Investment and Insider Trading

Dan Bernhardt
Queen's University

Burton Hollifield
University of British Columbia
and Carnegie Mellon University

Eric Hughson
University of British Columbia
and California Insitute of Technology

We study insider trading in a dynamic setting. Rational: but uninformed traders choose between investment projects with different levels of insider trading. Insider trading distorts investment toward assets with less private information. However, when investment is sufficiently information elastic, insider trading can be welfare-enhancing because of more informative prices. When insiders repeatedly receive information, they trade to reveal it when investment is information elastic because good news increases investment and hence future insider profits. Thus, more information is revealed and uninformed agents are exploited less frequently by insiders. Both effects are Parento-improving. Finally, we consider various insider-trading regulations.

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One of the more controversial issues in stock market policy is the regulation of insider ‘trading. This article develops a dynamic general equilibrium economy in which the costs and benefits of regulating different types of insider trade can be analyzed. Our analysis allows explicit welfare comparisons among economies with different types of regulations concerning insider trading. This allows us to characterize the circumstances in which particular forms of regulation of inside trading are optimal.

Insiders' trading reveals private information, and to the extent that this information is correlated with future productive opportunities, insider trading can enhance productive efficiency. Since insider-trading profits come at the expense of uninformed traders, rational uninformed traders invest less in firms with substantial insider trading, inefficiently distorting investment away from such firms., We analyze the trade-off between these effects. As well, we detail the circumstances where insiders will choose to exploit their inside information and where they will choose to trade in such a way that their informa-. tion is revealed to the public.

Consider an insider who repeatedly receives private information. For example, consider an insider with information about a resource discovery, which requires external capital to exploit fully. The firm must raise significant capital, and the amount of capital raised is sensitive to the public's perception of the project's value. How should the insider trade in this situation? We show that, if the insider expects to have enough future opportunities to trade on her private information, then in equilibrium she will trade to reveal her private information at the beginning of her relationship with the firm. This will increase investment and allow her to exploit her future inside information more profitably. Uninformed investors gain both because prices are more informative and because the insider does not trade against them as often. Both of these effects increase investment efficiency. Thus, insiders with an enduring relationship with the firm can lead to a Pareto improvement relative to one-time insiders, making all participants, including outsiders, better off.

We view our analysis as particularly relevant to start-up firms, small resource exploration stocks, new product development, risky high technology R&D, etc. It is in these firms where initial investment is likely to be information elastic, sensitive to the current stock price. One can imagine such an insider initially forsaking immediate trading profits from information about a resource discovery by making sufficient stock purchases to reveal credibly the good news. She then expects to receive greater future insider-trading profits associated with the increased exploration made possible by the investment following her trades.

Because prices contain more information when Insiders trade, insider trading may be beneficial. If inside information is socially valuable, permitting insider trading may result in a superior allocation of resources. Manne (1966) was the first to make this argument. George (1989) documents how insider trading may lead to more efficient prices in a rational expectations model. In a static partial-equilibiium model, Leland (1992) argues that insiders may improve investment decisions. Fishman and Hagerty (1992) point out that allowing insiders to trade could possibly lead to less informative prices. The increased competition from insiders may reduce the incentives of others to purchase costly Information. Thus, it is possible that in equilibrium less information is gathered so that prices are less informative.

The empirical evidence presented by Damodaran and Liu (1993), and Seyhun (1986) suggests that insiders do trade in advance of information release. Further, their insider information seems to be impounded in stock prices [Muelbroek (1992), Donaldson and Hatheway (1993)].

Manne (1966), Dye (1984), and Carlton, Fischel, and Fischel(1983) argue that insider trading may be a way for firms to compensate management optimally. However, Fischer (1992) shows that, in the presence of agency problems, insider trading may be a suboptimal way to compensate management. We do not directly consider these issues In our analysis.

The arguments that insider trading is socially costly include Brudney (1979), who claims that insider trading is unfair to uninformed investors. Glosten (1989) develops a model where insider trading leads to imperfect risk-sharing and where, if there is too much private information, there is a loss of liquidity in the market. This imposes costs on liquidity traders. Leland (1992) points out that insider trade may reduce the liquidity of the market, hurting uninformed traders.[1]

Our article is closest in spirit to Ausubel (1990). In Ausubel's general equilibrium environment, agents first make production decisions recognizing that there will subsequently be preference shocks to agents that are private information to one agent type, after which there is trade. The equilibrium price in this competitive rational expectations economy is necessarily partially revealing. Ausubel shows that a policy of forcing the insider to reveal hi private information in order to trade may be Pareto optimal. Insider trade resolves uncertainty for the

[1]Manove (1989) looks at the investment distortions caused by allowing insider trading. He constructs a static model in which insiders can capture a share of the profits made by investment. This reduces the incentive for firms to make profitable investments, distorting invesment. His equilibrium concept is nonstandard; those who bid above a certain level are allocated shares and shares are not necessarily allocated to the highest bidders. Further, agents do not act optimally.

uninformed, leading them to increase production of their output good. In turn, this in creases the equilibrium value of the insider's good.

As Ausubel observes, inside information revealed in his model is not productive in nature and has no implications for future investment. Rather, insiders gain because initial production is altered by expectations of future information release. In contrast, in our environment, information has implications for future productivity. Like Ausubel, anticipation of insider trading distorts investment, but our model has the additional feature that current investment is affected by information released by past insider trading.

Our insider trades in a competitive dealership market, which forces her to consider the effects of her trades on the equilibrium price and the information it contains. All other agents must take account of this strategic behavior. In our dynamic environment, the decisions of whether and how to exploit inside information are closely intertwined with the nature of the insider's relationship with the firm, as well as the firm's past and current performance.

We first detail how rational, but uninformed, investors are affected by the presence of insiders in some markets. Recognizing that they may have to trade in a market where some agents have private information so that they will not get the "fair" price for their holdings, uninformed investors overinvest in safe assets. The return to the assets with insiders must be greater to compensate the investors.

The presence of the insiders, however, can be beneficial to the uninformed investors, ex ante. Information that past insiders possessed may be revealed through the trading process. The information in past prices provides useful information about future productive opportunities. If past prices are sufficiently correlated with future payoffs, then past insider trade is valuable in targeting the investment of the uninformed. As a consequence, net trading volume predicts future payoffs on production technologies.

The net effects of insider trade on the welfare of the uninformed investors are ambiguous. Investors prefer to have had insiders trade in the past for the information revealed through past prices but do not want insiders in the future when they may have to trade against them. When there is enough persistence in production shocks, the value of the information content in prices outweighs the investment distortion costs so that the presence of an insider is socially beneficial.

We detail the trading strategy of different types of insiders. Insiders differ with respect to the number of times that they will be privy to inside information about a firm. Short-term insiders, insiders such as a Boesky who have private information only once, care only about maximizing their immediate profits and hence always trade to conceal their information. Long-term insiders, insiders who have future access to private information, weigh the possible immediate profits from concealing their inside information against the future investment consequences of their immediate trades. If they purchase enough to raise current prices, beliefs of uninformed investors will be affected so that more will be invested. This increases future insider-trading profits.

We show that an equilibrium always exists and is unique. The long-term insider always tries to conceal her private information unless an insider seeing good news gains more future trading profits for a given level of investment than an insider seeing bad news. The more future inside trading opportunities insiders expect to have, the more an insider initially trades independent of her information. This is because an insider who sees bad news also has an incentive to increase purchases or short sell less to affect investor beliefs. Indeed, an insider seeing bad news may even purchase a positive amount in an attempt to convince the uninformed that her private information is good.

If, instead, a long-term insider seeing good news gains more from increased investment and values future profits sufficiently, then she trades so that initial prices arc fully revealing; she forsakes immediate insider profits for long-term gains. By purchasing enough shares the insider credibly conveys the good news to investors, information that she may not be able to credibly reveal in other ways. In this instance investors strictly prefer to face long-term to short-term insiders. With long-term insiders, past prices contain more information and there is less chance that the uninformed investors will be exploited by an insider in the future.

Explicit numerical solution of parameterized versions of the economy reveals three general findings:

1. Unless prices contain a substantial amount of investment-relevant information (i.e., there is substantial persistence in project payoffs), most of the welfare gains accrue to the insider, and investors are made worse off by the insider.
2. The insider's utility is relatively insensitive to the amount of persistence in project payoffs.
3. if the long-term insider behaves differently from a short-term insider, then most of the gains accrue to the uninformed investors; their gain in profit from having the insider may exceed the insider's profit.

The plan of the article is as follows. We first develop and analyze a general equilibrium, overlapping generations economy with uninformed, but rational, ‘liquidity" traders and a short-term inside trader. Section 2 extends the analysis to consider long-term insiders who will have private information about payoffs in successive periods. Section 3 considers the consequences of different regulations of inside trading. In contrast to Ausubel, standard forms of regulation are often welfare reducing. Section 4 concludes. All proofs are contained in the Appendix.

1. Short-term Insider.

In this section we develop the overlapping generations economy. The economy features rational, but uninformed, liquidity traders who live for three periods. When the liquidity traders are young, they must allocate their investment capital between a risky and a risk-free asset that pay off two periods hence. In the next period an insider will acquire advance information about the payoff of the risky asset, and some of the liquidity traders will have to liquidate their portfolios. Trading is through a competitive, risk-neutral uninformed market maker. The market maker observes only the net order flow, so that he may not be able to determine the realization of the risky asset. Because the productive shocks are positively autocorrelated, any information revealed through equilibrium prices is useful for the *next generation* of liquidity traders.

Consider an overlapping generations economy with dates $t = -\infty \ldots, -1, 0, 1 \ldots \infty$. There are three types of agents in the economy: uninformed traders, insiders, and market makers. All agents are risk-neutral. A continuum of measure one of three-period-lived uninformed traders is born each period t. Each uninformed investor is endowed with one unit of productive capital, which can be used to invest in the two projects, A and B. These projects pay off in consumption goods two periods hence. The payoff to project B is random. For simplicity, we assume that the payoffs at time $t + 2$ to time t projects are given by

$$K_A^t, \qquad \theta^{t+2} h(K_B^t), \tag{1}$$

where $h(\cdot)$ is a neoclassical, concave production function and K_i^t is the amount of capital invested in project i at t which comes to fruition in $t + 2$. The superscript in K_i^t refers to the date at which the investment is made. The production function $h(\cdot)$ satisfies

$$h(0) = 0, \; h'(0) = \infty, \; h'(\cdot) > 0, \; h''(\cdot) < 0.$$

The conditions on the derivatives of the production technology ensure that the equilibrium features investment in both projects. Since the safe project has a linear technology, one can interpret its return as the numeraire.

