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# Insider trading and the efficiency of stock prices

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and

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*We analyze several aspects of the debate on insider trading regulations. Critics of such regulations cite various benefits of insider trading. One prominent argument is that insider trading leads to more informationally efficient stock prices. We show that under certain circumstances, insider trading leads to less efficient stock prices. This is because insider trading has two adverse effects on the competitiveness of the market: it deters other traders from acquiring information and trading, and it skews the distribution of information held by traders toward one trader. We also discuss whether shareholders of a firm have the incentive to restrict insider trading on their own.*

## 1. Introduction

■ Corporate managers and directors have access to better information than outsiders do about the prospects of their firm. With this information, corporate insiders and those they tip off can earn excess stock trading profits.<sup>1</sup> Because of this advantage, the Securities and Exchange Commission (SEC) has regulated insider trading in the United States since 1934. These regulations are the subject of much debate. Proponents of insider trading regulations argue that insider trading is harmful because it leads to (i) a loss of liquidity in the market, (ii) perverse managerial incentives, and (iii) a perception of unfairness and loss of investor confidence in capital markets.<sup>2</sup> Critics of insider trading regulations question the merits of these arguments and contend that even if insider trading did involve social costs, regulation is unnecessary since corporate shareholders would have the incentive to restrict it on their own; see, for instance, Carlton and Fischel (1983). Further, critics cite various social benefits associated with insider trading. One prominent argument is that trading by insiders with superior information leads to more informationally efficient stock prices; see, for instance, Manne (1966). The social benefit of more efficient prices is a more efficient allocation of resources.

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<sup>1</sup> Evidence on this is provided by studies that report that insiders consistently earn trading returns that exceed risk-adjusted benchmarks. See, for instance, Jaffe (1974a, 1974b), Elliott, Morse, and Richardson (1984), Seyhun (1986), and Meulbroek (1990).

<sup>2</sup> For perspectives on (i), (ii), and (iii), see Glosten (1989), Easterbrook (1985), and Brudney (1979) respectively.

This article analyzes the effect of insider trading on the informational efficiency of stock prices in an imperfectly competitive market. We show that with insider trading, the aggregate amount of information possessed by traders in the market is greater. Nevertheless, under certain circumstances, insider trading leads to less efficient stock prices. This is because insider trading has two adverse effects on stock price efficiency. First, with insider trading, the number of informed traders in the market is lower—the presence of a better-informed insider deters noninsiders from acquiring information and trading. Second, with insider trading, the information in the market is not evenly distributed across traders—the insider has an informational advantage. Both of these effects lead to a less competitive market and less efficient prices. This analysis is contained in Section 2.

Section 3 provides a general discussion of the relation between the private and social benefits and costs of insider trading and the incentives of firms' shareholders to restrict insider trading on their own. Whether shareholders would make the socially optimal decision regarding whether to restrict insider trading depends on how stock price efficiency is related to productive efficiency. As an illustration, we extend the securities market model to include a production decision, the efficiency of which is directly related to share price efficiency. For this extended model, a firm's shareholders have the incentive to allow insider trading even though it is not socially optimal. Specifically, stock price efficiency entails positive externalities. These results lend support to a rule restricting insider trading, thus facilitating "equal access" to information in securities markets. While the rationale for such a rule is generally discussed in terms of fairness (see the discussion of Brudney (1979)), equal access may lead to efficiency gains. Section 4 concludes.

## 2. Insider trading and stock price efficiency

■ A firm has publicly traded shares with a per-share value of  $\theta$ . There are two types of informed traders who trade these shares. One type comprises risk-neutral "market professionals" who can be thought of as securities analysts, brokers, or arbitrageurs. At a cost of  $F > 0$ , market professional  $i$  can privately observe the signal  $\theta + \eta_i$ . There is also a single risk-neutral "insider" who costlessly and privately observes the signal  $\theta + \epsilon$ .<sup>3</sup> Assume that  $\tilde{\theta}$ ,  $\tilde{\eta}_i$  (for all  $i$ ), and  $\tilde{\epsilon}$  are mutually independent normally distributed random variables with means  $\bar{\theta}$ , 0, and 0 respectively and precisions  $h_\theta$ ,  $h_\eta$ , and  $h_\epsilon$  respectively. Assume that the insider has access to higher-quality information. That is,  $h_\epsilon > h_\eta$ ; the insider's signal contains less noise.

The modelling of the securities market follows the noncompetitive model of Kyle (1984, 1985) and Admati and Pfleiderer (1988).<sup>4</sup> In addition to the informed traders, there are liquidity traders, whose share demands are exogenous, and a competitive risk-neutral market maker. Let  $z$  denote the net market order of the liquidity traders, where  $\tilde{z}$  is normally distributed with mean 0 and precision  $h_z$  and is independent of  $\tilde{\theta}$ ,  $\tilde{\eta}_i$  (for all  $i$ ), and  $\tilde{\epsilon}$ . Informed traders and liquidity traders submit market orders to the market maker. In turn, the market maker takes the position that balances supply and demand and sets the share price.

A trader who buys  $x$  shares earns a trading profit of  $x(\theta - p)$ , where  $p$  is the share price. Let  $R$  denote the rules governing insider trading;  $R = I$  denotes the case when insider trading is allowed and  $R = N$  denotes the case when insider trading is not allowed. Symmetric

<sup>3</sup> The results do not change if the insider faces a cost of acquiring information, as long as the cost is low enough so that given the opportunity, the insider acquires information and trades. Otherwise, insider trading regulations are irrelevant. A sufficient condition for the results that follow is that the insider's information cost be no higher than that of market professionals.

<sup>4</sup> For other noncompetitive securities market models, see Grinblatt and Ross (1985) and Laffont and Maskin (1990).

trading strategies among market professionals are considered. Let  $X(\theta + \eta_i, R)$  denote market professional  $i$ 's trading strategy;  $X$  specifies the trader's market order as a function of the signal observed and the rules on insider trading ( $x_i$  denotes trader  $i$ 's actual order). The insider's trading strategy is denoted  $Y(\theta + \epsilon, R)$ ;  $Y$  specifies the insider's market order as a function of the signal observed and the rules on insider trading ( $y$  denotes the insider's actual order). Of course,  $Y(\theta + \epsilon, N) = 0$ ; if insider trading is prohibited, the insider does not trade. Let  $\omega$  denote the order flow,  $\omega = \sum x_i + y + z$ . Let  $P(\omega, R)$  denote the market maker's pricing function;  $P$  specifies the price as a function of the order flow and the rules on insider trading ( $p$  denotes the actual price). The market maker's expected profit is zero if

$$P(\omega, R) = E[\tilde{\theta} | \omega, R]. \tag{1}$$

For a given number of informed market professionals (to be endogenously determined), a securities market equilibrium consists of trading strategies  $X$  and  $Y$  and a pricing function  $P$  such that (i)  $X$  and  $Y$  maximize the expected trading profit of each market professional and the insider, respectively, taking the other traders' strategies and  $P$  as given, and (ii)  $P$  satisfies (1) taking  $X$  and  $Y$  as given. Informed traders take the effect of their own trades on price into account. They take the pricing function, but not the price, as given.

