}\right]}{\partial x_j(\sigma)} = \left(1 - \frac{N(N+1)\beta^2\sigma^2}{\sigma_u^2 + N^2\beta^2\sigma^2}\right)\sigma^2, \tag{11}$$

for all $j \in J$. For convenience, we make the further transformation of variables

$$\begin{aligned} k_1 &= \beta \frac{N\sigma}{\sigma_u}, \\ k_2 &= \beta^c \frac{N\sigma}{\sigma_u}, \end{aligned}$$

where k_1 becomes the control variable in the insider's problem and k_2 is a constant entering into the determination of $E[\pi^c]$; i.e., $E[\pi^c] = (\beta^c\sigma^2)/(N+1)$, $\beta^c = \sigma_u/(\sqrt{N}\sigma)$.

We begin with the Laplace distributions for which the shape parameter is $\alpha = 2$. Integrating (8) for this choice of α we obtain

$$F(-y \mid \delta = -\sigma, X) = \frac{1}{2} \exp\left(-\frac{\sqrt{2}}{\sigma_u}(\hat{y} - \sigma\beta)\right), \tag{12}$$

Hence,

$$\frac{\partial F(-y \mid \delta = -\sigma, X)}{\partial \beta} = \frac{\sqrt{2}}{\sigma_u} F(-y \mid \delta = -\sigma, X). \qquad (13)$$

Substituting from (12) and (13) into the right-hand side of (10) and equating with the right-hand side of (11) leads to the following necessary condition for a solution other than Cournot behavior in every period:

$$\frac{(N - k_1^2)(1 + k_2^2)}{(k_1 k_2 - 1)(k_2 - k_1)} = \frac{\sqrt{2}}{\sigma_u} \frac{F(-\hat{\sigma} \mid \delta = -\sigma, X)}{\frac{1-\gamma}{\gamma-\gamma^T} + F(-\hat{y} \mid \delta = -\sigma, X)}$$

Since, for $T = \infty$ and γ close to 1, the right-hand side approximates but does not exceed $\sqrt{2}$, and the left-hand side exceeds $\sqrt{2}$ for $N \geq 2$, then we arrive at the following result:

Proposition 3 *Assume no public reporting of insider trades, perfect private information, and Laplace distributed liquidity demands. For any number of insiders, $N \geq 2$, and discount factor γ, there does not exist a trigger strategy $(\hat{y}, T)$ equilibrium to the infinitely-repeated insider trading game under which insiders improve upon expected profits from Cournot behavior.*

In the case of normally distributed liquidity demands, further analysis implies

$$\begin{aligned}\frac{\partial F(-\hat{y} \mid -\sigma)}{\partial \beta_i} &= \frac{\sigma}{\sqrt{2\pi}\sigma_u} \exp\left(-\frac{1}{2}\left(\frac{-\hat{y} + N\beta\sigma}{\sigma_u}\right)^2\right) \\ &= \frac{\sigma}{\sqrt{2\pi}\sigma_u} \exp\left(-\frac{1}{2}\left(\frac{-\hat{y} + k_1\sigma_u}{\sigma_u}\right)^2\right).\end{aligned}$$

Thus, after rearrangement and simplification, the first-order conditions obtained by equating the right-hand sides of (10) and (11) can be re-expressed as follows:

$$\frac{(N - k_1^2)(1 + k_2^2)}{(k_1 k_2 - 1)(k_2 - k_1)} = \sigma_u \frac{\frac{1}{\sqrt{2\pi}\sigma_u} \exp\left(-\frac{1}{2}\left(\frac{-\hat{y}+k_1\sigma_u}{\sigma_u}\right)^2\right)}{\frac{1-\gamma}{\gamma-\gamma^T} + \int_{-\infty}^{-\hat{y}} \frac{1}{\sqrt{2\pi}\sigma_u} \exp\left(-\frac{1}{2}\left(\frac{-z+k_1\sigma_u}{\sigma_u}\right)^2\right) dz}. \qquad (14)$$