The technology shock, θ^t, follows a two-state Markov process taking on either the value H or L, where $0 < L < H$. Denote the probability transition function for θ^t by

$$\pi(\theta^t) = \text{Prob}(\theta^{t+1} = H \mid \theta^t),$$
$$\pi(H) = \text{Prob}(\theta^{t+1} = H \mid \theta^t = H),$$
$$\pi(L) = \text{Prob}(\theta^{t+1} = H \mid \theta^t = L).$$

Without loss of generality we rewrite

$$\pi(H) = \pi(1-\gamma)+\gamma,$$
$$\pi(L) = \pi(1-\gamma), \tag{2}$$

where π is the unconditional probability that $\theta^t = H$ The parameter γ measures the persistence in the process. We assume that the process is positively autocorrelated, so $0 \leq \gamma < 1$. If $\gamma = 0$ then the technology shock is *i.i.d.* and, as γ approaches one, then the technology shocks become perfectly positively correlated over time. The positive persistence in the technology shock implies that $\pi(H) \geq \pi(L)$, so that $E[\theta^{t+2} \mid \theta^t = H] \geq E[\theta^{t+2} \mid \theta^t = L]$. We sometimes refer to $\theta^t = H$ as "good news."

In period $t + 1$, a random measure $\{l, h\}$, $0 < l < h < 1$, of the uninformed investors receive an uninsurable liquidity shock. Either measure h or measure l of the uninformed traders receives this liquidity shock that forces them to sell in period $t + 1$ all claims to period $t + 2$ output. We assume that these shocks are equally likely and are independent of the technology shocks. Hence, $1-[(h+l)/2]$ is the unconditional probability that a particular uninformed trader will not receive a liquidity shock, $h/2$ is the unconditional probability that he has to sell in the h state, and $l/2$ is the unconditional probability that he has to sell in the l state. Thus, there are four possible $\{\theta^t, s^t\}$ shock combinations that can occur in the economy: $\{(H, h), (H, l), (L, h), (L, l)\}$.

The economy has two market makers, one for each project. The role of each market maker is to take opposite sides of all trades in the markets for the claims on the projects' outputs at $t + 2$. These market makers stand ready to buy/sell all demands at $t + 1$ for claims to output at $t + 2$. Each market maker sees past prices, past θ's, and current net order flow in his own market, but not that in the other market.[2] As

[2] This assumption is made to reduce notational clutter. Equilibrium outcomes are unchanged if market makers could observe net order flows in both markets or equivalently if there were a single market maker. In these instances, the insider must transact in both markets so that order flow in market A contains no information about the realization of liquidity trade and hence cannot

in Admati and Pfleiderer (1988) and Kyle (1985), each competitive specialist pools orders and sets a price in units of the current output good which, conditional on his information, leaves him zero expected profits. The specialist is not liquidity constrained.[3,4]

Besides the uninformed investors and the market maker, there is an insider. At time *t*, the insider learns the value of θ^{t+1}. As in Kyle (1985), she uses this information as well as the pricing schedule to determine her asset trades. We assume that the insider is not liquidity constrained.[5] In this section we assume that this insider has only a temporary relationship with the firm, she receives inside information about the firm only once. Hence she trades to maximize expected current period profits. In Section 2, we analyze the case where the insider has a long-term relationship with the firm.

We assume that each uninformed investor ‘has his own project,” which he sells to the appropriate specialists in the event of a liquidity shock the next period. Alternatively, we could reinterpret our model as one in which there is a single profit-maximizing entrepreneur who owns the production technology but lacks capital. Consequently, he must raise capital by selling claims to future output to uninformed investors. Equilibrium outcomes–investment levels and market-clearing shale prices–are identical for these two formulations.

We now define some useful notation. Let $K^t \equiv \{K_A^t, K_B^t\}$ represent aggregate capital invested at time *t* in projects *A*, *B* that pay off at time t + 2 and let q^t be the insider’s trade in market *B* in period *t*. Then,

$$v_B^t = q^t - s^t \tag{3}$$

is the ‘net order flow observed by the market maker in market *B*. The specialist’s pricing function in market $i \in \{A, B\}$ is given by $P_i(v_i^t, K^{t-1}, \theta^t)$, and realized equilibrium prices are given by p_i^t.

Figure 1 illustrates the time line for a representative period t. We consider perfect Bayesian equilibrium of this model. This equilibrium

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reveal information about the θ realization. The insider can do this by making the same transactions in both markets or by choosing an uninformative stochastic purchase in market *A*. The assumption that each specialist observes only the net order flow in his market avoids this added complexity.

3 We assume that the specialist in both asset markets has endowments of consumption goods both when trade occurs and when the asset pays out. His endowment during the trading round is large enough to cover any purchases he might make then and large enough when the asset pays out to cover any short position that he might have during the trading round. That is, he must be able to "settle on delivery."

4 An alternative interpretation of the market maker is as an (uninformative) subset of uninformed traders who do not receive the liquidity shock. Then, they are willing to buy or sell the risky asset if they expect to obtain the same profits they would earn from the safe asset. We have retained the standard market maker formulation for ease of presentation.

5 Formally, we assume that the insider has an endowment of consumption good at the trading round that is large enough to cover any equilibrium purchases she might make.

Time t
— Output of $t-2$'s project is paid out, revealing θ^t.
— New uninformed agents and insider are born.
— θ^{t+1} is revealed to the insider.
— Liquidity shock to uninformed agents born at $t-1$.
— Insider and uninformed submit orders; orders are pooled.
— Market maker observes net order flow; orders are filled at p_i^t.
— New uninformed make investment decisions K^t.
Time $t+1$ —

Figure 1
Time line–short-lived insider

concept requires that, at each time and information set, each player acts optimally, conditional on beliefs about the technology and liquidity shocks, the distribution of future prices of claims to the technologies, and the strategies of the other players. Further, we require that all agents' beliefs ate restricted to the support of the technology and liquidity shocks and satisfy Bayes' rule wherever possible.

Definition. A symmetric[6] perfect Bayesian equilibrium with a short-term insider is a collection of the following at each date *t:*

1. Investments by each uninformed trader given his conjecture at time t about the price distribution of claims at $t+1$ in projects *A, B,* which pay off in two periods, $k^t(p_B^t, \theta^t) \equiv \{k_A^t(p_B^t, \theta^t), k_B^t(p_B^t, \theta^t)\}$, yielding aggregate investment levels, $K^t(p_B^t, \theta^t)$, such that
$$K^t(p_B^t, \theta^t) = k^t(p_B^t, \theta^t).^7$$
2. A strategy for the insider in project B that details her purchases as a function of the public information, (K^{t-1}, θ^t), and her private information, θ^{t+1}, given her conjectures about the market maker's pricing function: $q(\theta^{t+1}, \theta^t, K^{t-1}; P_B(\cdot))$.[8]
3. A belief function $\mu : \mathcal{R} \times \mathcal{R} \times \{H, L\} \Rightarrow [0, 1]$ giving the beliefs of the market makers and uninformed investors that the insider observed $\theta^{t+1} = H$ conditional on the current order flow and the current public information(K^{t-1}, θ^t).
4. A pricing function for each specialist which, given public information (K^{t-1}, θ^t) and the net order flow in the specialist's market, determines the price $P_i(v_i, K^{t-1}, \theta^t)$, $i = A, B$ at which each specialist buys/sells the asset.

[6]Asymmetric equilibria feature the same aggregate investment levels and prices. For expositional reasons we present the symmetric version of the equilibrium, where all uninformed have the same strategies.

[7]Without loss of generality uninformed traders are assumed to make the same investment decisions. The equality follows since there is a measure one of uniformed agents.

[8]We suppress arguments of $q(\theta^{t+1}, \theta^t, K^{t-1}; P_B(\cdot))$ where they are clear from the context.

Such that

1. The insider selects $q(\theta^{t+1}, \theta^t, K^{t-1}; P_B(\cdot))$ to maximize expected profits, where expectations are taken over the liquidity shocks:

$$\max_q E[q(\theta^{t+1} b(K_B^{t-1}) - P_B(q - s^t, K^{t-1}, \theta^t)) \mid \theta^{t+1}], \tag{4}$$

   and her conjecture about the specialist's pricing function satisfies rational expectations.
2. The specialist in each market i sets $P_i(v_i^t, K^{t-1}, \theta^t)$ to earn zero expected profits, conditional on all information available to him. This implies that, for **B**,

$$P_B(v_B^t, K^{t-1}, \theta^t) = E[\theta^{t+1} \mid v_B^t, K^{t-1}, \theta^t] b(K_B^{t-1}), \tag{5}$$

   and, for **A**,

$$P_A(v_A^t, K^{t-1}, \theta^t) = K_A^{t-1}, \tag{6}$$

   where expectations are taken Using the market maker's beliefs defined above and the beliefs satisfy Bayes' rule where applicable.
3. Each uninformed trader chooses his project allocation to maximize expected lifetime payouts:

$$\begin{aligned} \max_{k_A^t, k_B^t} k_A^t &+ \left(1 - \frac{b + l}{2}\right) E[\theta^{t+2} \mid \theta^t, p_B^t] b(k_B^t) \\ &+ \frac{b}{2} E[P_B(q - b, K^t, \theta^t) \mid \theta^t, p_B^t] \\ &+ \frac{l}{2} E[P_B(q - l, K^t, \theta^t) \mid \theta^t, p_B^t] \end{aligned} \tag{7}$$

$$\text{subject to: } k_A^t + k_B^t \leq 1,$$

   where each uninformed's beliefs about θ^{t+1} are consistent with the market maker's and each uninformed's conjectures about next period's price satisfy rational expectations.

The first term in Equation (7) refers to an uninformed agent's investment in the riskless technology. The second term refers to the expected payoff of the risky technology, given the uninformed does not receive a liquidity shock. The third and fourth terms refer to the expected payoff in the event of a high and low liquidity shock, respectively. This formulation of the equilibrium incorporates the result that the uninformed will not trade in the market when they are young or middle aged unless required by a liquidity shock to cash in their holdings prematurely. In the analysis below we show that the insider's trades must take a particular form in any pure-strategy equilibrium. Further, the insider's expected profits are strictly positive in any equilibrium, so that prices cannot be perfectly revealing. Since the insider must earn positive profits in any equilibrium, we provide the set of equilibrium trading strategies that result in positive expected profits for the insider; the equilibrium strategy must be in this set.

Lemma 1. In any pure strategy equilibrium, the short-term insider's trading strategy is given by

$$\begin{aligned} q(\theta^{t+1} &= H, \theta^t, K_B^{t-1}; P_B) = \alpha(\theta^t, K^{t-1}; P_B)(b-l), \\ q(\theta^{t+1} &= L, \theta^t, K_B^{t-1}; P_B) = (\alpha(\theta^t, K^{t-1}; P_B) - 1)(b-l), \end{aligned} \tag{8}$$

where $0 \leq \alpha \leq 1$. *Further, the insiders's expected profits before observing the production shock are constant across all values of* α, $0 \leq \alpha \leq 1$. *The insiders expected profits are strictly positive and are given by*

$$\frac{(b-l)(H-L)}{2}\pi(\theta^t)(1-\pi(\theta^t))b(K_B^{t-1}) \equiv IP(\pi(\theta^t))b(K_B^{t-1}). \tag{9}$$

The zero expected profit condition for the market maker requires that the expected losses of the uninformed investors must equal the insiders expected profits: the investors therefore require the insider premium $IP(\pi(\theta^t))$ to compensate them for the insider's presence in asset *B*. Since the investment distortion is determined by the size of the insiders expected profits, Lemma 1 implies that the size of the distortion is the *same* in any possible equilibrium. Lemma 1 also implies that the only three (net order flow, price) pairs for asset *B* that will be observed in equilibrium are

$$\{\alpha(b-l) - l, Hb(K_B^{t-1})\},$$
$$\{\alpha(b-l) - b, [\pi(\theta^t)H + (1-\pi(\theta^t))L]b(K_B^{t-1})\},$$
$$\{(\alpha-1)(b-l) - b, Lb(K_B^{t-1})\}.$$

We now show that an equilibrium exists and that the equilibrium beliefs of the market maker *uniquely identify* the quantity traded by the insider when she sees θ^{t+1}. *The insiders equilibrium trading volumes are unique, as are the set of prices, investment levels, and allocations along the equilibrium path.*[9]

[9]In a similar vein, Rochet and Vila (1994) demonstrate uniqueness of equilibrium for a slightly different class of trading games. There, the key features ate that the surplus (the value of the adjusting project) constant, independent of trading decisions of the insider and that the Insider knows the value of the liquidity shock before trading.