*Lemma 1.* Suppose insider trading is allowed and  $m$  market professionals become informed. There is a unique equilibrium in which  $X$ ,  $Y$ , and  $P$  are linear functions, and it is given by

$$X(\theta + \eta_i, I) = \beta(m, I)(\theta + \eta_i - \bar{\theta}), \tag{2a}$$

$$Y(\theta + \epsilon, I) = \alpha(m, I)(\theta + \epsilon - \bar{\theta}), \tag{2b}$$

and

$$P(\omega, I) = \bar{\theta} + \lambda(m, I)\omega, \tag{2c}$$

where

$$\beta(m, I) = \frac{h_\eta(2h_\theta + h_\epsilon)}{\lambda(m, I)[2(2h_\theta + h_\eta)(h_\theta + h_\epsilon) + mh_\eta(2h_\theta + h_\epsilon)]},$$

$$\alpha(m, I) = \frac{h_\epsilon(2h_\theta + h_\eta)}{h_\eta(2h_\theta + h_\epsilon)} \beta(m, I),$$

and

$$\lambda(m, I) = \frac{\{h_z[h_\epsilon(2h_\theta + h_\eta)^2(h_\theta + h_\epsilon) + mh_\eta(2h_\theta + h_\epsilon)^2(h_\theta + h_\eta)]\}^{1/2}}{[2(2h_\theta + h_\eta)(h_\theta + h_\epsilon) + mh_\eta(2h_\theta + h_\epsilon)]h_\theta^{1/2}}.$$

*Proof.* See Appendix A.

Lemma 1 extends the trading models of Kyle (1984) and Admati and Pfleiderer (1988) to the case of informed traders with different-quality information. Since the insider is better informed than the market professionals, he trades more aggressively. That is,  $h_\epsilon > h_\eta$  implies that  $\alpha(m, I) > \beta(m, I)$ .

Prior to acquiring information, the expected trading profit of an informed market professional is computed by substituting (2a), (2b), and (2c) into the expected profit function,  $E[X(\tilde{\theta} + \tilde{\eta}_i, I)(\tilde{\theta} - P(\tilde{\omega}, I))]$ . With  $m$  informed market professionals and an insider, a market professional's expected trading profit, gross of the cost of acquiring information, is given by (see Appendix B)

$$\pi(m, I) = \frac{h_\eta(2h_\theta + h_\epsilon)^2(h_\theta + h_\eta)}{2(2h_\theta + h_\eta)(h_\theta + h_\epsilon) + mh_\eta(2h_\theta + h_\epsilon)} \times \left\{ \frac{1}{h_\theta h_\theta [h_\epsilon(2h_\theta + h_\eta)^2(h_\theta + h_\epsilon) + mh_\eta(2h_\theta + h_\epsilon)^2(h_\theta + h_\eta)]} \right\}^{1/2}. \quad (3)$$

Notice that  $\pi(m, I)$  is decreasing in  $m$ ; as more market professionals become informed and trade, there is more competition, and their expected profits are lower. Market professionals become informed if the expected trading profit covers the cost of the information. If  $\pi(0, I) \leq F$ , then no market professionals become informed. Otherwise,  $m_I$  market professionals become informed, where (ignoring the integer constraint)  $\pi(m_I, I) = F$ .

Now consider the case in which insider trading is prohibited. If  $m$  market professionals become informed, the securities market equilibrium is given by Lemma 1 with  $h_\epsilon = 0$ . A market with no insider is equivalent to a market with an insider who has no information. Thus,

$$X(\theta + \eta_i, N) = \beta(m, N)(\theta + \eta_i - \bar{\theta}), \quad (4a)$$

$$Y(\theta + \epsilon, N) = 0, \quad (4b)$$

and

$$P(\omega, N) = \bar{\theta} + \lambda(m, N)\omega, \quad (4c)$$

where  $\beta(m, N)$  equals  $\beta(m, I)$  evaluated at  $h_\epsilon = 0$  and  $\lambda(m, N)$  equals  $\lambda(m, I)$  evaluated at  $h_\epsilon = 0$ . Further, given that  $m$  market professionals become informed, their expected trading profit,  $\pi(m, N)$ , equals  $\pi(m, I)$  evaluated at  $h_\epsilon = 0$ . With no insider,  $m_N$  market professionals become informed, where  $\pi(m_N, N) = F$  (this must hold since  $\pi(0, N) = \infty$ ).

For a given number of market professionals, their expected trading profit is lower with insider trading:  $\pi(m, I) < \pi(m, N)$ . Thus, insider trading deters some market professionals from becoming informed:  $m_I < m_N$ . Now consider how the presence of an insider affects price efficiency.

Share price efficiency is measured by the posterior precision of  $\theta$ , conditional on the share price. Let  $\phi(m, R)$  denote this precision as a function of  $m$ , the number of informed market professionals, and  $R$ , the rules governing insider trading. It can be shown that<sup>5</sup>

$$\phi(m, N) = h_\theta + \frac{mh_\theta h_\eta}{2h_\theta + h_\eta} \quad (5a)$$

and

$$\phi(m, I) = \phi(m, N) + \frac{h_\theta h_\epsilon}{2h_\theta + h_\epsilon}. \quad (5b)$$

Each trader contributes  $h_\theta \tau / (2h_\theta + \tau)$  to the posterior precision of  $\theta$ , where  $\tau = h_\eta$  for a market professional and  $\tau = h_\epsilon$  for the insider. It is clear from (5a) and (5b) that if the supply of informed market professionals is inelastic with respect to the rules governing

<sup>5</sup> Observing the share price is equivalent to observing the order flow,

$$\alpha(m, R)(\theta + \epsilon - \bar{\theta}) + \sum \beta(m, R)(\theta + \eta_i - \bar{\theta}) + z,$$

which is equivalent to observing  $\theta + (\alpha(m, R)\epsilon + \beta(m, R) \sum \eta_i + z) / (\alpha(m, R) + m\beta(m, R))$ . The precision of this signal, conditional on  $\theta$ , is

$$(\alpha(m, R)^2/h_\epsilon + m\beta(m, R)^2/h_\eta + 1/h_z) / (\alpha(m, R) + m\beta(m, R))^2.$$

Substituting in for  $\alpha(m, R)$  and  $\beta(m, R)$  yields (5a) and (5b).

insider trading, then allowing the insider to trade leads to a more efficient price. As discussed above, though, some market professionals are deterred by insider trading. If a sufficient number are deterred, the share price is less efficient.

When insider trading is prohibited, the level of price efficiency is given by  $\phi(m_N, N)$ . Define  $\bar{m}$  to be the number of informed market professionals needed in the presence of an insider such that price efficiency is unchanged by insider trading. That is,  $\phi(\bar{m}, I) = \phi(m_N, N)$ , or (using (5a) and (5b))

$$\bar{m} = m_N - \frac{h_\epsilon(2h_\theta + h_\eta)}{h_\eta(2h_\theta + h_\epsilon)} \tag{6}$$

If  $m_I > \bar{m}$ , then the price is more efficient with insider trading, and if  $m_I < \bar{m}$ , then the price is less efficient with insider trading.

First consider the case in which  $\bar{m} > 0$ . Let  $\delta_i = E[\tilde{\theta} - \bar{\theta} | \theta + \eta_i]$ . With no insider trading, market professional  $i$  trades against  $m_N - 1$  other market professionals. Given (4a) and (4c), he expects the other  $m_N - 1$  market professionals to submit orders totalling  $(m_N - 1)\beta(m_N, N)\delta_i$  and the expected price as a function of his trade,  $x_i$ , to equal

$$P((m_N - 1)\beta(m_N, N)\delta_i + x_i, N) = \bar{\theta} + \lambda(m_N, N)(m_N - 1)\beta(m_N, N)\delta_i + \lambda(m_N, N)x_i \tag{7}$$

In effect, market professional  $i$  expects to face an upward-sloping inverse supply curve for shares with intercept  $\bar{\theta} + \lambda(m_N, N)(m_N - 1)\beta(m_N, N)\delta_i$  and slope  $\lambda(m_N, N)$ . Now suppose there is insider trading and  $\bar{m}$  market professionals. Given (2a), (2b), and (2c), market professional  $i$  expects the other  $\bar{m} - 1$  market professionals to submit orders totalling  $(\bar{m} - 1)\beta(\bar{m}, I)\delta_i$ , the insider to submit an order of  $\alpha(\bar{m}, I)\delta_i$ , and the expected price, as a function of his trade,  $x_i$ , to equal

$$P((\bar{m} - 1)\beta(\bar{m}, I)\delta_i + \alpha(\bar{m}, I)\delta_i + x_i, I) = \bar{\theta} + \lambda(\bar{m}, I)((\bar{m} - 1)\beta(\bar{m}, I) + \alpha(\bar{m}, I))\delta_i + \lambda(\bar{m}, I)x_i \tag{8}$$