When penalty phases are characterized by Cournot play, $k_2 = \sqrt{N}$, condition (14) becomes

$$\frac{(N - k_1^2)(1 + N)}{(k_1\sqrt{N} - 1)(\sqrt{N} - k_1)} = \frac{\sigma_u f(\hat{y} \mid \delta = \sigma)}{\frac{1-\gamma}{\gamma-\gamma^T} + (1 - F(\hat{y} \mid \delta = \sigma))}, \qquad (15)$$

where we have exploited $f(-\hat{y} \mid \delta = -\sigma) = f(\hat{y} \mid \delta = \sigma)$ and $F(-\hat{y} \mid \delta = -\sigma) = 1 - F(\hat{y} \mid \delta = \sigma)$. Writing the first-order-conditions in this manner contributes to the proof of the proposition below:

PROPOSITION 4 *Assume insiders possess perfect private information and liquidity demands are normally distributed. For any number of insiders, $N \geq 2$, and sufficiently large discount factor, γ, there exists a trigger strategy $(\hat{y}, T)$ that satisfies the first-order-conditions for an equilibrium to the infinitely-repeated insider trading game, and under which aggregate expected insider profits exceed those from Cournot behavior.*

PROOF: The left-hand side of (15) is positive and finite for all $k_1 \in (1, \sqrt{N})$. The right-hand side is increasing in the hazard rate, $f/(1-F)$, which, in turn is increasing in critical value, $\hat{y}$. The hazard rate for a normal distribution is strictly monotone increasing over the real line (Bagnoli and Bergstrom, 1989). Set the duration of the penalty phase $T = \infty$. A discount factor, γ, can always be found sufficiently close to 1 such that $(1 - \gamma)/\gamma$ becomes arbitrarily small, thereby allowing the effect of the hazard rate to dominate in determining the magnitude of the right-hand side.

The second-order conditions are more difficult to assess. Unfortunately, convexity of the distribution function F is not sufficient in itself to ensure that the value function W given by (9) is concave.[16] However, numerical examples display at least quasi-concavity, implying in those examples, that first-order-conditions are sufficient as well as necessary in characterizing an equilibrium.[17]

Proposition 4 demonstrates the existence of a cooperative equilibrium when liquidity traders' demands are normally distributed and the discount factor is sufficiently high. Figure 6.3 depicts the right-hand side of (15) as a function of the critical value, $\hat{y}$, for a series of three discount factors γ_1, γ_2,and γ_3, which, moving to the left, become closer to 1. The remaining parameters are $N = 2, \sigma_u^2 = \sigma^2 = 1, k_2 = \sqrt{2}$. Also, k_1 is fixed at slightly less than k_2. These values imply a left-hand side of approximately 8.5. Hence, as the graph shows, a $\hat{y}$ close to -2.25 for $\gamma = \gamma_3$ will satisfy the first-order-condition for a cooperative equilibrium. Figure 6.4 depicts the natural log of the value function (9) for values of $\beta_1 \in (.3, 1.3)$, given $\beta_2 = .704 < 1/\sqrt{2} \approx .707, \gamma = \gamma_3$, and N, σ_u^2, and σ^2 as above.[18] The optimum at $\beta_1 = \beta_2 = .704$ confirms the existence of a cooperative equilibrium in which demands are less than those under Cournot competition (Figure 6.5).

A comparison of results for Laplace and normally distributed liquidity demands suggests the kurtosis of the distribution is crucial to the existence of cooperative equilibria. The intuition for this observation