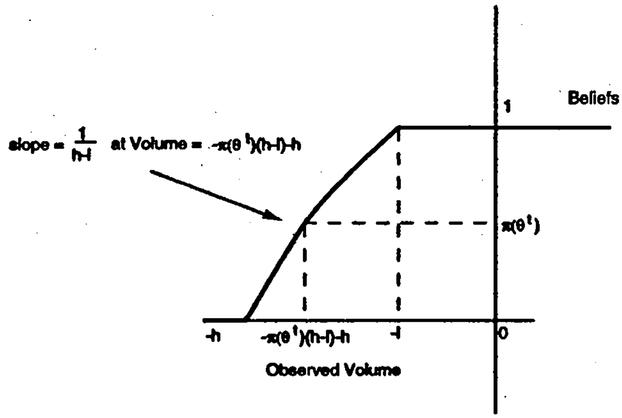

Figure 2
Equilibrium beliefs

The intuition for the uniqueness result is as follows. If the insider sees a high realization and hence purchases a positive quantity, this will be revealed when there is little liquidity trade. Conversely, if the insider sees a low realization and hence short sells, this will be revealed when there are high liquidity sales. In equilibrium, the insider seeing a high realization must trade so that, when there is a high liquidity shock, the market maker cannot distinguish her from an insider seeing a low realization when there is a low liquidity shock. Beliefs must be $\pi(\theta^t)$ in this case. For such a strategy to be optimal, the indifference curves for both types of insiders must be tangent at these beliefs and implied trading volumes in {net order flow, market maker beliefs) space. There is a unique net order flow where such a tangency exists. Figure 2 illustrates a belief schedule that supports the equilibrium.

Proposition 1. *The investment levels of the uninformed and the strategies of the insider are the same across all equilibria; only the market maker's off-equilibrium belief differ across equilibria. The following characterizes the set of equilibria that can arise with a short-term insider:*

- **A.** *The insider trades* $(1-\pi(\theta^t))(h-l) > 0$ *if her private information is* H *and* $-\pi(\theta^t)(h-l) < 0$ *if she observes L.*
- **B.** *The market maker in market A sets price equal to* K_A^{t-1} *for all net order flows. The market maker's pricing function in B satisfies*

$$P_B(v_B^t, K_B^{t-1}, \theta^t) = (\mu(v_B^t, \theta^t, K_B^{t-1})(H-L)+L)b(K_B^{t-1}), \quad (10)$$

where the market maker's belie&, $\mu(v_B^t, \cdot, \cdot)$, *satisfy Bayes' rule:*

$$\mu(v_B^t, \cdot, \cdot) = \begin{cases} 0 & v_B^t \le -b \\ \pi(\theta^t) & v_B^t = -\pi(\theta^t)(b-l) - l, \\ 1 & v_B^t \ge -l \end{cases} \tag{11}$$

and for $-b < v_B^{t+1} < -l$, *satisfy the following bound:*

$$\max\left\{0, 1 - \frac{(1-\pi(\theta^t))^2(b-l)}{v_B^t + b}\right\} \le \mu(v_B^t, \cdot, \cdot)$$
$$\le \min\left\{1, -\frac{(\pi(\theta^t))^2(b-l)}{v_B^t + l}\right\}.$$

C. *Investment by each uninformed trader solves*

$$1 = \left(E[\theta^{t+2} \mid \theta^t, p_B^t] - E[IP(\pi(\theta^{t+1})) \mid \theta^t, p_B^t]\right) b'(K_B^t), \tag{12}$$

where

$$E[IP(\pi(\theta^{t+1})) \mid \theta^t, p_B^t] = \mu IP(\pi(H)) + [1-\mu] IP(\pi(L))$$

is the expected insider premium. Note that the expectations reflect the belief associated with the price set by the market maker in the current period.

Condition (B) ensures that asset prices are equal to expected values conditional on quantities traded. This implies that a risk-neutral uninformed investor cannot profit by trading in the asset markets. If the quantity traded by the uninformed affects the netorder-flow, the adverse selection premium causes the trader to expect losses. Hence, such an investor does not trade in equilibrium. The risk-free technology ensures that young informed investors prefer investing productive capital in real projects to purchasing shares.

Since the risky technology has a stricly concave production function, there is a unique efficient level of investment, $\hat{K}_B^t$, which solves

$$1 = E[\theta^{t+2} \mid \theta^t, p_B^t] b'(\hat{K}_B^t). \tag{13}$$

A comparison of Equations (12) and (13) immediately reveals that the effect of insider trading is to induce discretionary, but uninformed, investors to invest disproportionately in asset *A* where there is no adverse selection.

Proposition 2 The equilibrium level of investment is inefficently distorted toward the safe asset A and away from asset B in the *sense that*

$K_B^t < \hat{K}_B^t$, where $\hat{K}_B^t$ is the efficient level of investment in project B conditional on current public information.

More generally, this investment distortion exists in any economy charcterized by *differing* degrees of insider trade (inducing differing degrees of adverse selection) and discretionary, rational investment by the uninformed. These welfare costs are, however, offset by the fact that insider trading also helps the uninformed make better investment decisions through the conditioning of their forecasts of θ^{t+2} on the information contained in the current price, p_B^t. The presence of the insider leads to a finer public information set.

To a first-order approximation, the difference between expected, output with the insider and with no insider depends on the size of

$$\|E[IP(\pi(\theta^{t+1})) \mid \theta^t, p_B^t]\|, \tag{14}$$

relative to the size of

$$\|E[\theta^{t+2} \mid \theta^t, p_B^t] - E[\theta^{t+2} \mid \theta^t]\|. \tag{15}$$

When (14) is larger than (15), the distortion effect of the insider dominates the benefit of a finer information set, and vice versa. This leads to the following comparative statics results, on a state-by-state basis.

Corollary 1. *Comparative statics:*

1. *Increasing the difference between the liquidity shocks (i.e. increasing h - l) increases the insiders profit without changing the value of information released by the insider, so that the distortionary effect of the insider is increased and total output is lowered.*
2. *Increasing H - L. has two effects on expected output. First, it increases the insider premium, increasing the investment distortions. However, it also increases the expected value of the insider's information.*
3. *Changing γ. Both the expected insider-premium and the value of the insider's information are concave in γ and reach maxima between zero and one. At $\gamma = 0$, the insider has no valuable information, and at $\gamma = 1$ the insider has no private information. The information effect dominates the distortion effect around $\gamma = 0$, while the opposite holds around $\gamma = 1$.*

These results follow from Equations (14) and (15) and the definition of *IP*. Intuitively, as $h - l$ increases, so does the trade size that the insider can successfully conceal, increasing the insider premium. When the productivity shock is i.i.d., an increase in $H - L$ increases the insider premium and has no beneficial information effect, since the insider's information has value in future production decisions.

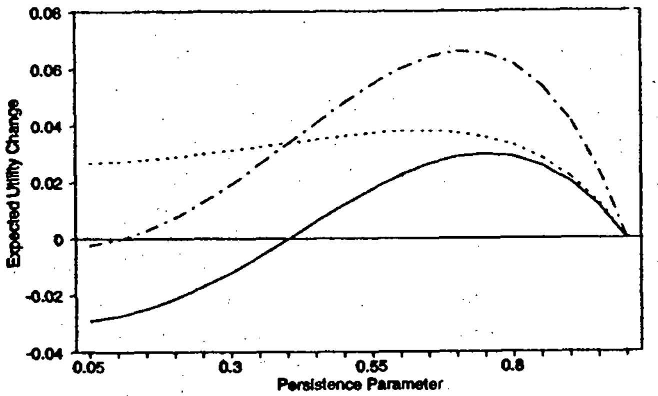

Figure 3
Change in expected utility–short-lived insider
This figure plots the change in unconditional expected utilities of the insider trader (- - -), the liquidity traders (–), and the change in the sum of the expected utilities of the insider and liquidity traders (–) from introducing the insider trader in the economy against the persistence parameter, γ. Parameter values are given by L= 0.1, H= 5.0, h = 0.75, l = 0.25, and π = 0.1.

More generally, the net effect on expected output of an increase in $H - L$ depends on whether or not the investment distortion effect of increasing the insider premium dominates the information effect. Note that for uninformed agents born when the insiders information is not revealed through prices (states $\{H, l\}$ and $\{L, h\}$), there is only a distortionary effect from the insider. We now document the trade-offs in a numerical example.

1.1 Example

Suppose that the unconditional probability of a production shock of H is given by 0.1, the state-space for the productivity shocks is {0.l, 5.0}, the liquidity shocks are given by h = 0.75, l = 0.25, and the production function is given by

$$b(k_B) = \sqrt{k_B}.$$

We interpret each "generation" as a year. Figure 3 graphs the change in expected utility for the different traders due to the introduction of an insider to the economy for different levels of the persistence parameter, γ. The sum of the utility differences is the expected change in output. Since all agents are risk-neutral, this measure corresponds to the Pareto criterion: from an ex ante perspective, maximizing expected output maximizes the sum of the expected payoffs to the insider and the uniformed traders.

At $\gamma = 0$, the productivity shock is *i.i.d.*, so the insider's private information has no value in future production decisions. At this point, the uninformed investors pay the insider premium without getting any useful information. At g equal to one, there is no private information in the economy. As g increases from zero, the expected productive value of the insider's private information increases and reaches an interior maximum, so that the change in expected output due to introducing the insider takes on the humped shape in Figure 3. Most of any productive gains to introducing the insider to the economy accrue to the insider. Unless there is substantial persistence in the productivity shock ($\gamma > .4$), uninformed investors are hurt by the insider. In particular, for persistence values of $\gamma \in [.13, .4]$, the net social gain due to the insider is positive, but liquidity traders are hurt. The relationship between persistence parameter, γ, and the insider's gains is quite flat relative to that for liquidity traders and it peaks at a lower persistence value.

2. Long-term Insider

We now introduce a long-term insider to project *B*, one who has insider information in the future as well as the present. Specifically, the long-term insider is assumed to have inside information about two consecutive projects. This allows us to capture the qualitative effects of a long-term insider.