In effect, market professional  $i$  expects to face an upward-sloping inverse supply curve for shares with intercept  $\bar{\theta} + \lambda(\bar{m}, I)((\bar{m} - 1)\beta(\bar{m}, I) + \alpha(\bar{m}, I))\delta_i$  and slope  $\lambda(\bar{m}, I)$ . Using the definition of  $\bar{m}$ , given by (6), it can be shown that

$$\lambda(m_N, N)(m_N - 1)\beta(m_N, N) = \lambda(\bar{m}, I)((\bar{m} - 1)\beta(\bar{m}, I) + \alpha(\bar{m}, I)),$$

and given that  $h_\epsilon > h_\eta$ , it can be shown that  $\lambda(m_N, N) < \lambda(\bar{m}, I)$ . The intercepts of (7) and (8) are equal but the slopes are not. Market professional  $i$  would find it less profitable to trade when facing (8) as compared to (7) for any  $\delta_i$ . Since market professional  $i$ 's expected trading profit equals his information cost when facing (7) with no insider trading, his expected trading profit is lower than his information cost when facing (8) with insider trading. That is,

$$\pi(\bar{m}, I) < \pi(m_N, N) = F \tag{9}$$

Therefore, fewer than  $\bar{m}$  market professionals become informed when insider trading is allowed, and the stock price is less efficient.<sup>6</sup>

Now consider the case in which  $\bar{m} \leq 0$ . Since  $m_I \geq 0$ , we have that  $m_I \geq \bar{m}$ , and thus the price is at least as efficient with insider trading. In this case, informed market professionals

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<sup>6</sup> The strength of this result relies on the fact that the integer constraint associated with the number of informed market professionals was ignored. Accounting for this constraint,  $m_N$  must satisfy  $\pi(m_N, N) \geq F > \pi(m_N + 1, N)$  and  $m_I$  must satisfy  $\pi(m_I, I) \geq F > \pi(m_I + 1, I)$ . For  $m_N$  and  $m_I$  determined this way, there are parameter values such that  $m_I > \bar{m} > 0$ , in which case insider trading leads to a more efficient price.

are completely crowded out by the insider. This follows from (9) and the fact that for  $m \geq \bar{m}$ ,  $\pi(m, I)$  is decreasing in  $m$ ; if  $\bar{m} \leq 0$ , then  $\pi(0, I) < \pi(\bar{m}, I) < F$ , which implies that  $m_I = 0$ . This is the case when, with no insider, there are few informed market professionals in the market. For instance, say  $m_N = 1$ . Then, allowing the insider to trade leads the single informed market professional to drop out of the market. He is replaced by the better-informed insider and price efficiency is improved. Restating these results:

*Proposition 1.* If  $\bar{m} > (\leq) 0$ , then insider trading leads to a less (equally or more) efficient stock price.

Now consider how varying the quality of the insider's information affects price efficiency. First consider the range over which insider trading does not completely crowd out market professionals, i.e.,  $m_I > 0$ . An increase in  $h_\epsilon$  leads to a decrease in the number of informed market professionals. This decrease can be bounded. By implicitly differentiating the equilibrium condition  $\pi(m_I, I) = F$  and using the fact that  $h_\epsilon > h_\eta$ , it can be shown that (see Appendix B)

$$-\frac{1}{h_\eta} < \frac{\partial m_I}{\partial h_\epsilon} < -\frac{2h_\theta(2h_\theta + h_\eta)}{h_\eta(2h_\theta + h_\epsilon)^2}. \tag{10}$$

Differentiating  $\phi(m_I, I)$  with respect to  $h_\epsilon$  yields

$$\frac{\partial \phi(m_I, I)}{\partial h_\epsilon} = \frac{h_\theta h_\eta}{2h_\theta + h_\eta} \frac{\partial m_I}{\partial h_\epsilon} + 2 \left\{ \frac{h_\theta}{2h_\theta + h_\epsilon} \right\}^2. \tag{11}$$

The right-hand side of (10) implies that  $\partial \phi(m_I, I) / \partial h_\epsilon < 0$ . The stock price becomes less efficient as the insider's information improves.

Over the range in which insider trading completely crowds out market professionals, i.e.,  $m_I = 0$ , price efficiency is increasing in  $h_\epsilon$ . The insider is the sole trader, and as his information gets better the stock price becomes more efficient. In terms of (11),  $\partial m_I / \partial h_\epsilon = 0$ , and thus  $\partial \phi(m_I, I) / \partial h_\epsilon > 0$ . Restating these results:

*Proposition 2.* Suppose insider trading is allowed. If  $m_I > (=) 0$ , then the better the information of the insider, the less (more) efficient is the share price.

Propositions 1 and 2 present conditions under which insider trading leads to a less efficient stock price, and the problem is more severe the better the insider's information. These conditions hold for firms in which, for instance, a market professional's cost of acquiring information is low, the insider's informational advantage is low, and/or the stock is actively traded by liquidity traders. That is,  $\bar{m}$  and  $m_I$  are decreasing in  $F$ ,  $h_\epsilon$ , and  $h_z$ . Firms with these characteristics also have many informed market professionals following them. In practice, what types of firms are these? The finding of Arbel and Strebel (1982), that the number of securities analysts who regularly follow a firm is positively correlated with firm size, suggests that they are large firms. Thus, large (small) firms may be the ones for which insider trading is detrimental (beneficial) for stock price efficiency.

Interestingly, despite the ultimate effect on share price efficiency, the aggregate amount of information acquired by traders in the market is greater with insider trading than without insider trading. That is,

$$m_I h_\eta + h_\epsilon > m_N h_\eta. \tag{12}$$

Further, with insider trading, the aggregate amount of information acquired by traders is greater the better the insider's information. That is,

$$\frac{\partial(m_I h_\eta + h_\epsilon)}{\partial h_\epsilon} = \frac{\partial m_I}{\partial h_\epsilon} h_\eta + 1 > 0. \quad (13)$$

The inequality in (13) follows from the left-hand side of (10). Inequality (12) follows from (13) and the fact that  $m_I h_\eta + h_\epsilon$  equals  $m_N h_\eta$  at  $h_\epsilon = h_\eta$ . The reason the increase in acquired information is not reflected in the stock price is because insider trading has two adverse effects: (i) the total number of informed traders decreases, i.e.,  $m_I + 1 < m_N$  and  $m_I + 1$  is decreasing in  $h_\epsilon$ ; and (ii) the distribution of information held by traders is skewed toward one trader.