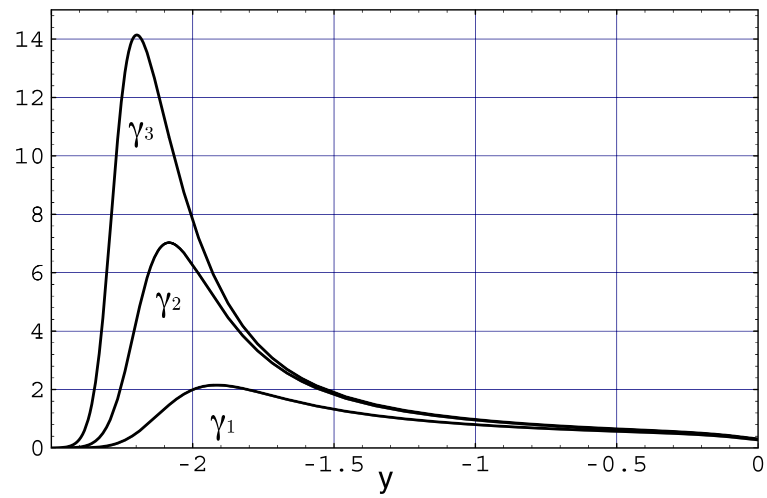

Figure 6.4. First Order Condition as a Function of y and γ. This figure plots the right-hand side of the first order condition, $\frac{\sigma_u f(y)}{\frac{\gamma}{1-\gamma}+1-F(y)}$ as a function of the order flow, y, for discount factors $\gamma_1 = .9$, $\gamma_2 = .99$, and $\gamma_3 = .999$.

is that platykurtic (closer to uniform) distributions offer more scope for detecting defections (i.e., over-aggressive trading) by insiders which shift the location parameter. By choosing an error distribution that is sufficiently platykurtic, the hazard rate increases at an increasing rate. For instance, we employ the following distribution function in developing the right-hand side of (15) (i.e., a shape parameter $\alpha = \frac{1}{4}$):

$$F(-\hat{y} \mid -\sigma, X) = \int_{-\infty}^{-\hat{y}} \frac{\exp \frac{|y+k_1\sigma_u|^8}{2\sigma_u}}{\sqrt{\sigma_u} 2^{\frac{9}{8}} \Gamma\left(\frac{9}{8}\right)} dy,$$

Figure 6.6 depicts the new right-hand side of (15). Given an infinite penalty phase duration ($T = \infty$), discount factor γ close to one, and k_1 close to $\sqrt{2}$, then the right-hand side will equal the left-hand side for some $\hat{y}$ greater than 2. Setting $\hat{y} = 2.4$, we find equilibrium values of $\beta_1 = \beta_2 = 0.576$ which are closer to the shared monopoly demand of $\frac{1}{2}$ than under the earlier normality assumption.

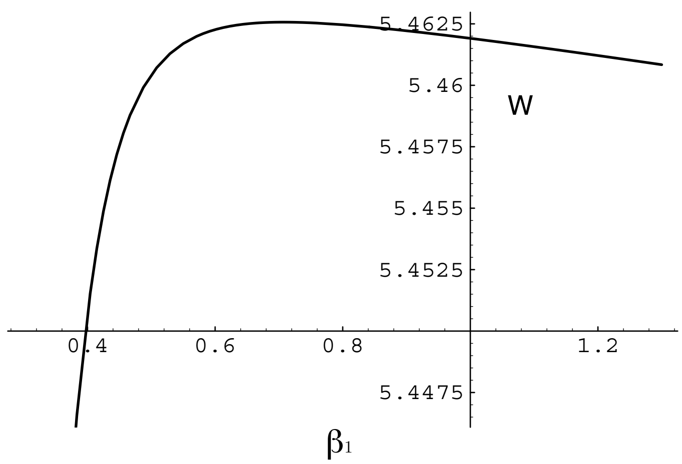

Figure 6.5. Value function for $\beta_2 = 0.704$. This figure plots the natural log of the value function, W, as a function of $\beta_1 \in (0.3, 1.3)$, given $\beta_2 = 0.704$.

4.3 General Imperfect Monitoring

Although trigger strategies have the advantage of simplicity, they are not optimal (from the insider's point of view) for inducing cooperative behavior. Abreu et al. (1986) show that optimal strategies are bang-bang in the sense that either the best cooperative solution or the non-cooperative solution is played each round in equilibrium. The process governing which solution is played is Markov. Since noise in the monitor under imperfect information implies non-degenerate transition probabilities, then the cooperative solution cannot be achieved in every period even when our restriction to trigger strategies is removed. This, in turn, suggests that, qualitatively, there is little to be gained from solving for optimal strategies even if that were feasible for non-normal cases.