We interpret the "two consecutive projects" more generally as a period in which investment is information elastic, followed by a longer term in which external investment requirements are smaller and less information elastic. For example, consider an insider with information about a resource discovery, which requires external capital to exploit fully. The firm must raise significant capital, and the amount of capital raised is sensitive to the public's perception of the project's value. Consequently, the insider may forsake immediate trading profits derived from the knowledge of the resource discovery by making sufficient share purchases to reveal the good news through the market price. This increased investment will pay off subsequently for the insider, when new investment requirements do not fluctuate as much with project payoffs, when the insider trades on her future inside information. Short-term trading profits are sacrificed for the greater future insider-trading profits associated with greater exploitation and exploration.

Because greater current investment raises future expected profits for the insider independent of her current private information, even an insider seeing bad news has an incentive to try to convince the public that future prospects are good. As a result, a long-term insider buys more; or short-sells less, than a short-term insider in order to try to convince the market that prospects are good.

One can identify long-term insiders, not so much by their long-term relationship with their firm, but by the stage of development of the firm. When investment in the firm is information elastic and the current level of investment in the firm is low (e.g., at the start-up of a firm), a long-term insider will behave very differently from an insider at a firm where future investment is less information/price elastic (perhaps because there are reliable sources of information other than price), or where current investment is already substantial. Even if an insider at a start-up firm does not trade to reveal her information (i.e., make sufficient purchases to convey good news), she will still make greater purchases (short-sell less in the event of bad news) than will an insider at a more established firm. Further, as Section 3 details, optimal policy prescriptions may be very different for short- and long-term insiders.

For expositional ease, we consider the following production technology:[10]

$$b(k_B) = \sqrt{k_B} \tag{16}$$

With this technology, investment is such that output of project B is linear in the beliefs μ of the uninformed that the current technology shock is high. For clarity, we drop the date t subscripts and use the subscript and superscript o to index states and functions associated with the "old insider" and index those associated with the "young" insider by y. We analyze perfect Bayesian equilibria of this model.

The "old insider" has the same horizon as the short-term insider, so that both behave identically. Consequently, the equilibrium pricing function for the short-term insider clears the market when the long-term insider is old. The "young insider" trades to maximize discounted expected profits. She considers the effects of her trades on the information content of prices, weighing the current profits from insider trading against the change in the present value of future insider profits due to the effect of the release of news on investment. We use $\rho > 0$ to denote the weight placed on second project insider-trading profits. The fact that fund-raising/investment takes place primarily at the beginning of an insider's affiliation with a firm but that the insider will have many subsequent opportunities to trade on future information without affecting investment is captured by $\rho > 1$. In this case, ρ represents the expected number of times that the insider subsequently expects to have opportunities to trade on her information

[10] The qualitative results generalize to different production technologies

Time t	—	Output of $t-2$'s project is paid out, revealing θ^t.
	—	Generation t uninformed agents and young insider are born.
	—	θ^{t+1} is revealed to the young insider.
	—	Liquidity shock to uninformed agents born at $t-1$.
	—	Young insider and generation $t-1$ uninformed submit orders; orders are pooled.
	—	Market maker observes net order flow; orders are filled at p_t^t.
	—	Generation t uninformed make investment decisions K^t.
Time $t+1$	—	Output of $t-1$'s project is paid out, revealing θ^{t+1}.
	—	Generation $t+1$ uninformed agents are born; insider is now old.
	—	θ^{t+2} is revealed to the old insider.
	—	Liquidity shock to uninformed agents born at t.
	—	Old insider and generation t uninformed submit orders; orders are pooled.
	—	Market maker observes net order flow; orders are filled at p_t^{t+1}.
	—	Generation $t+1$ uninformed make investment decisions K^{t+1}.
	—	Old insider dies.
Time $t+2$	—	

Figure 4
Time line-long-lived insider

without affecting future investment." Figure 4 illustrates the timing of the game.

Following the analysis of the short-term insider case, given beliefs μ_y that the current technology shock is H, the uninformed investor's first-order conditions for investment, k_B^o, which pays off when the insider is old, are

$$1 = (E[\theta^o \mid \theta, p_B^y] - E[IP(\pi(\theta^y)) \mid \theta, p_B^y])\frac{1}{2\sqrt{k_B^o}}. \tag{17}$$

Here θ^o refers to the unknown technology shock that the insider will trade on when old; θ^y is the young insider's private information; θ is last period's publicly observed technology shock; and $E[IP(\cdot) \mid \cdot]$ is the insider premium that the uninformed expect to pay.

Using the uninformeds' beliefs μ_y that the current technology shock is H, we can solve for the current new aggregate investment in project B, K_B^o. Substituting from Equation (17) yields

$$\sqrt{K_B^o} = C + D\mu_y, \tag{18}$$

[11]Our interpretation of r is that, in practice, the horizon for the long-term insider can be decomposed into two intervals of time: first, a period at the start-up of a firm (at the beginning of the insider's affiliation with the firm) where (i) the amount of capital in place is low, (ii) a significant portion of investment takes place, and (iii) investment is stock-price sensitive because there are few other sources of credible information; second, a longer period of time where (i) the ratio of the amount of capital in place relative to the amount of possible investment is greater, (ii) investment is less stock-price sensitive (e.g., because the firm is closer to its optimal capital level, more analysts follow the firm so there are other sources of information), and (iii) the insider can trade on her information without substantially affecting investment in the firm.

where

$$C = \frac{1}{2}\left[\pi(L)H + [1-\pi(L)]L + \frac{(b-l)(H-L)}{2}\pi(L)[1-\pi(L)]\right]$$
$$>0, \tag{19}$$

$$D = \frac{(H-L)}{2}[\pi(H)-\pi(L)]\left[1-\left(\frac{(b-l)}{2}\right)[1-\pi(H)-\pi(L)]\right]$$
$$\geq 0. \tag{20}$$

Given the uninformed investors' beliefs μ_y and the young insider's private information, θ^y, her expected discounted future insider profits equal

$$\rho IP(\pi(\theta^y))[C + D\mu_y].$$

The young insider submits an order $q^y(\theta^y, \theta, K_B^y; \mu_y)$ to maximize lifetime expected profits, where she explicitly takes into account the effects of her trades on the beliefs of uninformed investors:

$$\max_{q^y} E\left[\begin{array}{c} q^y[\theta^y - (\mu_y(q^y - s^y, \cdot)(H-L) + L)]\sqrt{K_B^y} \\ +\rho IP(\pi(\theta^y))(C + D\mu_y(q^y - s^y, \cdot)) \end{array}\middle|\ \theta^y\right]. \tag{22}$$

Expectations are taken with respect to the liquidity shock. The long-term insider's conjecture about the specialist's belief function satisfies rational expectations. Her objective function reflects the condition that the specialist's beliefs correspond to those of the current uninformed investors both on and off the equilibrium path. The first term represents the long-term insider's first period insider-trading profits. The second term gives the present value of future insider-trading profits. This depends on the insider's first period trade through the uninformed's beliefs, as a function of the first period price.

Inspection of the long-term insider's objective function reveals that the insider. gets no benefit from revealing her private information when young if either D or ρ are zero. If ρ = 0, the long-term insider does not care about future profits, so she maximizes one-period profits. D is zero when the technology shock is *i.i.d.* so that the current technology realization does not help to predict future realizations and hence the uninformed investor's expectations of future productivity shocks are unaffected by the insider's private information Consequently, necessary conditions for the equilibrium with a long-term insider to differ from that with a short-term insider are ρ > 0 and $\pi(H) > \pi(L)$.

We now analyze equilibria in which these necessary conditions are satisfied. Suppose-that the capital in place for the young insider is $\tilde{K}$,

$0 < \tilde{K} \leq 1$. We first provide necessary bounds on $\tilde{K}$ for the young insider to reveal fully her private information in the equilibrium of the resulting trading game. Then, we determine conditions on $\tilde{K}$ for the equilibrium to feature concealment.

One can analyze each long-term insider independently, in which case one would take this level of capital, K, as exogenous. Since, in the real world, the amount of capital in place generally increases with the age of the firm, it may make sense to consider levels of capital in place for the young long-term insider at a start-up firm that are lower than the "endogenous" amount of capital in place in the stationary overlapping generations environment.

The following proposition provides the conditions on the capital stock when the insider is young for a fully revealing equilibrium to exist.

Proposition 3. *A fully revealing equilibrium exists in which the young insider reveals her private information* if and only if *the capital stock in place satisfies*

$$0 < \sqrt{\tilde{K}} \leq \rho\Psi, \tag{23}$$

where

$$\Psi \equiv \frac{1}{(H-L)(b-l)} D[IP(\pi(H)) - IP(\pi(L))]. \tag{24}$$

Let

$$\bar{v} \in \left[\frac{\rho IP(\pi(L))D}{(H-L)\sqrt{\tilde{K}}} - l, \frac{\rho IP(\pi(H))D}{(H-L)\sqrt{\tilde{K}}} - b\right]. \tag{25}$$

The insider seeing good news trades $q_H > \bar{v} + b$, *and the insider seeing bad news trades* $q_L < \bar{v} + l$.

Supporting beliefs and equilibrium investment levels are given in the Appendix.

Necessary and sufficient conditions for Ψ to be larger than zero so that revelation may occur in equilibrium are given in the following.

Corollary 2. Necessary *and sufficient conditions for* Ψ *to positive so that the insider ever contemplates completely revealing her private information are*

$$\pi(H) > \pi(L), \tag{26}$$

and

$$\pi < 1/2, \tag{27}$$

where π *is the unconditional probability that* $\theta^t = H$.

These are the necessary conditions for next periods insider premium to be greater for an insider who currently observes a good realization: $IP(\pi(H)) > IP(\pi(L))$. The insider who sees good news gains more from convincing uninformed investors that. the realization is good than the insider who sees bad news. Otherwise, the equilibrium could not be fully revealing. For the insider to see bad news and then convince the uninformed that the realization is good is inconsistent with equilibrium; the insider's nonmimicry condition would be violated. From now on, we assume that $\pi \leq 1/2$, so that $IP(\pi(H)) \geq IP(\pi(L))$, and $\Psi \geq 0$.

Even if $IP(\pi(H)) > IP(\pi(L))$, the amount of capital in place, $\tilde{K}$, must still be sufficiently small for the equilibrium to be revealing; future expected profits generated by trading sufficiently to reveal good news must exceed the trading profits the insider could obtain by trading to conceal her information. Equation (24) provides the specific bound on capital.

If $\tilde{K}$ is low enough that the insider who sees good news wants to reveal it, then she must trade enough that the insider with bad news has no incentive to mimic her. The condition that $q_H \geq \bar{v} + b$ describes the necessary minimum bound on the trade size. Similarly, the insider seeing bad news must sell sufficient quantities to ensure that the insider with good news has no incentive to trade in such a way that her trade might be confused with that of the insider with bad information in order to earn short-term profits. If the insider short-sells, the uninformed believe that the productivity realization was a bad one so she can-not earn positive insider profits.