To understand the effects of (i) and (ii) on price efficiency, consider the following parameterization. Suppose there are  $m$  market professionals and let  $h_\eta = (1 - \gamma)\tau/m$  and let  $h_\epsilon = \gamma\tau$ , where  $0 \leq \gamma \leq 1$  and  $\tau > 0$ . The aggregate amount of information acquired by traders is fixed at  $m(1 - \gamma)\tau/m + \gamma\tau = \tau$ . The parameter  $\gamma$  measures the fraction of information in the market that is held by the insider. Using (5b), the level of price efficiency equals

$$\phi(m, I) = h_\theta + \frac{h_\theta(1 - \gamma)\tau}{2h_\theta + (1 - \gamma)\tau/m} + \frac{h_\theta\gamma\tau}{2h_\theta + \gamma\tau},$$

which is increasing in  $m$ . That is, holding  $\tau$  fixed, more traders with less precise information results in a more efficient price than fewer traders with more precise information. This is because with more traders, the market is more competitive, and more of the information is reflected in the order flow. To see the effect of (ii), consider varying the relative access to information between market professionals and the insider by varying  $\gamma$ . It can be verified that the maximum level of price efficiency is achieved when all traders have access to the same quality of information—that is, when  $\gamma = 1/(m + 1)$ , which is equivalent to setting  $h_\eta = h_\epsilon = \tau/(m + 1)$ . Therefore, unequal access to information has adverse effects even when the number of traders is held fixed. Unequal access leads to less aggressive trading by the market professionals and more aggressive trading by the insider, but the net effect is an order flow that is less sensitive to traders' information and thus less informative. Restating these results:

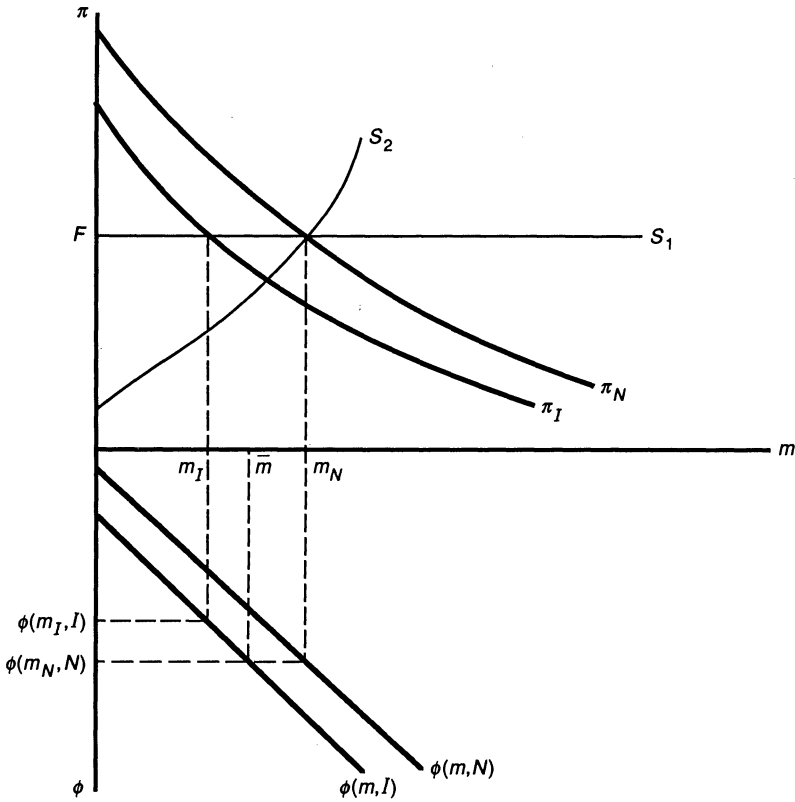
*Proposition 3.* Holding the aggregate amount of information acquired by traders in the market fixed, (i) stock price efficiency is increasing in the number of market professionals, and (ii) holding the number of market professionals fixed, stock price efficiency is maximized when information is evenly distributed between market professionals and the insider.

The analysis is based on an assumption that all market professionals face the same cost,  $F$ , of acquiring information. In other words, the supply of informed market professionals is perfectly elastic at an expected profit of  $F$ . The results are sensitive to this assumption. This is illustrated in Figure 1 for the case of  $\bar{m} > 0$ . With the horizontal supply curve  $S_1$ , share price efficiency is reduced by insider trading. This is Proposition 1. The supply curve  $S_2$  corresponds to a case in which the cost of becoming informed varies among market professionals. The rate at which market professionals are deterred by an insider is lower for an upward-sloping supply curve than for a horizontal supply curve. The steeper the supply curve, the fewer the number of market professionals that are deterred by insider trading and thus the more beneficial is insider trading for price efficiency. For the supply curve  $S_2$ , share price efficiency is improved by insider trading because fewer than  $m_N - \bar{m}$  market professionals are deterred.

In the analysis, traders are assumed to behave noncompetitively. That is, they take into account the effect of their trades on the price. In related work, George (1988) shows that in a competitive model, insider trading (defined as trading by individuals with less costly access to information) leads to more efficient stock prices. The key to the difference behind the results is as follows. In the competitive model, traders' information acquisition



FIGURE 1



decisions depend on the amount of information conveyed by the equilibrium price, but not on the distribution of information across traders. In the noncompetitive model, traders' information acquisition decisions depend on both the amount of information conveyed by the equilibrium price and the distribution of information across traders. In particular, for a given level of price informativeness, an individual trader's gain from acquiring information is lower when he trades against better-informed traders. This is not the case in the competitive model and is what leads to the difference in results. We believe that our approach is more appropriate. Traders with significant informational advantages should be expected to make large trades, and evidence indicates that large trades do move stock prices. Some evidence on the size of trades for one sample of insiders is provided by Meulbroek (1990), who studies the trades of 320 individuals who were subsequently prosecuted by the Securities and Exchange Commission for insider trading violations. She finds that on the days of these insider trades, the mean (median) ratio of the insiders' trading volume relative to total trading volume is 41.7% (11.3%). Evidence that large buys (sells) lead to significant stock price increases (decreases) is provided by, among others, Holthausen, Leftwich, and Mayers (1987, 1990). Further, the latter study finds that most of the price change is permanent, which is consistent with the price change being due to information conveyed by the trade. Therefore, it seems that the perspective gained from a model of imperfect competition is more relevant than that from a model with perfect competition.

### 3. Price efficiency, resource allocation, and shareholder incentives regarding insider trading rules

■ The results of Section 2 indicate that allowing a better-informed insider to trade can lead to a less efficient share price. In this section, we discuss how the private costs and

benefits of insider trading compare to the social costs and benefits when the insider has a contractual relationship with the firm. This tells us how the decision of a firm's shareholders on whether to allow the insider to trade compares to the socially optimal decision.<sup>7</sup>

What is the social cost of insider trading? If insider trading decreases share price efficiency, then there are several (not mutually exclusive) possible costs. First, share price efficiency may affect the quality of investment decisions within the given firm. For example, a firm's share price may act as a signal in directing production decisions within the firm; see Leland (1990). Alternatively, greater share price efficiency may provide an incentive for firms' managers to make better investment decisions. This is because more efficient prices better reflect the investment decisions that are made; see Fishman and Hagerty (1989). In addition, the distortions induced by adverse selection that arise when firms raise external capital may be lower, the more efficient are firms' stock prices. This is because more efficient stock prices reduce the informational asymmetry between firms and prospective investors; see Myers and Majluf (1984). Second, share price efficiency may affect the quality of investment decisions outside the given firm. For example, stock prices may serve as signals conveying information to those outside the firm. The more efficient these signals, the better they serve in directing the allocation of resources into or out of various industries. How does the social cost of insider trading compare to the private cost? As with any negative externality, shareholders will give too little regard to the cost of insider trading if some of the cost is borne by shareholders of other firms. Thus, shareholders' private costs of insider trading will be less than the social cost unless all benefits of an efficient share price are captured by the given firm.

What is the social benefit of insider trading? With insider trading, fewer market professionals become informed,  $m_I < m_N$ . This saves  $(m_N - m_I)F$  in expenditures on information acquisition. How does the social benefit of insider trading compare to the private benefit? For this discussion, we take the shareholders of the firm to be the liquidity traders of the previous section, and we focus on their expected income. While the results are suggestive, it should be noted that since we have not specified liquidity traders' utility functions or motives for trading, we cannot make conclusive statements regarding their welfare. To understand the relation between the social and private cost of insider trading, it must be noted that insider trading profits are a form of compensation for corporate insiders; see Manne (1966). Therefore, shareholders can recoup their expected trading losses to the insider by lowering his salary by the amount of his expected trading profit. Shareholders cannot, however, recoup their expected trading losses to market professionals with whom they have no contractual relationship. Thus, while the expected trading profits of both the insider and market professionals come at the expense of the shareholders, the net losses of shareholders only equal the expected trading profits of the market professionals. These losses are minimized by allowing insider trading, since the insider serves to crowd out some of the market professionals. This is the argument of Bradley, Khanna, and Slezak (1991). Here, the benefit of insider trading for shareholders equals  $m_N\pi(m_N, N) - m_I\pi(m_I, I)$ . Since  $\pi(m_N, N) = F$  and if  $m_I > 0$   $\pi(m_I, I) = F$ , this benefit equals  $(m_N - m_I)F$ . Thus, the private benefit of insider trading to shareholders equals the social benefit; in effect, shareholders fully account for market professionals' expenditures.