5. Imperfect Private Information

We can generalize our earlier results with perfect monitoring by assuming that private information is imperfect and insider trades are publicly disclosed *ex post*. These conditions approximate analysts' trades on their earnings forecast before they are publicly announced.[19]

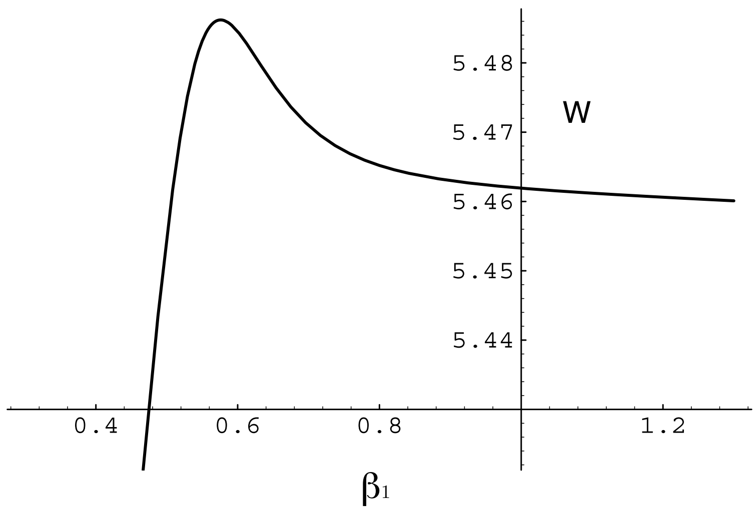

Figure 6.6. Value function for $\beta_2 = 0.576$. This figure plots the natural log of the value function, W, as a function of $\beta_1 \in (0.4, 1.2)$, given $\beta_2 = 0.576$.

Specifically, we assume that liquidity demands are normally distributed and private signals have the following structure:

$$\theta_{jt} = \delta_t + e_{jt}\ ,\ e_{jt} \sim NID(0, \sigma_e^2).$$

The one-shot Cournot and Kyle monopolist solutions, where the monopolist observes all of the signals, are now

$$\beta^c = \frac{\sigma_u}{\sqrt{N}(\sigma_e^2 + \sigma^2)^{\frac{1}{2}}},$$

$$\lambda^c = \frac{\sigma^2}{2\sigma_e^2 + (N+1)\sigma^2} \frac{\sqrt{N}(\sigma_e^2 + \sigma^2)^{\frac{1}{2}}}{\sigma_u},$$

$$E(\pi^c) = \frac{\sigma^2}{2\sigma_e^2 + (N+1)\sigma^2} \frac{\sigma_u(\sigma_e^2 + \sigma^2)^{\frac{1}{2}}}{\sqrt{N}},$$

and

$$\beta^k = \frac{\sqrt{N}\sigma_u}{(\sigma_e^2 + N\sigma^2)^{\frac{1}{2}}},$$

$$\lambda^k = \frac{\sqrt{N}\sigma^2}{2\sigma_u(\sigma_e^2 + N\sigma^2)^{\frac{1}{2}}},$$
$$E(\pi^k) = \frac{\sqrt{N}\sigma^2\sigma_u}{2(\sigma_e^2 + N\sigma^2)^{\frac{1}{2}}},$$

respectively. Hence,

$$\frac{1}{N}E(\pi^k) = \frac{\sqrt{N}\sigma^2\sigma_u}{2N(\sigma_e^2 + N\sigma^2)^{\frac{1}{2}}}.$$

Similar to the perfect information case, $E(\pi^k)/N > E(\pi^c)$ implying that insiders can implement the monopoly solution for values of γ close to one.

PROPOSITION 5 *Assume public reporting of insider trades and imperfect private information. For any number of insiders, $N \geq 2$, and a sufficiently large discount factor, γ, there exists an equilibrium to the infinitely-repeated insider trading game such that aggregate demand and expected insider profits in each period correspond to the Kyle monopolist solution.*

PROOF: As in the case with perfect information, the expected gain from defection in any given period is finite, while expected future losses from henceforth playing the Cournot solution can be made arbitrarily large by setting γ sufficiently close to 1.[20]

Tacit coordination in this case has two consequences: a reduction in demand by eliminating the effects of competition, and constructive sharing of information. Interestingly, in the absence of tacit coordination, insiders prefer not to share information. Analogous to product market games, there is more to gain from having rivals trade less intensely when extreme signals are realized than to lose from having rivals trade more intensely when non-extreme signals are realized. However, once the effects of competition are mitigated, then insiders jointly benefit from more precise private information.