The largest that $\tilde{K}$ can be is one. If Equation (24) is satisfied for $\tilde{K} = 1$, then in equilibrium the young insider always reveals her private information. The right-hand side of Equation (24) is strictly increasing in ρ when the necessary conditions for complete revelation to occur are satisfied. Hence,

Corollary 3. If $\Psi > 0$, and

$$\rho > \left(\frac{1}{\Psi}\right). \tag{28}$$

then the young insider reveals her private information at all equilibrium information sets.

If the young insider cares enough about her future trading profits, then she fully reveals her private information when young. As Ψ decreases, the required ρ increases. If, instead, there is sufficient capital in place, then the insider conceals her private information:

Proposition 4. *In the trading game when the long-term insider is young, an equilibrium involving the insider trading such that in states {(H, l), (L, b)] trading volume is uninformative and in states {(H, h), (L, l)} trading volume is fully informative exists* if and only if *the capital stock in place, K, is large enough:*

$$\sqrt{\bar{\bar{K}}} \geq \rho\Psi, \tag{29}$$

where $\rho\Psi$ *is defined as in Equation (24). If* $\sqrt{\bar{\bar{K}}} > \rho\Psi$ *is satisfied, the strategy of the insider is unique: only the off-equilibrium beliefs of the uninformed investors and market makers differ across equilibria. The insider's trades are given by*

$$\begin{aligned} H: q_H^c &= (1-\pi(\theta))(b-l) \\ &\quad + \left[\frac{\rho D}{2(H-L)}\{\pi(\theta)IP(\pi(H)) + [1-\pi(\theta)]IP(\pi(L))\}\right], \\ L: q_L^c &= -\pi(\theta)(b-l) \\ &\quad + \left[\frac{\rho D}{2(H-L)}\{\pi(\theta)IP(\pi(H)) + [1-\pi(\theta)]IP(\pi(L))\}\right], \end{aligned} \tag{30}$$

where $\pi(\theta)$ *denotes the prior probability that the insider's information will be H.*

Supporting beliefs and equilibrium investment levels are given in the Appendix.

When this equilibrium obtains, even though young long-term insiders trade to conceal their information like the short-term insiders, their equilibrium orders equal those of short-term insiders plus an additional quantity,

$$\rho D\left[\frac{1}{2(H-L)}\{\pi(\theta)IP(\pi(H)) + [1-\pi(\theta)]IP(\pi(L))\}\right].$$

This additional amount reflects the fact that even a long-term insider who sees bad news has an incentive to increase purchases or short-sell less in order to influence investor beliefs. If insiders value future profits sufficiently, an insider seeing bad news purchases a positive amount in an attempt to conceal her news from investors. That is, she incurs a short-term loss to increase investment. and thus future inside-trading profits.

As insiders value future profits more (i.e., as ρ increases) or as the sensitivity of investment to investor beliefs increases (i.e., as D increases), equilibrium long-term insider orders grow, so that the equilibrium volume at which the market maker cannot discern good news from bad rises. As $\rho D \to 0$, the long-term insider's trades converge to the short-term insider's.

When $\Psi > 0$ (a necessary condition for any revelation to occur), no pure pooling equilibrium exists in which the young insider trades the same quantity irrespective of her private information. This follows because there is no volume at which both types receive payoffs of at least their full-information values. Together with Propositions 1, 3, and 4, this implies that, for $\tilde{K} \neq \rho\Psi$, the pure strategy equilibrium uniquely identifies the young insider's payoffs and the investment by the uninformed born that period.

When $\tilde{K} = \rho\Psi$, both fully revealing and partially concealing equilibria exist. This is of importance when the level of capital in place for a young insider is *endogenous*. Then, in general equilibrium, uninformed investment must be consistent with the subsequent actions of insiders. Since expected payoffs to investors are discontinuous in whether the insider conceals her information, the general equilibrium may require mixing to smooth the payoffs of the uninformed investors. In this case, the market maker randomizes over the pricing functions thatsupport the fully revealing and partial pooling equilibria, choosing the partially concealing pricing function with probability ω, $0 \leq \omega \leq 1$ so that a fully revealing equilibrium occurs with probability $1 - \omega$.

Since the market maker earns zero expected profits in both equilibria, he is indifferent to the mixing probability. The mixing probability chosen by the market maker is such that the resulting equilibrium price distribution satisfies the rational expectations of the uninformed who trade against the young insider and hence is consistent with their investment. The probability that the market maker selects the revealing equilibrium price schedule, ω, keeps $\rho/\sqrt{\tilde{K}(\omega)}$ constant across different values of $\tilde{K}$ and ρ.

Let $\pi(\theta^o)$ be the probability that $\theta^y = H$, before the young insider receives her private information. Following the discussion above, let $\phi(\tilde{K}, \omega, \pi(\theta^o))$ be the young insider's expected insider premium:

$$\phi(\tilde{K}, \omega, \pi(\theta^o)) = \begin{cases} 0, & \tilde{K} < \rho\Psi \\ \omega IP(\pi(\theta^o)), & \tilde{K} = \rho\Psi \\ IP(\pi(\theta^o)), & \tilde{K} > \rho\Psi. \end{cases} \tag{31}$$

The young insider's expected first period trading profits are therefore given by

$$\phi(\tilde{K}, \omega, \pi(\theta^o))\sqrt{\tilde{K}}. \tag{32}$$

Lemma 2. *The equilibrium investment of the uninformed born when the insider is old is given by*

$$\sqrt{K_B^y(\theta, p_B^o)} = \begin{cases} \frac{E[\theta^y|\theta, p_B^o]}{2}, & \frac{E[\theta^y|\theta, p_B^o]}{2} < \rho\Psi \\ \frac{E[\theta^y|\theta, p_B^o] - E[IP(\pi(\theta^o))|\theta, p_B^o]}{2}, & \frac{E[\theta^y|\theta, p_B^o] - E[IP(\pi(\theta^o))|\theta, p_B^o]}{2} > \rho\Psi \\ \rho\Psi & \text{otherwise} \end{cases} \tag{33}$$

When $\sqrt{K_B^y(\theta, p_B^o)} = \rho\Psi$, *the mixing probability chosen by the market maker,* $\omega(\theta, p_B^o)$, *is consistent with the investment by the uninformed, so that*

$$\omega(\theta, p_B^o) = \frac{E[\theta^y \mid \theta, p_B^o] - 2\rho\Psi}{E[IP(\pi(\theta^o)) \mid \theta, p_B^o]}. \tag{34}$$

Combining the above propositions and lemma, existence and uniqueness of equilibrium with a long-term insider follows:

Proposition 5. *An equilibrium to the long-term insider game exists. Further, the expected profits of all market participants are unique across all possible equilibria.*

Since $E[\theta^y \mid H] \geq E[\theta^y \mid L]$, then if $E[\theta^y \mid H] \leq 2\rho\Psi$, in equilibrium, the young insider always reveals her private information at all information sets. If $IP(\pi(H)) > IP(\pi(L))$, so that $\Psi > 0$, then there is always a weight on future profits, ρ∗, large enough such that the young insider reveals her information in all states. The critical ρ∗ is given by

$$\rho^* = \frac{E[\theta^y \mid H]}{2\Psi}.$$

If Ψ > 0 and the insider values her future profits enough, the young insider always trades to reveal her private information in equilibrium.

We now present an important welfare result: If the long-term insider ever chooses with positive probability to reveal her information, then the uninformed prefer to trade against a long-term insider rather than against a short-term insider. Since investment improves in this case, even the insiders are better off, leading to a strict Pareto improvement over the short-term insider case.

Proposition 6. *The uninformed weakly prefer to trade against a long-term insider. Further, if*

$$\max_{n\in\{L,H\}} (E[\theta^y \mid n] - E[IP(\pi(\theta^o) \mid n)]) < 2\rho\Psi, \tag{35}$$

then the uninformed strictly prefer trading in an economy witb a long-term insider to trading against a short-term insider. In this case, the

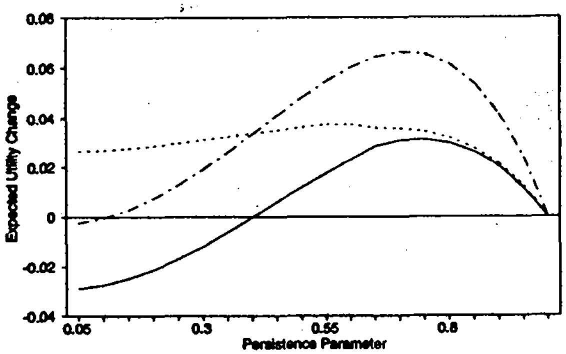

Figure 5a
Change in expected utility – long-lived young insider
This figure plots the change in unconditional expected utilities of the insider trader (- - -), the Liquidity traders (——), and the change in the sum of the expected utilities of the insider and liquidity traders (— - —) from introducing the long-lived insider trader in the economy in the first period of the insiders life against the persistence parameter, γ. Parameter values are given by L = 0.1. H = 5.0, h = 0.75, l = 0.25, and p = 0.1.

equilibrium with a long-term insider ex ante strictly Pareto dominates that with a short-term insider.

Intuitively, the uninformed gain both because long-term insiders do not always create adverse selection problems and because more information is released through prices. The above inequality ensures that there is a positive probability that the young insider trades to reveal fully her information. An uninformed investor is aided by more informative prices in the past (no adverse selection) because they help target current investment and are helped by less adverse selection in the future because they will not pay an insider premium as often.

2.1 Example

We maintain the parametric specifications, π = 0.1, $h - l$ = 0.5, H = 5, L = 0.1, and assume that the young insider does not discount future profits so that ρ = 1. Figures *5a* and *5b* plot the change in unconditional expected utility for the agents, first when the insider is young and then when he is old. For sufficiently small amounts of persistence, the young long-term insider always conceals, so that the equilibrium expected utility with the long-term insider is the same as that with the short-term insider. There is a sharp increase in the payoffs to the uninformed when y is sufficiently large that the young insider begins to reveal her private information in equilibrium. Most of the gains from having a long-term insider who trades to reveal information when young accrue to the uninformed. Indeed, the gains of the uninformed may exceed expected insider profits.

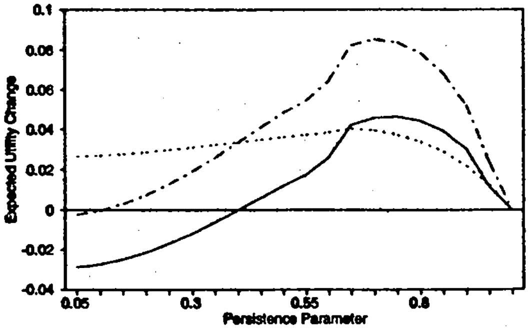

Figure 5b
Change in expected utility—long-lived insider, old insider
This figure plots the change in unconditional expected utilities of the insider trader (- - -), the liquidity traders (——), and the change in the sum of the expected utilities of the insider and liquidity traders (— - —) from introducing the long-lived insider trader in the economy in the second period of the insider's life against the persistence parameter, γ. Parameter values are given by $L = 0.1$, $H = 5.0$, $b = 0.75$, $l = 0.25$, and $\pi = 0.1$.