The above discussion implies that if the cost of a less efficient share price, and thus the cost of insider trading, accrues only to the given firm, then shareholders would make the socially optimal decision regarding whether to allow insider trading. This is because shareholders' benefits from insider trading are aligned with social benefits. This is consistent with the argument of Carlton and Fischel (1983). If some of the cost of a less efficient share

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<sup>7</sup> Even though insider trading is regulated, some firms have their own additional rules. For example, Avon Products had a rule specifying that officers of the firm could only trade between the fifth and sixteenth trading days following quarterly earnings announcements. See Louis, "The Unwinnable War on Insider Trading," *Fortune*, July 13, 1981.

price is borne outside the firm, however, then shareholders might have the incentive to allow insider trading when it is not socially optimal.<sup>8</sup>

The above arguments have been made without reference to the specific way in which share price efficiency is beneficial. Once a benefit of share price efficiency is explicitly considered, though, do the results concerning insider trading and share price efficiency still hold? If the effects of share price efficiency accrue entirely outside the given firm, and thus the value of the given firm is unaffected by share price efficiency, then the analysis goes through as in Section 2. Suppose, though, that the value of a firm depends on how efficient its share price is. Then, unlike the analysis of Section 2, the value of the firm's shares must be treated as endogenous rather than exogenous. How does this affect the relation between insider trading and share price efficiency? To address this issue, we extend the previous analysis by modelling a benefit to share price efficiency. The extended model formalizes the idea that price efficiency is beneficial because stock prices are signals that direct the allocation of resources. We show that in this setting, the previous results concerning the relation between insider trading and share price efficiency continue to hold.

Suppose the uncertainty about a firm's profitability stems from uncertainty about the demand for its output. In particular, the firm of Section 2 is in an industry with linear inverse demand; output price equals  $\theta - bQ$ , where  $Q$  is industry output,  $b > 0$ , and the distribution of  $\theta$  is the same as in Section 2. Further, the firm's output is fixed at one unit, the cost of which is  $c \geq 0$ .<sup>9</sup> Call this firm the incumbent. Suppose there is also a competing firm, called the entrant. The entrant observes the share price of the incumbent and then chooses its level of output. In this setting, share price efficiency is important because it determines the efficiency with which the entrant makes its production decision.

Assume the entrant's marginal cost of production is  $c$  and let  $q \geq 0$  denote its output. Using the information contained in the incumbent's share price,  $p$ , and knowing the rules governing insider trading,  $R$ , the entrant's problem is given by

$$\max_{q \geq 0} E[(\tilde{\theta} - b(1 + q) - c)q | p, R].$$

The solution to this problem is given by

$$q = \max \left\{ \frac{E[\tilde{\theta} | p, R] - b - c}{2b}, 0 \right\}. \quad (14)$$

If the incumbent's share price suggests that output demand is strong enough, the entrant produces a positive level of output.<sup>10</sup>

In solving for a securities market equilibrium, there is an important difference between the original model and this extended model. Previously, the terminal value of the traded shares was exogenous. Now the terminal value of the traded shares, those of the incumbent, is determined endogenously: the entrant's production decision, which is made on the basis of the incumbent's stock price, affects the price of output and thus affects the incumbent's terminal value. Specifically, normalizing the number of shares to one, the incumbent's terminal value is  $\theta - b(1 + q) - c$ . We continue to assume that agents behave strategically. This means that traders and the market maker take into account their effect on the incumbent's stock price, the effect of the stock price on the entrant's production decision, and

<sup>8</sup> If market professionals faced varying costs of acquiring information, as illustrated in Figure 1, then the alignment between the private and social benefit would not be perfect. The private benefit of insider trading would exceed the social benefit.

<sup>9</sup> By fixing the firm's output we avoid issues concerning managerial incentives and insider trading. With output fixed, the manager cannot make a bad production decision and simultaneously sell shares of the firm. See Dye (1984) and Easterbrook (1985) for discussions of insider trading and managerial incentives.

<sup>10</sup> Stock prices are an indirect means by which firms share information with their competitors. For a discussion of the incentives to share information directly in oligopolistic markets, see, for instance, Kirby (1988).

finally, the effect of the entrant’s production decision on the terminal value of the incumbent’s shares.

Consider the following production strategy:  $q^*(p) = \max \{p/b, 0\}$ . If the entrant follows this strategy, then the condition that the incumbent’s share price equal its expected value conditional on the order flow,  $\omega$ , is given by

$$P(\omega, R) = \begin{cases} E[\tilde{\theta}|\omega, R] - b(1 + P(\omega, R)/b) - c & \text{if } P(\omega, R) \geq 0 \\ E[\tilde{\theta}|\omega, R] - b - c & \text{if } P(\omega, R) < 0. \end{cases} \quad (15)$$

Rearranging (15),

$$P(\omega, R) = \begin{cases} \frac{E[\tilde{\theta}|\omega, R] - b - c}{2} & \text{if } P(\omega, R) \geq 0 \\ E[\tilde{\theta}|\omega, R] - b - c & \text{if } P(\omega, R) < 0. \end{cases} \quad (16)$$

If the market maker’s pricing function satisfies (16), then

$$E[\tilde{\theta}|p, R] = \begin{cases} 2p + b + c & \text{if } p \geq 0 \\ p + b + c & \text{if } p < 0. \end{cases}$$

Substituting in for  $E[\tilde{\theta}|p, R]$  in (14) indicates that if the market maker’s pricing function satisfies (16), the entrant’s optimal level of output equals  $q^*(p)$ . Further, if the entrant follows the strategy  $q^*(p)$ , a pricing function that satisfies (16) yields a zero expected profit for the market maker. In addition, the profit of a trader who buys  $x$  shares of the incumbent equals

$$\begin{aligned} & \begin{cases} x[\theta - b(1 + P(\omega, R)/b) - c - P(\omega, R)] & \text{if } P(\omega, R) \geq 0 \\ x[\theta - b - c - P(\omega, R)] & \text{if } P(\omega, R) < 0 \end{cases} \\ = & \begin{cases} x[\theta - b - c - 2P(\omega, R)] & \text{if } P(\omega, R) \geq 0 \\ x[\theta - b - c - P(\omega, R)] & \text{if } P(\omega, R) < 0. \end{cases} \end{aligned} \quad (17)$$

Now, consider a securities market equilibrium in which the market maker’s pricing function satisfies (16) and informed traders maximize their expected profit.<sup>11</sup>

*Lemma 2.* Suppose insider trading is allowed and  $m$  market professionals become informed. There is an equilibrium with trading strategies  $X(\theta + \eta_i, I)$  and  $Y(\theta + \epsilon, I)$  as given in Lemma 1 and

$$P(\omega, I) = \begin{cases} (\bar{\theta} - b - c + \lambda(m, I)\omega)/2 & \text{if } \omega \geq -(\bar{\theta} - b - c)/\lambda(m, I) \\ \bar{\theta} - b - c + \lambda(m, I)\omega & \text{if } \omega < -(\bar{\theta} - b - c)/\lambda(m, I), \end{cases} \quad (18)$$

where  $\lambda(m, I)$  is as given in Lemma 1.

*Proof.* See Appendix A.