To better understand how insiders benefit from information sharing without exchanging signals, suppose one insider gets a high private signal realization and another gets a low realization. The first trader would go too far long and the second too far short relative to demands based on both signals. However, the price adjustment would tend to be lower than that based on the first insider's demands and higher than that based on the second insider's demands. The first (second) insider loses from having set her demands too high (low), but benefits from the smaller price adjustment. The net result is that expected profits match the expected profits of a single insider with both signals who chooses the monopoly demand. Hence, if a strategy can be found which induces each insider to select a demand equal to half the intensity a monopolist who receives both signals would choose, then the total profits to insiders would equal a monopolist's profits based on all of the information.

6. Conclusion

In this paper, we consider how insiders in a financial market may tacitly coordinate trades to their mutual benefit to limit the aggregate quantities they trade. Analogous to tacit coordination to reduce output in oligopolistic product markets, we show that traders benefit when they trade less intensely on their private information. Whether insiders can achieve the full Kyle monopoly solution depends upon the extent to which they can monitor each other's trades. Given public reporting of insider trades, we demonstrate implementability of the monopoly solutions for sufficiently large discount factors. Even without public reporting, moving support for the aggregate order flow may suffice to implement the monopoly solution, albeit for discount factors strictly larger than the critical discount factor for the case with public reporting. Working within the error class of distributions, we show that some gains to tacit coordination are also achievable for sufficiently large discount factors when there is unbounded support and, hence, no positive probability of certain detection of defections. While the restrictions to linear price schedules and simple trigger strategies limit the generality of our results in this last case, it seems reasonable to conclude that (i) some degree of tacit coordination is achievable by corporate insiders with common and repeated access to private information, and (ii) public reporting of insider trades exacerbates the problem of such coordination.

Our principal findings that corporate insiders may benefit (at the expense of liquidity traders) from regulations that require *ex post* reporting of their trades run contrary to the intent of insider trading regulations. Given repeated rounds of trading, mandatory public reporting of insider trades improves insiders' ability to monitor each other's demand, thereby facilitating tacit coordination. This is especially true when private signals relate to information routinely revealed through public announcements, such as earnings releases, and the cohort of insiders remains stable for many periods, as is often the case with corporate officers, directors and principal stock holders. Relaxing the assumption of perfect information, we also consider settings in which insiders, say financial analysts, have imperfect information. The results are qualitatively similar, although an added feature in this setting is that insiders, constructively, behave as if they were able to pool their private signals.

The Sarbanes-Oxley Act does not change the definition of an insider or the types of transactions which must be reported; however, the Act shortens the filing deadline for Forms 4 from the tenth of the month following the trade to the second business day after a reportable transaction occurs. Also, the types of transactions for which delayed reporting on Form 5 is allowed is narrowed. While the shortening of the reporting interval may in effect reduce the liquidity available to disguise insiders demands in the sense of Kyle's multi-round trading model, it also may have made it easier to coordinate trades. In addition, pre-planned trading programs under Rule 10b5-1 may facilitate trade coordination by insiders. The effects of this rule on the abnormal returns and profitability of insider trade are analyzed by Jagolinzer (2004).

Similar to Fishman and Hagerty (1995) and John and Narayanan (1997), our results contribute to a deeper understanding of the potential consequences of regulations that require the public reporting of insider trades. Although our analysis abstracts away from manipulation in the sense of the above studies, it reinforces the view that, *ceteris paribus*, public reporting of insiders' trades may be counter-productive. Of course, insider trading regulations are not limited to public reporting of insiders' trades, e.g., disgorging profits on short-swing transactions pursuant to section 16(b) of the Securities and Exchange Act, 1934. However, this requirement could be enforced without making reported trades publicly available to other insiders and market makers.[21] Since the short-swing profit rule is itself controversial,[22] then our results also add to the debate on the merit of that regulation.

Finally, we observe that the impact of insider trading in the price discovery process depends on the degree of competition among corporate insiders. In turn, this degree of competition depends on the availability of a public record of insider trades, and the nature of other market participants' liquidity demands. Our results suggest that, ceteris paribus, public disclosure of insider trades, paradoxically, inhibits rather than advances price discovery.