3. Regulation of Inside Trading

Consider now the consequences of possible government regulation of inside trading. If, as in Ausubel, insiders must always truthfully announce their information before trading, then they earn no profits. Consequently, if there are even the slightest costs of information acquisition, no information is acquired, and prices are uninformative. Even with a short-term insider, our numerical examples reveal that the benefits of informative prices can exceed the harmful consequences of investment distortions due to inside trading. Therefore, in contrast to Ausubel, regulation is not generally welfare enhancing. In Ausubel, disclose or refrain legislation can be optimal because of the expected positive effects of disclosure on the value of the insider's existing holdings through the general equilibrium effects on investment by the uninformed prior to trading with insiders. No such effect exists here because insiders have no prior holdings.

Our analysis provides some insight about when inside trading should be regulated. When investment is not information elastic (i.e., when information about current payoffs has little effect on investment), then the costs of insider trading outweigh its benefits. Surprisingly, our model suggests that legislation which effectively precludes insider trading is welfare enhancing for established firms but is not welfare enhancing for start-up firms, whose insiders must raise cap ital. Insiders at start-up firms already have incentives to reveal their information truthfully. More intuitively, the model suggests that, when regulation is optimal, short-term insiders who are not affiliated with the firm (e.g., Boesky) should not be able to trade on inside information. Perhaps a countervailing force on the benefits of allowing inside trade at start-up firms is that the volatility of liquidity trade may be greater for such firms, which makes inside trading mote profitable.

There are other regulations that are more effective in revealing past inside trading but that may have adverse welfare consequences. Sufficiently large shareholders do not have to announce their information in advance of trading but must file 13D forms with the SEC within 10 business days of their trades, detailing the magnitudes of their trades. The effects of introducing 13D's that become public information in our economy is as follows:

The trades of short-term insiders are completely unaffected by such regulation as they do not care about the information content of their trades. Welfare, however, is increased because their trades and, hence, their information are always made public, so that investment is better targeted.

However, when the trades of long-term insiders are revealed by the 13D's, young long-term insiders always trade to exploit their private information, since the 13D's make their trades public information shortly thereafter. In this case, the 13D regulation of a *young* long-term insider cannot be welfare enhancing. The equilibrium is now qualitatively identical to that with a regulated short-term insider in that both the expected trading losses of the uninformed each period and welfare are unaffected by whether the insider has repeated access to information. The only difference is that the equilibrium trade sizes of the young long-term trader will exceed those of the short-term insider, reflecting the nonmimicry conditions for insiders seeing bad news. Investors are less well off than with an unconstrained young long-term insider who can only credibly communicate good news indirectly through the market-clearing price by making sufficient purchases.

Carlton, Fischel, and Fischel (1983) argue that the individual firm should determine the form of its insider-trading regulation, since they have the incentive to make the optimal decision. If the "firm" consists of its current shareholders in our model, then they would always want to ban future insider trading but demand it in the past. In this way they receive the informational gains of insider trading but do not have to incur its costs. If the "firm," instead, has the same horizon as that of a long-term insider and seeks to maximize the earnings of the uninformed, then it might want to permit insider trading when the long-term insider is young and would trade to reveal her information but ban insider trading when the insider is old and would like to exploit it. But then the long-term insider would seek to exploit her information when young, so that the optimum cannot be achieved by having the individual firm choose its form of insider-trading regulation. If the unregulated long-term insider is the optimal form of insider trading, the "firm" would seek to overcome these time consistency problems by committing itself to not banning insider trading. Of course, there may be no feasible way to do this.

If, with time, sources of information other than inside trading become better, stricter insider-trading regulations may become optimal. The recent moves of many countries such as Germany or Japan toward stricter regulation [see, e.g., Gaillard (1992)] can be interpreted in this light.

Finally, one might wonder why it is necessary for insiders to make stock purchases to communicate news rather than have firms "announce" good news. There are several plausible reasons why direct announcements are not used. Direct announcements of information that is not immediately verifiable may not be credible, because all firms have an incentive to increase investment. It is hard to understand how firms could commit to truthful revelation of information that is not credible. On the other hand, insider trades *can* be a credible way to signal good news.

False or overly optimistic pronouncements are made all of the time, and there is generally no recourse in the courts, especially if insiders do not trade against that information at that moment (i.e., short-sell if they have negative information but proclaim good news). To the extent that it is generally possible to make such announcements and trade against them without adverse legal consequences, insiders seeing bad news have an incentive to try to raise prices by announcements and then short-sell. Any incremental resulting investment would just increase future profits.

Thus, for direct announcements to have an effect in equilibrium, they must provide verifiable information. Providing verifiable information to investors may also provide information to business competitors which they can exploit to the detriment of the firm. As a consequence, firms may want to reveal good news indirectly through a signal-the effect of their share purchases on the stock price. This may credibly reveal good news without revealing the nature of the good news [see, e.g., Bernhardt and LeBlanc (1994)].

4. Conclusions

This article introduces inside traders into a dynamic general equilibrium economy in which *rational,* but uninformed, traders invest in assets with different levels of adverse selection. The investments of these liquidity traders depend crucially on the information held by the insider which is revealed through the equilibrium price. We distinguish insiders by the length of time over which they have access to inside information. We examine the consequences for their incentives either to conceal their information so as to obtain immediate profits or to trade in such a way that they reveal their information and thereby influence investment. When inside information has little predictive power for future payoffs, introducing an inside trader to the economy causes welfare losses because insiders always seek to profit by concealing their information. Further, any slight benefits of informative prices fail to counterbalance the direct costs of trading in a market with an insider. Insider trading distorts investment so that the marginal costs of capital are unequal across otherwise identical investment opportunities.

However, when an insider's information has high value in investment decisions, the insider's presence is socially beneficial. This is particularly true when the insider has a stake in future investment. To the extent that she influences future investment decisions through her inside trading, the insider may trade in such a way as to reveal her information. To convince investors that she has observed good news or to conceal her bad news, the insider has to hold a large stake in her firm. Prices are then more informative and uninformed investors are more likely to receive "fair" prices for their holdings. We believe that this characterization accurately portrays the behavior of many long-term insiders at small exploration or R&D firms.

Appendix

Proof of Lemma 1

Proof. The proof is broken up into two steps. First, we show that the insider must always earn positive expected profits in any equilibrium. We then demonstrate the strategies that support positive expected profits.

Since the market maker earns zero expected profits for any given net order flow, then

$$Lb\left(K_B^{t-1}\right) \leq P_B\left(v_B^t, K^{t-1}, \theta^t\right) \leq Hb\left(K_B^{t-1}\right).$$

This follows because, were the price outside these bounds, the market maker would buy/sell the asset at a price greater or less than payoffs in any possible state, violating the competitive zero expected profits condition. In any fully revealing equilibrium, the insider's expected profits must be zero state by state, since the price must equal the expected value of the asset conditional on the insider's private information. The fact that net order flow prices are between $Lb(K^{t-1})$ and $Hb(K^{t-1})$ implies that the insider can earn positive expected profits in at least one state so that the equilibrium cannot be fully revealing. In state H, for any order submitted by the insider, q, her expected profits are

$$q\left[Hb\left(K_B^{t-1}\right)-\left(\frac{1}{2}\right)\left(P_B\left(q-b,K^{t-1},\theta^t\right)+P_B\left(q-l,K^{t-1},\theta^t\right)\right)\right]. \tag{A1}$$

For this to be nonpositive, it must be that, for $v_B^t > -b$,

$$\left(\frac{1}{2}\right)\left(P_B\left(v_B^t,K^{t-1},\theta^t\right)+P_B\left(v_B^t+b-l,K^{t-1},\theta^t\right)\right)\geq Hb\left(K_B^{t-1}\right). \tag{A2}$$

Similarly, it must follow that, for $v_b^t < -l$,

$$\left(\frac{1}{2}\right)\left(P_B\left(v_B^t,K^{t-1},\theta^t\right)+P_B\left(v_B^t+l-b,K^{t-1},\theta^t\right)\right)\leq Lb\left(K_B^{t-1}\right). \tag{A3}$$

Let $-b < v_B^t < -l$. To satisfy Equation (A2), we must have $P_B(v_B^t,\cdot,\cdot) = Hb(K_B^{t-1})$. But to satisfy Equation (A3), $P_B(v_B^t,\cdot,\cdot) = Lb(K_B^{t-1})$.

Suppose the insider sets

$$q(H,K_B^{t-1})-b = q(L,K_B^{t-1})-l,$$

so that the market maker cannot determine the production shock in the states $\{H, h\}$ and $\{L, l\}$. Substituting the market maker's zero expected profit condition *in* for *equilibrium* prices and using Bayes' rule, we see that the insider's *equilibrium* expected profits in states H and L are given by

$$\begin{aligned} H &: q(H,K_B^{t-1})\frac{1}{2}(H-L)(1-\pi(\theta^t))b(K_B^{t-1}) \\ L &: [q(H,K_B^{t-1})-(b-l)]\frac{1}{2}(H-L)\pi(\theta^t)b(K_B^{t-1}) \end{aligned} \tag{A4}$$

respectively. These are both nonnegative if and only if

$$0 \leq q(H,K_B^{t-1}) \leq (b-l).$$

Inspection reveals that the only other ways to induce adverse selection are either to set

$$q(H,K_B^{t-1}) = q(L,K_B^{t-1})$$

or to set

$$q(H,K_B^{t-1})-l = q(L,K_B^{t-1})-b.$$

But these trades cannot make nonnegative expected profits in both states H and L. So, set the insider's trades to $\alpha(b-l)$ in state H and

$(\alpha-1)(b-l)$ in state L. Substituting these expressions into Equation (A4) and taking expectations gives the following for expected insider profits:

$$\frac{1}{2}(b-l)(H-L)\pi(\theta^t)(1-\pi(\theta^t))b(K_B^{t-1}) \equiv IP(\pi(\theta^t))b(K_B^{t-1}), \quad \text{(A5)}$$

which does not depend on a and is strictly greater than zero. ■

Proof of Proposition 1

Proof: Verification that (A), (B), (C) describe an equilibrium. Statement (C) follows directly from Lemma 2, since the liquidity traders know that the expected loss to the insider is given by

$$\frac{(b-l)(H-L)}{2}\{\mu\pi(H)[1-\pi(H)]+(1-\mu)\pi(L)[1-\pi(L)]\}b(K^t).$$

If the insider's private information is H (L), any volume less (greater) than zero results in negative expected profits for the insider, as long as the market maker's pricing function lies between $Lb(K_B^{t-1})$ and $Hb(K_B^{t-1})$. Therefore, we need only to verify that the insider does not wish to trade any other positive (negative) volume if she observes H (L). Using the above pricing function, the insider's expected profits from following the equilibrium strategies are given by

$$\begin{aligned} H &: \left(\frac{1}{2}\right)(1-\pi(\theta^t))^2(b-l)(H-L)b(K_B^{t-1}), \\ L &: \left(\frac{1}{2}\right)(\pi(\theta^t))^2(b-l)(H-L)b(K_B^{t-1}). \end{aligned} \quad \text{(A6)}$$

The insider's expected profits are for an order of size $(b-l) > q > 0$ in state H are given by

$$\begin{aligned} &\left[H-\left(\frac{1}{2}\right)(H+\mu(q-b,\cdot,\cdot)(H-L)+L)\right]b(K_B^{t-1}) \\ &= q\left(\frac{1}{2}\right)[1-\mu(q-b,\cdot,\cdot)](H-L)b(K_B^{t-1}) \\ &\le q\left(\frac{1}{2}\right)\left[1-\max\left\{0,1-\frac{(1-\pi(\theta^t))^2(b-l)}{q}\right\}\right](H-L)b(K_B^{t-1}), \\ &\qquad (\text{since } q-b=v_B^t) \\ &\le \left(\frac{1}{2}\right)(1-\pi(\theta^t))^2(b-l)(H-L)b(K_B^{t-1}), \end{aligned}$$

using the left-hand side of the inequality in Equation (11). But

$$\left(\frac{1}{2}\right)(1-\pi(\theta^t))^2(b-l)(H-L)b(K_B^{t-1})$$

represents the insider's expected profits in state H from submitting the proposed equilibrium volume of

$$(1-\pi(\theta^t))(b-l).$$

If the insider submits an order $q \geq (b-l)$,beliefs will be given by 1 irrespective of the level of the liquidity shock. In this case, her profits will be zero. Therefore, the proposed equilibrium volume is optimal given the above pricing function. Similar logic shows that volume $-\pi(\theta^t)(b-l)$ is optimal in state L given the beliefs in condition (B). Hence, given the beliefs in condition (B) the strategies presented in condition (A) are indeed optimal.