The equilibrium price function differs from that of Lemma 1. Now, for order flows exceeding  $-(\bar{\theta} - b - c)/\lambda(m, I)$ , the price is only one-half as sensitive to the order flow. That is, the coefficient on  $\omega$  is  $\lambda(m, I)/2$  instead of  $\lambda(m, I)$ . The equilibrium trading strategies have not changed, though. This is because the total cost of trading a share on the net profit per share traded is still  $\lambda(m, I)$ . This can be seen by substituting  $P(\omega, I)$  into

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<sup>11</sup> The trading profit in (17) is stated for a trader with no current shareholdings. In this extended model, current shareholders of the incumbent have an incentive, beyond any information they have, to sell shares. This is because share sales have the effect of lowering the current share price, which reduces the entrant’s output. This raises the value of any remaining shares held. In equilibrium however, this trading would be taken into account by the market maker, and the outcome is unchanged.

(17); a trader who buys  $x$  shares earns a trading profit of  $x(\theta - \bar{\theta} - \lambda(m, I)\omega)$ , which is the same as in Section 2. The intuition is that if a trader buys one share, then the share price only increases by  $\lambda(m, I)/2$ , but the terminal value of the share decreases by  $\lambda(m, I)/2$ . The latter effect occurs because the entrant increases his output in response to a higher share price, which leads to a lower output price, which leads to a lower terminal value for the incumbent. Thus, in equilibrium, traders' profit functions, strategies, and expected profits are unchanged.

When insider trading is prohibited, the equilibrium trading strategies are obtained by replacing  $X(\theta + \eta_i, I)$  and  $Y(\theta + \epsilon, I)$  with  $X(\theta + \eta_i, N)$  and  $Y(\theta + \epsilon, N)$  as given by (4a) and (4b), and by replacing  $\lambda(m, I)$  in the price function with  $\lambda(m, N)$ , where  $\lambda(m, N)$  equals  $\lambda(m, I)$  evaluated at  $h_\epsilon = 0$ .

The measures of share price efficiency,  $\phi(m, R)$ , are unchanged and are given in (5). Therefore, the effects of insider trading on price efficiency are unchanged. Propositions 1, 2, and 3 hold in this extended model.

Now consider the effect of stock price efficiency on the incumbent's expected terminal value. Substituting in for the entrant's production decision using (14), the incumbent's expected terminal value equals

$$\bar{\theta} - b \left\{ 1 + E \max \left\{ \frac{E[\tilde{\theta} | P(\tilde{\omega}, R), R] - b - c}{2b}, 0 \right\} \right\} - c.$$

In equilibrium, the random variable  $E[\tilde{\theta} | P(\tilde{\omega}, R), R]$  is normally distributed with mean  $\bar{\theta}$  and variance  $\tau/h_\theta(h_\theta + \tau)$ , where  $\tau$  is the precision (conditional on  $\theta$ ) of the signal observed by the entrant, i.e., the incumbent's stock price. Since this variance is increasing in  $\tau$ , and since the incumbent's value is concave in  $E[\tilde{\theta} | P(\omega, R), R]$ , the incumbent's expected value is decreasing in  $\tau$ . The incumbent's expected terminal value is actually higher when its stock price is less efficient. The intuition is as follows. As the incumbent's stock price becomes more efficient, the entrant makes a more efficient production decision. This benefits the incumbent when consumer demand is low and harms the incumbent when consumer demand is high. The latter effect outweighs the former, since the entrant's output is bounded below by zero but is not bounded above.

The entrant's expected profit is lower with a less efficient stock price because its production decision is based on less information. Note that if the entrant must incur a cost of entry, prior to observing the incumbent's share price, then a reduction in stock price efficiency could act as an entry deterrent. Expected consumer surplus is also lower with a less efficient stock price because output is less sensitive to consumer demand. The decreases in the entrant's expected profit and in expected consumer surplus resulting from a decrease in stock price efficiency more than offset the increase in the incumbent's expected profit.<sup>12</sup> Thus, if insider trading leads to a less efficient stock price, welfare in the product market is lower.<sup>13</sup>

<sup>12</sup> This is seen as follows. Expected consumer surplus equals

$$\frac{b}{2} E \left[ \left( 1 + \max \left\{ \frac{E[\tilde{\theta} | P(\tilde{\omega}, R), R] - b - c}{2b}, 0 \right\} \right)^2 \right].$$

Expected consumer surplus plus the incumbent's expected profit equals

$$\bar{\theta} - \frac{b}{2} - c + \frac{b}{2} E \left[ \max \left\{ \frac{E[\tilde{\theta} | P(\tilde{\omega}, R), R] - b - c}{2b}, 0 \right\}^2 \right]$$

and is lower, the less efficient is the incumbent's stock price. The entrant's expected profit is also lower with a less efficient stock price. Therefore, the sum of total expected profits and expected consumer surplus is lower the less efficient the stock price. See Rogerson (1980) for a discussion of when expected consumer surplus is a valid measure of welfare.

<sup>13</sup> Ausubel (1990) discusses another reason why insider trading may lead to less efficient production decisions. Asymmetric information in a market reduces trade between agents. In turn, this reduces the incentives to produce the commodities to be traded.

For this example, if insider trading reduces share price efficiency, then the incumbent's shareholders have no incentive to restrict it. On the contrary, shareholders may have the incentive to restrict insider trading only if it increases share price efficiency.<sup>14</sup>

#### 4. Concluding remarks

■ It is sometimes argued that equal access to information in securities markets is important for reasons of fairness. Fairness aside, the results of this article indicate that equal access may be important for reasons of stock price efficiency. These results stem from the deleterious effects of insider trading on the competitiveness of the securities market.

Under SEC rule 10b-5, it is unlawful for insiders to trade securities on the basis of material nonpublic information without first disclosing the information.<sup>15</sup> Who, though, is an insider? A key case in developing an answer to this question is *Chiarella v. United States*.<sup>16</sup> Chiarella, an employee of a financial printing company, traded the securities of firms on the basis of confidential information that these firms were to be the targets of acquisitions by clients of the printing company. Chiarella was convicted, but the Supreme Court reversed the decision on appeal. In doing so, the Court limited the scope of rule 10b-5 by rejecting the notion that it applies to potentially everyone. Rather, it was deemed necessary that the individual have a fiduciary obligation to those on the other side of his trades. And while Chiarella may have had a fiduciary obligation to his employer, he was not deemed to have had a fiduciary obligation to other marketplace traders. In his dissenting opinion in *Chiarella* (page 251), Justice Blackmun held that the scope of rule 10b-5 had been narrowed too much: "I would hold that persons having access to confidential material information that is not legally available to others generally are prohibited by Rule 10b-5 from engaging in schemes to exploit their structural informational advantage through trading in affected securities." In response to this development, the SEC pursued the "misappropriation" theory. Under this theory, rule 10b-5 liability applies to those who violate a fiduciary obligation, though not necessarily to marketplace traders, by trading on someone else's information. This theory was first accepted in *United States v. Newman*.<sup>17</sup> The facts of this case are similar to those of *Chiarella*. Employees of an investment banking firm purchased stock of firms on the basis of confidential information that these firms were to be the targets of acquisitions by clients of the investment bank. Though the employees had no fiduciary relationship with marketplace traders, they did have a fiduciary relationship with their employer, which was violated when they traded.<sup>18</sup>

What do our results suggest about the merit of this direction of case law? Our results show that under certain circumstances, allowing trading on the basis of information that is publicly available (though perhaps costly), and prohibiting trading on the basis of information that is not publicly available makes the market more informationally efficient. This is the case irrespective of an individual's relationship with marketplace traders. Therefore, under these circumstances, our results support the overall direction taken by case law in (i) limiting the scope of rule 10b-5 by not applying it to everyone, and (ii) expanding the scope of

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<sup>14</sup> The implications regarding incumbent shareholder incentives may not be robust to various changes in this extended model. For instance, an entrant capacity constraint, the production of complementary rather than substitute goods, or price rather than quantity competition may lead to a case in which the incumbent share value is higher with a more efficient stock price.