Notes

1. See Hoskin et al. (1986) for a description of information typically disclosed concurrent with periodic earnings announcements.

2. Under this requirement insiders must hold their positions following the purchase or sale of shares in their firm for a minimum of six months to exploit their information advantage.

3. We are indebted to David Hsieh for this observation.

4. Companies frequently set blackout periods prior to earnings announcements during which corporate insiders are not permitted to trade. for example, trading may only be allowed

on the twenty days beginning three days after an earnings announcement. However, this does not preclude trading on information expected to surface in the next earnings announcement. In fact, limiting the window for insider trading may enhance tacit coordination by clustering insider trades.

5. Laura Saunders Egodigwe, "EDS insiders unloaded $22.7 million worth of stock in 6-week span," *Wall Street Journal* (May 6, 1998), p. C1.

6. Laura Saunders Egodigwe, "Curative insiders sell stock before warning by FDA is disclosed," *Wall Street Journal* (April 22, 1998), p. C1.

7. Bob Gabele. "The inside story: Increased scrutiny makes interpreting their trades tougher" *Barron's* (April 6, 1998), p. 20.

8. To ease the analysis, we rule out multiple rounds of trading between public revelation of inside information. In so doing, we suppress an interesting issue concerning the effect of public disclosing of insider trades before such revelation. Huddart et al. (1998) show the existence of a mixed strategy equilibrium in which insiders add noise to their information-based demands to preserve some of their private information for future rounds of trade.

9. Recall that private information is short-lived implying no scope for strategic behavior in the sense of manipulating prices for future trading advantage by going contrarian. Hence, an insider can only profit from private information by trading in the same direction as the private signal.

10. The case $\theta_{j1} = -\sigma$ is symmetrical.

11. We provide conditions under which these trigger points yield monopoly profits to insiders in aggregate. When this choice of trigger points yields monopoly profits to insiders in aggregate, then no alternative strategy can do better. In particular, other choices of trigger points are dominated. Choosing trigger points less in absolute value than $\hat{y}$ implies that sometimes a penalty phase is entered when no deviation has occurred. Since monopoly profits can be implemented with zero probability of falsely triggering a penalty phase, trigger points less in absolute value than $\hat{y}$ are dominated. Choosing trigger points greater in absolute value than $\hat{y}$ implies defections resulting in order flows greater in absolute value than $\hat{y}$ go unpunished. Since such defections can be punished without falsely triggering a penalty phase by using trigger points $(-\hat{y}, \hat{y})$, then trigger points greater in absolute value than $\hat{y}$ are dominated.

12. Note that λ replaces $\bar{y}$ as the endogenous parameter defining the market maker's strategy.

13. In the absence of commitment, *ex post*, a breakeven market maker would have incentive to deviate from a linear price schedule unless the distributional assumptions support expectations that are linear in order flow. Our assumption allows us to consider a family of distributions for liquidity demands. Varying the kurtosis of liquidity demands illustrates the sensitivity to an insider's defection of the probability realized demand, y, falls outside the critical order flow values.

14. The case $\theta_{jt} = -\sigma$ is symmetric.

15. See Admati and Pfleiderer for a derivation of $E[\pi^c]$.

16. Porter (1983) claims that convexity of the distribution function is sufficient for concavity of the value function. However, it can be shown by counterexample that a ratio of concave and convex functions need not be concave. Green and Porter (1984) do not address the issue of existence and do not report on second-order conditions.

17. A qualitatively similar case would be to assume that insiders' trades are reported, but that private signals contain additive noise. Since the characterizations of demands and price adjustments are more complex and no new insights appear to be present, we do not extend our analysis to this case.

18. The log transformation is useful to demonstrating concavity and ensuring numerical precision.

19. See Abdel-khalik and Ajinka (1982) for discussion and analysis of returns in this case. Their findings suggest that profitable trading strategies can be found based on advance knowledge of forecast revisions and abnormal returns cannot be earned shortly after their public release.

20. Details are available from the authors upon request.

21. Fishman and Hagerty (1995) make a similar point, and cite the reporting of futures positions to the Commodities Futures Trading Commission (CFTC).

22. See Fishman and Hagerty (1995), pp. 665-666, for a discussion of this debate.

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