In this proposed equilibrium, the market maker only observes volumes of

$$(1-\pi(\theta^t))(b-l)-b, \text{ or } (1-\pi(\theta^t)(b-l)-l \text{ in state } H;$$
$$(1-\pi(\theta^t))(b-l)-l, \text{ or } (-\pi(\theta^t))(b-l)-l \text{ in state } L.$$

Thus, for observed equilibrium volumes, beliefs are consistent with Bayes' rule. For off-equilibrium volumes, beliefs satisfying Equation (11) lie between 0 and 1. Therefore, given the insider's strategies in condition (A), the beliefs in condition (B) are consistent with equilibrium. Thus, (A), (B), (C) describe an equilibrium.

Uniqueness. By Lemma 1, in any equilibrium the insider must trade $\alpha(b-l)$ in state H and $(\alpha-1)(b-l)$ in state L, where $0 \leq \alpha \leq 1$. Suppose that

$$\{\alpha(b-l), (\alpha-1)(b-l)\}$$

describes equilibrium strategies of the game. Let $m(v)$ be the beliefs of the market maker that support this equilibrium. The proof that α is unique is divided into two claims.

Chaim 2. If $m(v)$ supports an equilibrium a, so does the revised set of beliefs:

$$m^*(v) = \begin{cases} m(v) & -b < v < -l \\ 1 & v \geq -l \\ 0 & v \leq -b \end{cases} \tag{A7}$$

Proof. In state *H*, for $(b-l) > q > 0$, for α to be an equilibrium, $m(v)$ must satisfy

$$\begin{aligned}\frac{\alpha(b-l)(H-L)(1-\pi(\theta^t))}{2} &\geq q(H-L)\\ &\quad \times \left(1-\frac{[(m(q-b)+m(q-l)]}{2}\right)\\ &\geq q(H-L)\\ &\quad \times \left(1-\frac{[m(q-b)+1]}{2}\right)\\ &= q(H-L)\\ &\quad \times \left(1-\frac{[m^*(q-b)+m^*(q-l)]}{2}\right)\end{aligned}$$

since $q > 0$.

If the insider trades $d \geq (b-l)$, then the beliefs will be H under $m^*(\cdot)$, leaving the insider zero expected profits for this trade. Therefore, beliefs $m^*(\cdot)$ will still make $\alpha(b-l)$ an optimal choice in H if beliefs $m(\cdot)$ do. Similar reasoning holds for state L. ∎

Claim 2. In any equilibrium, $\alpha = 1-\pi(\theta^t)$.

Proof: By claim 1, we can take beliefs such that

$$m(v) = 1,\ \ v > -l,\ \ m(v) = 0,\ \ v < -b.$$

For a trade q_H, such that $0 < q_H < (b-l)$, $q_H - l > -l$, so $m(q-l) = 1$. The profits the insider would earn by trading $0 < q_H < (b-l)$ in state H are given by

$$\begin{aligned}&q_H\left[H-\frac{1}{2}(H+(m(q_H-b)H+(1-m(q_H-b))L))b(K_B^{t-1})\right]\\ &\quad = q_H(H-L)\frac{1}{2}(1-m(q_H-b))b(K_B^{t-1}).\end{aligned}$$

It is straightforward to verify that any equilibrium belief function must be nondecreasing in observed volume, which implies that the insider's objective function is concave. Thus, if the belief function is differentiable, the first-order conditions characterize the insider's optimal trading rule in state H. The first-order condition is given by

$$(1-m(q_H-b)) - q_H\frac{\partial m(q_H-b)}{\partial v}\frac{\partial v}{\partial q_H} = 0.$$

Substituting in the equilibrium conditions that $q_H = \alpha(b-l)$ and

$m(\alpha(b-l)-b)=\pi(\theta^t)$, we obtain

$$\frac{\partial m(q_H-b)}{\partial v}=\frac{1-\pi(\theta^t)}{\alpha(b-l)}. \tag{A8}$$

Insider profits in state L from submitting an order q_L such that $-(b-l)<q_L<0$ can be written as

$$q_L\left[L-\frac{1}{2}(L+m(q_L-l)H+(1-m(q_L-l))L)\right]b(K_B^{t-1})$$
$$=-q_L m(q_L-l)(H-L)\frac{1}{2}b(K_B^{t-1}).$$

Again, assuming differentiability of $m(\cdot)$, the first-order conditions for the insider in state L evaluated at the equilibrium beliefs and volume imply that

$$\frac{\partial m(q_L-l)}{\partial v}=\frac{-\pi(\theta^t)}{(\alpha-1)(b-l)}. \tag{A9}$$

Since

$$q_H-b=\alpha(b-l)-b=(\alpha-1)(b-l)-l=q_L-l$$

is the net order flow observed when the market maker does not infer the insider's private information, we have, using Equations (A8) and (A9),

$$\frac{1-\pi(\theta^t)}{\alpha(b-l)}=\frac{-\pi(\theta^t)}{(\alpha-1)(b-l)}.$$

Solving the above equation for a implies that the unique solution is given by

$$\alpha=1-\pi(\theta^t).$$

Thus, if the beliefs are differentiable around the equilibrium, there is a unique equilibrium quantity traded by the insider in each state.

We now sketch the proof that the equilibrium belief function must be differentiable at the observed net order flow of $\alpha(b-l)-b$ for any possible equilibrium a. The belief function must be continuous at that point. Suppose that there is a jump so that

$$\lim_{v\downarrow\alpha(b-l)-b}\mu(\alpha(b-l)-b)=\mu(\alpha(b-l)-b)+\xi,\ \ \xi>0.$$

Then an insider who observes L would sell slightly less and increase his profits by $(\alpha-1)(b-l)\frac{1}{2}(H-L)b(K_B^{t-1})\xi>0$. An analogous argument applies if there is a discontinuity from below.

The same reasoning can be used both to show that the belief function must be differentiable at $\alpha(b - l) - b$: if there is a jump in the slope of the belief function at the equilibrium, the insider is able to make a small deviation from the equilibrium trades leading to a strict in- in profits. This proves claim 2. ■

Therefore,

$$\left\{\left(1-\pi(\theta^t)\right)(b-l), -\pi(\theta^t)(b-l)\right\}$$

are the only strategies by the informed that can be supported in equilibrium. This a implies that the belief function of the market maker and the investment stategies of the uninformed are as presented in conditions (B) and (C). ■

Proof of Proposition 2

Proof. Together, Equations (12) and (13) imply that

$$b'(\hat{K}_B^t) < b'(K_B^t). \tag{A10}$$

The strict concavity of *b(·)* implies that $\hat{K}_B^t > K_B^t$. ■

Statement of Proposition 3

A fully revealing equilibrium exists in which the young insider reveals her private information *if and only if* the capital stock in place satisfies

$$0 < \sqrt{\bar{K}} \leq \rho\Psi, \tag{A11}$$

where

$$\Psi \equiv \frac{1}{(H-L)(b-l)} D[IP(\pi(H)) - IP(\pi(L))] \tag{A12}$$

The following describes the equilibrium strategies and belief functions:

A. Let

$$\bar{v} \in \left[\frac{\rho IP(\pi(L))D}{(H-L)\sqrt{\bar{K}}} - l, \frac{\rho IP(\pi(H))D}{(H-L)\sqrt{\bar{K}}} - b\right]. \tag{A13}$$

The insider seeing good news trades $q_H > \bar{v} + b$, and the insider seeing bad news trades $q_L < \bar{v} + l$.

B. The beliefs of the market makers and uninformed investors that $\theta^y = H$ are a function of the trading volume *v* that they observe and are given by

$$\mu_y(v) = \begin{cases} 0, & v < \bar{v} \\ 1, & v \geq \bar{v}. \end{cases} \tag{A14}$$

C. The investment of the uninformed is given by

$$K_B^o = \min\left\{1, (C + D\mu_y)^2\right\}. \tag{A15}$$

Proof of Proposition 3

Proof. If the insider reveals her private information in equilibrium, then her equilibrium payoffs are given by

$$\begin{aligned} H &: \rho IP(\pi(H))[C + D] \\ L &: \rho IP(\pi(L))C \end{aligned}$$

Let $\mu(v)$ be the equilibrium belief function. For notational ease, define

$$\tilde{\mu}(q) \equiv \frac{1}{2}[\mu(q - h) + \mu(q - l)],$$

the beliefs that the insider expects to receive given that she trades a quantity q. Suppose that the insider trades a quantity q in state H. Then, her payoffs would be given by

$$q(1 - \tilde{\mu}(q))(H - L)\sqrt{\bar{K}} + \rho IP(\pi(H))[C + D\tilde{\mu}(q)]. \tag{A16}$$

Optimality of the revealing equilibrium payoffs when the private information is H requires

$$\rho IP(\pi(H))[C + D] \geq q(1 - \tilde{\mu}(q))(H - L)\sqrt{\bar{K}} + \rho IP(\pi(H))[C + D\tilde{\mu}(q)],$$

or

$$0 \geq (1 - \tilde{\mu}(q))\left[q(H - L)\sqrt{\bar{K}} - \rho IP(\pi(H))D\right]. \tag{A17}$$

To satisfy Equation (A17), beliefs must satisfy

$$\tilde{\mu}(q) = 1, \quad q > \frac{\rho IP(\pi(H))D}{(H - L)\sqrt{\bar{K}}},$$

or, translating to beliefs, $\mu(v)$,

$$\mu(v) = 1, \quad v > \frac{\rho IP(\pi(H))D}{(H - L)\sqrt{\bar{K}}} - h. \tag{A18}$$