<sup>15</sup> The discussion of the law in this section is drawn from Macey (1984), Phillips and Lavoie (1988), and Langevoort (1991).

<sup>16</sup> 445 U.S. 222 (1980).

<sup>17</sup> 664 F. 2d 12 (2d Cir. 1981), cert. denied, 464 U.S. 863 (1983).

<sup>18</sup> A well-known later case utilizing the misappropriation theory is *Carpenter v. United States*, 108 S. Ct. 316 (1987). In this case, a *Wall Street Journal* reporter and others traded on information that was to appear in the newspaper's "Heard on the Street" column. Here, the reporter's fiduciary relationship was with the newspaper.

rule 10b-5 by applying it to individuals who acquired their information solely because of some fiduciary relationship, whether contractual, personal, or other, even if this relationship is not with marketplace traders.

Public disclosure of the insider’s information is sometimes seen as an alternative to prohibiting insider trading. This is because disclosure eliminates the insider’s informational advantage. Would the insider voluntarily disclose his information? In other contexts, it has been shown that the market can ensure voluntary disclosure. This is because failure to disclose leads the market to believe “the worst”; see Grossman (1981) and Milgrom (1981). This type of result does not hold here. To see this, consider the following. Suppose the insider can submit only buy orders. Also suppose the market maker’s beliefs in response to a less than full disclosure are that the insider’s signal is the highest possible value consistent with what was disclosed. With such beliefs, the insider earns no trading profits whether or not he fully discloses his information. Thus he would be willing to fully disclose. A similar argument applies if the insider can submit only sell orders. The insider, however, can submit buy or sell orders. Given this, there are no market maker beliefs that always eliminate the insider’s trading profit if he withholds some information. And since full disclosure leads to a zero profit, insiders will not fully disclose voluntarily.

Now consider a mandatory disclosure rule. Like insider trading, public disclosure of the insider’s information deters noninsiders from acquiring information and trading. This is because their relative informational advantage is reduced. Nevertheless, as Kyle (1984) has shown, when all informed traders have access to same-quality signals, the net effect of a public disclosure is a more efficient price. Therefore, requiring the insider to disclose his information leads to a more efficient price than simply banning him from trading. Of course, such a rule is equivalent to a ban on insider trading if it deters the insider from ever collecting the information. A “disclose or abstain from trading” rule like SEC rule 10b-5, where the insider must disclose any material nonpublic information before trading, also eliminates the incentive to acquire information solely for trading. Unlike mandatory disclosure, however, it preserves the incentive to acquire information for business purposes.<sup>19</sup>

**Appendix A**

■ Proofs of Lemmas 1 and 2 follow.

*Proof of Lemma 1.* For notational simplicity, we write  $\alpha(m, I)$ ,  $\beta(m, I)$ , and  $\lambda(m, I)$  as  $\alpha$ ,  $\beta$ , and  $\lambda$  respectively. Market professional  $j$ , taking (2a), for  $i \neq j$ , (2b), and (2c) as given, solves the following problem:

$$\max_{x_j} E[x_j(\bar{\theta} - \bar{\theta} - \lambda(\sum_{i \neq j} \beta(\bar{\theta} + \tilde{\eta}_i - \bar{\theta}) + x_j + \alpha(\bar{\theta} + \tilde{\epsilon} - \bar{\theta}) + \tilde{z})) | \theta + \eta_j],$$

which can be rewritten as

$$\max_{x_j} x_j \left[ \left\{ \frac{h_\theta \bar{\theta} + h_\eta(\theta + \eta_j)}{h_\theta + h_\eta} - \bar{\theta} \right\} \cdot \{1 - \lambda(m - 1)\beta - \lambda\alpha\} - \lambda x_j \right].$$

The solution to this problem is given by

$$x_j^* = \frac{(1 - \lambda(m - 1)\beta - \lambda\alpha)h_\eta}{2\lambda(h_\theta + h_\eta)} (\theta + \eta_j - \bar{\theta}).$$

The insider, taking (2a) and (2c) as given, solves the following problem:

$$\max_y E[y(\bar{\theta} - \bar{\theta} - \lambda(\sum \beta(\bar{\theta} + \tilde{\eta}_i - \bar{\theta}) + y + \tilde{z})) | \theta + \epsilon],$$

which can be rewritten as

$$\max_y y \left[ \left\{ \frac{h_\theta \bar{\theta} + h_\epsilon(\theta + \epsilon)}{h_\theta + h_\epsilon} - \bar{\theta} \right\} \cdot \{1 - \lambda m \beta\} - \lambda y \right].$$

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<sup>19</sup> See Scott (1980) for a general discussion of disclosure and insider trading. For an analysis of mandatory and voluntary disclosure of trades, see Fishman and Hagerty (1991).

The solution to this problem is given by

$$y^* = \frac{(1 - \lambda m \beta) h_\epsilon}{2\lambda(h_\theta + h_\epsilon)} (\theta + \epsilon - \bar{\theta}).$$

A Nash equilibrium among traders is found by solving the following two equations:

$$\beta = \frac{(1 - \lambda(m - 1)\beta - \lambda\alpha)h_\eta}{2\lambda(h_\theta + h_\eta)}$$

and

$$\alpha = \frac{(1 - \lambda m \beta) h_\epsilon}{2\lambda(h_\theta + h_\epsilon)}.$$

This yields  $\beta$  and  $\alpha$  as given in Lemma 1. The pricing function must satisfy (1). Taking (2a) and (2b) as given,

$$E[\tilde{\theta}|\omega] = \bar{\theta} + \frac{\text{Cov}(\tilde{\theta}, \tilde{\omega})}{\text{Var}(\tilde{\omega})} \omega.$$

Therefore (2c) satisfies (1) if  $\lambda$  satisfies

$$\lambda = \frac{\text{Cov}(\tilde{\theta}, \tilde{\omega})}{\text{Var}(\tilde{\omega})} = \frac{\text{Cov}(\tilde{\theta}, \sum \beta(\tilde{\theta} + \tilde{\eta}_i - \bar{\theta}) + \alpha(\tilde{\theta} + \tilde{\epsilon} - \bar{\theta}) + \tilde{z})}{\text{Var}(\sum \beta(\tilde{\theta} + \tilde{\eta}_i - \bar{\theta}) + \alpha(\tilde{\theta} + \tilde{\epsilon} - \bar{\theta}) + \tilde{z})}.$$

Solving this equation yields  $\lambda$  as given in Lemma 1. This is the unique equilibrium in which  $X$ ,  $Y$ , and  $P$  are linear functions. *Q.E.D.*

*Proof of Lemma 2.* Suppose the pricing function is given by (18). Substituting (18) into (17), it can be seen that the profit of a trader who buys  $x$  shares is given by  $x(\bar{\theta} - \bar{\theta} - \lambda(m, I)\omega)$ . Therefore, by Lemma 1, a Nash equilibrium among traders is given by trading strategies  $X$  and  $Y$  as given by (2a) and (2b).