Suppose that the insider trader deviates from the equilibrium by trading a quantity q when her private information is L. Then, her expected profits are given by

$$-q\tilde{\mu}(q)(H - L)\sqrt{\bar{K}} + \rho IP(\pi(L))[C + D\tilde{\mu}(q)]. \tag{A19}$$

Optimality of the revealing payoffs in state L requires

$$\rho IP(\pi(L))C \geq -q\tilde{\mu}(q)(H-L)\sqrt{\bar{K}} + \rho IP(\pi(L))[C + D\tilde{\mu}(q)],$$

or

$$0 \geq \tilde{\mu}(q)\left[-q(H-L)\sqrt{\bar{K}} + \rho IP(\pi(L))D\right]. \tag{A20}$$

To satisfy Equation (A20),

$$\tilde{\mu}(q) = 0, \quad q < \frac{\rho IP(\pi(L))D}{(H-L)\sqrt{\bar{K}}},$$

or

$$\mu(v) = 0 \quad v < \frac{\rho IP(\pi(L))D}{(H-L)\sqrt{\bar{K}}} - l. \tag{A21}$$

A belief function $\mu(v)$ exists which satisfies Equations (A18) and (A21) *if and only if*

$$0 < \sqrt{\bar{K}} \leq \frac{\rho D}{(H-L)(b-l)}[IP(\pi(H)) - IP(\pi(L))].$$

Verification that conditions (A), (B), and (C) describe an equilibrium follows from the above arguments, since the pricing function satisfies Equations (A18) and (A20) ■

Proof of Corollary 2

Proof. For $\Psi > 0$, we require $D > 0$ and $IP(\pi(H)) > IP(\pi(L))$, since $D \geq 0$. Using the definition of D, Equation (20) in the text, a necessary and sufficient condition for $D > 0$ is that

$$\pi(H) > \pi(L).$$

Using the definition of $IP(\cdot)$,

$$\begin{aligned} IP(\pi(H)) - IP(\pi(L)) &= \frac{(b-l)(H-L)}{2} \\ &\quad \times [\pi(H)(1-\pi(H)) - \pi(L)(1-\pi(L))] \\ &= \frac{(b-l)(H-L)}{2} \\ &\quad \times [\pi(H) - \pi(L)][1 - \pi(H) - \pi(L)]. \end{aligned}$$

Since $\pi(H) > \pi(L)$ and $(b-l)(H-L) > 0$, for the above to be positive, we require $\pi(H) + \pi(L) < 1$. Using Equation (2), this condition can be written as

$$2\pi(1-\gamma) + \gamma < 1.$$

Since $0 \leq \gamma < 1$, the result follows. ■

Proof of Corollary 3

Proof. This follows from solving the equation $\rho\Psi \geq 1$ for ρ. ■

Statement of Proposition 4

In the trading game when the long-term insider is young, an equilibrium involving the insider trading such that in states $\{(H, l), (L, b)\}$ trading volume is uninformative and in states $\{(H, b), (L, l)\}$ trading volume is fully informative exists *if and only if* the capital stock in place, $\bar{K}$, is large enough:

$$\sqrt{\bar{K}} \geq \rho\Psi, \tag{A22}$$

where $\rho\Psi$ is defined as in Equation (24). If $\sqrt{\bar{K}} > \rho\Psi$ is satisfied, the strategy of the insider is *unique:* only the off-equilibrium beliefs of the uninformed investors and market makers differ across equilibria. The following describes an equilibrium with a piece-wise linear pricing schedule.

A. The insider's trades are given by

$$\begin{aligned} H : q_H^c &= (1-\pi(\theta))(b-l) \\ &\quad + \left[\frac{\rho D}{2(H-L)}\{\pi(\theta)IP(\pi(H)) + [1-\pi(\theta)]IP(\pi(L))\}\right], \\ L : q_L^c &= -\pi(\theta)(b-l) \\ &\quad + \left[\frac{\rho D}{2(H-L)}\{\pi(\theta)IP(\pi(H)) + [1-\pi(\theta)]IP(\pi(L))\}\right], \end{aligned} \tag{A23}$$

where $\pi(\theta)$ denotes the prior probability that the insider's information will be H.

B. The beliefs of the market maker and uninformed are given by

$$\mu_y(v) = \begin{cases} 0, & v \leq q_H^c - b - \pi(b-l) \\ 1, & v \geq q_H^c - l \\ \pi(\theta) + \Delta(v - q_H^c - b) & \text{else,} \end{cases} \tag{A24}$$

where

$$\Delta = \frac{(H-L)(1-\pi(\theta))}{(H-L)q_H^c - \frac{\rho IP(\pi(H))D}{2\sqrt{\bar{K}}}}.$$

C. The investment of the uninformed agents is given by

$$K_B^o = \min\left\{1, (C + D\mu_y)^2\right\}. \tag{A25}$$

Proof of Proposition 4

Proof: Necessity: In the equilibrium, the insider with good news trades q_H, and the insider with a technology shock of L must trade q_L so that

$$q_L - l = q_H - b.$$

The insider's expected profits are given by

$$\begin{aligned} H &: q_H \frac{(1-\pi(\theta))}{2}(H-L)\sqrt{\bar{K}} \\ &\quad + \rho I P(\pi(H))\left[C + D\frac{(1+\pi(\theta))}{2}\right], \end{aligned} \tag{A26}$$

$$\begin{aligned} L &: -[q_H - (b-l)]\frac{\pi(\theta)}{2}(H-L)\sqrt{\bar{K}} \\ &\quad + \rho I P(\pi(L))\left[C + D\frac{(\pi(\theta))}{2}\right], \end{aligned}$$

where $\pi(\theta)$ denotes the probability that the insider's private information is H, conditional on last period's publicly observed technology shock. Since the insider seeing good news can trade an unbounded amount, her profits would become unbounded if beliefs of the market maker did converge to one as the volume gets arbitrarily large. Similar reasoning applies to an insider seeing bad news; eventually beliefs must converge to 0 for a small enough volume. But then, in equilibrium, there are strategies for insiders with both types of information such that their separating profits can be obtained. Since the trades q_H and q_L must be optimal, the insider's profits evaluated at these trades must be at least as large as their separating payoffs. This implies the following inequality for the insider with a productivity shock of H,

$$\begin{aligned} &q_H \frac{(1-\pi(\theta))}{2}(H-L)\sqrt{\bar{K}} + \rho I P(\pi(H))\left[C + D\frac{(1+\pi(\theta))}{2}\right] \\ &\geq \rho I P(\pi(H))[C + D], \end{aligned}$$

or

$$q_H \geq \frac{\rho I P(\pi(H)) D}{(H-L)\sqrt{\bar{K}}}. \tag{A27}$$

Similarly, for the insider with shock L,

$$-[q_H-(b-l)]\frac{\pi(\theta)}{2}(H-L)\sqrt{\bar{K}}+\rho IP(\pi(L))\left[C+D\frac{(\pi(\theta))}{2}\right]$$
$$\geq \rho IP(\pi(L))C,$$

or

$$q_H \leq \frac{\rho IP(\pi(L))D}{(H-L)\sqrt{\bar{K}}}+(b-l). \qquad \text{(A28)}$$

A q_H exists which solves Equations (A27) and (A28) *if and only if*

$$\sqrt{\bar{K}} \geq \frac{\rho}{(H-L)(b-l)}D[IP(\pi(H))-IP(\pi(L))],$$

thus proving necessity.

Sufficiency. To prove sufficiency, we show that the strategies and beliefs given in the proposition give an equilibrium when the inequality in Equation (29) is satisfied. Statement (B) defines beliefs that are consistent on the equilibrium path and between zero and one off the equilibrium path. Statement (C) follows from an uninformed's first-order conditions. One can verify that maximizing the insider's expected payoffs subject to the belief function yields the trades given in statement (A), when Equation (29) is satisfied. This proves sufficiency.

Uniqueness. The proof that the insider's trades are unique follows the same logic as in the uniqueness proof for the short-term insider. The only way that we can find a set of consistent off-equilibrium beliefs is when the insider seeing shock H trades a quantity such that

$$q_H^c=\frac{\rho D}{2(H-L)}\{\pi(\theta)IP(\pi(H))+[1-\pi(\theta)]IP(\pi(L))\}+(1-\pi(\theta))(b-l).$$

■

Proof of Lemma 2

Proof: Since the uninformed act competitively, their first-order conditions are given by

$$1=(E[\theta^y \mid \theta, p_B^o]-E[\phi(K_B^y,\omega,\pi(\theta^o)) \mid \theta, p_B^o])\frac{1}{2\sqrt{k_B^y}}, \qquad \text{(A29)}$$

where again K_B^y denotes the aggregate investment of the uninformed for the project that pays off when the new insider is young. Also, $\pi(\theta^o)$ denotes the probability that $\theta^y = H$ conditional on the current old insider's private productivity shock. In equilibrium, we have $k_B^y = K_B^y$, and so the equilibrium $\{K_B^y(\theta, p_B^o), \omega(\theta, p_B^o)\}$ solves

$$\sqrt{K_B^y(\theta, p_B^o)} = \frac{E[\theta^y \mid \theta, p_B^o] - E[\phi(K_B^y(\theta, p_B^o), \omega(\theta, p_B^o), \pi(\theta^o)) \mid \theta, p_B^o]}{2}. \tag{A30}$$

Solving the above equation yields the result. ■

Proof of Proposition 5

Proof: Together, Propositions 3 and 4 imply that, for any capital stock that could be in place for the young insider, an equilibrium to the trading game exists. Further, the expected payoffs to the insider before seeing her private information are unique as long as the capital stock in place does not equal ρΨ. Lemma 2 implies that there is only one investment that the uninformed who will trade against the young insider will make at every information set. Further, the mixing probability for the market maker is unique and so, if the capital in place for the young insider equals ρΨ, her expected profits are unique.

In the last period of the insider's life, the game is isomorphic to the game with a short-term insider. go, the expected insider premium for the uninformed who trade against the old insider is unique, and thus each uninformed trader's investment decision is unique.

Thus, there is a single investment decision that can be made at any information set in the game such that rational expectations are satisfied about the distribution of future prices. This set of investment decisions clearly is an equilibrium. Since there is only one equilibrium investment decision at every node and since expected payoffs of the insider, market maker, and uninformed agents are unique functions of the investment levels, the equilibrium payoffs of the agents are unique. ■

Proof of Proposition 6

Proof. An uninformed investor who will trade against the old insider always has a weakly finer information partition with a long-term insider than a short-term insider; he is weakly more likely to know θ^y. Ceteris paribus, the expected profits of an uninformed investor are greater if he knows θ^y, since he can make the same investment independent of θ^y. Uninformed investors who trade against the young insider are also better off facing a long-term insider because they are less likely to face adverse selection in the next period and their information sets are the same whether or not the insider is a long-term or short-term insider.

If Inequality (35) is satisfied, then there is a positive probability that the young insider will trade to reveal her information completely in equilibrium. By the arguments given above, the uninformed investors strictly prefer this to trading against the short-term insider. In this case, the investment of the uninformed is closer to the efficient level than with a short-term insider, there will be less underinvestment in the risky technology. Therefore, expected output will be higher, leading to a strict ex ante Pareto improvement, since all agents are risk-neutral. ■

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