The pricing function must satisfy (16). By Lemma 1, taking (2a) and (2b) as given,

$$E[\tilde{\theta}|\omega] = \bar{\theta} + \lambda(m, I)\omega.$$

Substituting in for  $\bar{\theta} + \lambda(m, I)\omega$  in (18) yields

$$P(\omega, I) = \begin{cases} [E[\tilde{\theta}|\omega] - b - c]/2 & \text{if } \omega \geq -(\bar{\theta} - b - c)/\lambda(m, I) \\ E[\tilde{\theta}|\omega] - b - c & \text{if } \omega < -(\bar{\theta} - b - c)/\lambda(m, I). \end{cases}$$

Finally, since  $\omega \geq -(\bar{\theta} - b - c)/\lambda(m, I)$  if and only if  $E[\tilde{\theta}|\omega] - b - c \geq 0$ , we have that (18) satisfies (16). *Q.E.D.*

### Appendix B

■ Let

$$k_1 = 2(2h_\theta + h_\eta)(h_\theta + h_\epsilon) + mh_\eta(2h_\theta + h_\epsilon),$$

$$k_2 = h_\epsilon(2h_\theta + h_\eta)^2(h_\theta + h_\epsilon) + mh_\eta(2h_\theta + h_\epsilon)^2(h_\theta + h_\eta).$$

*Derivation of  $\pi(m, I)$*  ((3) in text). For notational simplicity, we write  $\alpha(m, I)$ ,  $\beta(m, I)$ , and  $\lambda(m, I)$  as  $\alpha$ ,  $\beta$ , and  $\lambda$  respectively. Note that

$$\alpha = \frac{h_\epsilon(2h_\theta + h_\eta)}{\lambda k_1}, \quad \beta = \frac{h_\eta(2h_\theta + h_\epsilon)}{\lambda k_1}, \quad \text{and} \quad \lambda = \frac{(h_2 k_2)^{1/2}}{k_1 h_\theta^{1/2}}$$

$$\begin{aligned} \pi(m, I) &= E[X(\tilde{\theta} + \tilde{\eta}_i, I)(\tilde{\theta} - P(\tilde{\omega}, I))] \\ &= E[\beta(\tilde{\theta} + \tilde{\eta}_i - \bar{\theta})(\tilde{\theta} - \bar{\theta} - \lambda(\sum_j \beta(\tilde{\theta} + \tilde{\eta}_j - \bar{\theta}) + \alpha(\tilde{\theta} + \tilde{\epsilon} - \bar{\theta}) + \tilde{z}))] \\ &= \beta[(1 - \lambda\alpha - \lambda m\beta)/h_\theta - \lambda\beta/h_\eta]. \end{aligned}$$

Substituting in for  $\alpha$ ,  $\beta$ , and  $\lambda$ , we have

$$\begin{aligned} \pi(m, I) &= \frac{h_\eta(2h_\theta + h_\epsilon)h_\theta^{1/2}}{(h_2 k_2)^{1/2}} \left[ \left( 1 - \frac{h_\epsilon(2h_\theta + h_\eta)}{k_1} - \frac{mh_\eta(2h_\theta + h_\epsilon)}{k_1} \right) / h_\theta - \frac{2h_\theta + h_\epsilon}{k_1} \right] \\ &= \frac{h_\eta(2h_\theta + h_\epsilon)}{k_1(h_\theta h_2 k_2)^{1/2}} [k_1 - h_\epsilon(2h_\theta + h_\eta) - mh_\eta(2h_\theta + h_\epsilon) - h_\theta(2h_\theta + h_\epsilon)] \end{aligned}$$



$$\begin{aligned}
 &= \frac{h_\eta(2h_\theta + h_\epsilon)}{k_1(h_\theta h_\epsilon k_2)^{1/2}} [2(2h_\theta + h_\eta)(h_\theta + h_\epsilon) - h_\epsilon(2h_\theta + h_\eta) - h_\theta(2h_\theta + h_\epsilon)] \\
 &= \frac{h_\eta(2h_\theta + h_\epsilon)^2(h_\theta + h_\eta)}{k_1(h_\theta h_\epsilon k_2)^{1/2}},
 \end{aligned}$$

which is (3) in the text.

Derivation of  $-\frac{1}{h_\eta} < \frac{\partial m_I}{\partial h_\epsilon} < -\frac{2h_\theta(2h_\theta + h_\eta)}{h_\eta(2h_\theta + h_\epsilon)^2}$  ((10) in text). Let  $k_{1I}$  and  $k_{2I}$  equal  $k_1$  and  $k_2$  (defined above) evaluated at  $m = m_I$ . Implicit differentiation of the equilibrium condition  $\pi(m_I, I) = F$  yields

$$\begin{aligned}
 \frac{\partial m_I}{\partial h_\epsilon} &= \frac{\partial \pi_I / \partial h_\epsilon}{\partial \pi_I / \partial m_I} = \frac{2k_1 k_2^{1/2}}{h_\eta(2h_\theta + h_\epsilon)^2 [1/2 k_1 k_2^{-1/2} (2h_\theta + h_\epsilon)(h_\theta + h_\eta) + k_2^{1/2}]} \\
 &\quad - \frac{1/2 k_1 k_2^{-1/2} [(2h_\theta + h_\eta)^2 (h_\theta + 2h_\epsilon) + 2m_I h_\eta (2h_\theta + h_\epsilon)(h_\theta + h_\eta)] + k_2^{1/2} [2(2h_\theta + h_\eta) + m_I h_\eta]}{h_\eta(2h_\theta + h_\epsilon) [1/2 k_1 k_2^{-1/2} (2h_\theta + h_\epsilon)(h_\theta + h_\eta) + k_2^{1/2}]}
 \end{aligned}$$

Multiplying the numerators and denominators through by  $k_2^{1/2}$ , substituting in for  $k_{1I}$  and  $k_{2I}$ , and collecting terms yields

$$\frac{\partial m_I}{\partial h_\epsilon} = -\frac{2h_\theta(2h_\theta + h_\eta) B}{h_\eta(2h_\theta + h_\epsilon)^2 C}, \quad \text{where}$$

$$B = (2h_\theta + h_\eta)^2 (h_\theta + h_\epsilon)(2h_\theta + 5h_\epsilon) + m_I h_\eta (2h_\theta + h_\epsilon)(6h_\theta^2 + 5h_\theta h_\eta + 5h_\theta h_\epsilon + 1/2 h_\epsilon h_\eta)$$

and

$$C = 2(h_\theta + h_\epsilon)(2h_\theta + h_\eta)[(2h_\theta + h_\epsilon)(h_\theta + h_\eta) + (2h_\theta + h_\eta)h_\epsilon] + 3m_I h_\eta (2h_\theta + h_\epsilon)^2 (h_\theta + h_\eta).$$

Using  $h_\epsilon > h_\eta$ , it can be verified that  $B > C$ . Therefore,

$$\frac{\partial m_I}{\partial h_\epsilon} < -\frac{2h_\theta(2h_\theta + h_\eta)}{h_\eta(2h_\theta + h_\epsilon)^2}.$$

To derive the left-hand side of (10), it must be shown that

$$\frac{2h_\theta(2h_\theta + h_\eta) B}{(2h_\theta + h_\epsilon)^2 C} < 1.$$

Subtracting the numerator of the left-hand side from the denominator and substituting in for  $B$  and  $C$  yields

$$\begin{aligned}
 (2h_\theta + h_\epsilon)^2 C - 2h_\theta(2h_\theta + h_\eta) B &= 2(h_\theta + h_\epsilon)(2h_\theta + h_\eta)[(2h_\theta + h_\epsilon)^3 (h_\theta + h_\eta) + (2h_\theta + h_\epsilon)^2 (2h_\theta + h_\eta) h_\epsilon \\
 &\quad - (2h_\theta + h_\eta)^2 (2h_\theta + 5h_\epsilon) h_\theta] + m_I h_\eta (2h_\theta + h_\epsilon)[3(2h_\theta + h_\epsilon)^3 (h_\theta + h_\eta) \\
 &\quad - 2h_\theta(2h_\theta + h_\eta)(6h_\theta^2 + 5h_\theta h_\eta + 5h_\theta h_\epsilon + 1/2 h_\epsilon h_\eta)].
 \end{aligned}$$

It can be verified that both the bracketed component in the first term and the bracketed component in the second term are increasing in  $h_\epsilon$  and are positive when evaluated at  $h_\epsilon = h_\eta$ . Therefore, the above expression is positive and the inequality is satisfied. Thus

$$-\frac{1}{h_\eta} < \frac{\partial m_I}{\partial h_\epsilon}.$$

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