Disclosure Policies of Investment Companies

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Abstract

We examine voluntary and mandated disclosure of portfolio holdings by investment companies (ICs) in a model where ICs are characterized as having a stream of investment ideas and providing liquidity to investors through redemptions. We show that the greater the IC's liquidity provision role, the more aggressively the IC trades on its ideas and the stronger is its preference to disclose voluntarily information about its holdings. We also show that mandatory disclosure can appear to increase competition when, in fact, it decreases information available in securities markets by crowding out private information acquisition. Our model's predictions are consistent with stylized facts (documented by others) that ICs take aggressive positions in response to poor performance and that disclosure has an asymmetric effect on the future performance of well versus poorly performing ICs.

Introduction

Recent years have witnessed several significant regulatory changes that affect capital markets. Many of these changes are aimed at increasing investor protection through enhanced transparency of securities issuers. For example, the provisions of Regulation FD and the Sarbanes-Oxley Act are directed at enhancing the transparency and accuracy of disclosures made by all public companies. The investment management industry in particular has attracted attention with the controversy surrounding late trading and market timing. These practices violate the letter or spirit of rules designed to ensure fairness in dealings between investment companies and their shareholders. Revelations that these practices were widespread and involved both hedge funds and mutual funds have led regulators to explore ways to increase transparency of companies in the investment management industry.

In an effort to monitor better the business practices of hedge funds, the SEC has recently adopted a rule requiring most hedge fund advisers to register with the SEC under the Investment Advisers Act. This change requires hedge funds to establish internal compliance systems and maintain records in accordance with SEC guidelines, and it subjects hedge funds to examination by the SEC. This rule also requires hedge fund advisers to disclose publicly basic information about themselves and the value of assets under management. Though this rule does not require hedge funds to disclose detailed information about their operations or holdings, memoranda to the SEC during the comment period expressed clear concern that this rule is a first step toward more extensive regulation and oversight.[1] In a separate action, the SEC ruled to increase the frequency with which mutual funds must publicly disclose their holdings from semiannually to quarterly. This rule brings greater public disclosure to an area where the degree of mandatory disclosure was already relatively high.

Though a public goods view of investor protection motivates these changes, it is not obvious that investment companies lack incentives to disclose as much information about their operations as investors want or need. This is especially true if the intended beneficiaries of the regulations are the investors who own these investment companies. Presumably, owners can dictate to the company whatever disclosure policy is in their interest without the intervention of a regulator. It therefore seems reasonable to examine the costs and benefits of disclosure, and to analyze the

[1] One letter quotes Alan Greenspan as saying in Senate testimony that, "should registration fail to achieve the intended objectives, pressure may become irresistible to expand the SEC's regulatory reach from hedge fund advisers to hedge funds themselves." See also "Hedge Funds Grow Up: Less Risk, More Regulation–and Lower Returns," *Bloomberg Markets,* February, 2005.

private incentives that optimizing investment companies have to disclose information about their operating decisions in the absence of a mandate. Gaining an understanding of the private incentives can help identify where private incentives for disclosure are strong, where in the industry private costs of existing and proposed disclosure mandates may be particularly high, and how companies will change their operating decisions in response to changes in disclosure regulations.

A great deal has been written about disclosure, but none of the existing models are well suited to analyzing the unique issues that characterize investment companies. Several models examine corporate disclosures of product quality and financial performance [examples are Grossman (1981), Diamond (1985), Teoh and Hwang (1991), Shavel (1994), Admati and Pfleiderer (2000), Dierker (2003), Fishman and Hagerty (2003, 2004)]. Other models examine disclosure of insider trades [Fishman and Hagerty (1992,1995a), Huddart, Hughes and Levine (2001)]. Investment companies have attributes in common with the agents in these models, but neither type of model alone describes the situation well. In this paper, we develop a model specifically suited to this purpose.

Our point of departure is the observation that investment companies share attributes of corporate and insider disclosers. Investment companies can increase the payoff to investment positions by increasing demand for the securities they hold in the same way disclosures about product quality or favorable financial performance enhance the value of corporate disclosers. However, investment companies are also similar to insiders in the sense that disclosure decreases the value to be gained from their investment ideas. Whether disclosure is in the interest of an investment company, and its investor owners, depends on the relative strengths of these effects.

We show that whether disclosure is desirable depends on how the investment company learns through time about the value of its investment opportunities and the nature of the securities it issues. Disclosure is desirable for investment companies that generate significant current and future investment ideas, and that issue securities with liberal redemption features (e.g., open-end mutual funds). Disclosure enables these firms to improve the prices received in exchange for holdings that are liquidated early—i.e., prior to when the information on which they trade is publicly revealed. Disclosure is not desirable for investment companies that issue securities with restrictive redemption privileges, or those for which future investment ideas are unimportant. These firms benefit more from secrecy and the ability to exploit information over time than from improving prices on holdings that are liquidated early. In fact, we show that competitive security pricing can break down if disclosure is mandated for some investment companies in this latter group because the mandate distorts their incentives to such a degree that an equilibrium with disclosure might not exist.

The perspective that disclosure is linked to redemptions has several implications that are consistent with existing empirical evidence. These are discussed in detail later in the paper. Perhaps the least obvious implication is that disclosure has an asymmetric effect on an investment company's performance depening on whether its past performance has been good or poor. In particular, since poor past performers are those for which net redemptions are greatest [see Sirri and Tufano (1998), Sapp and Tiwari (2004) and others], disclosure is predicted to have a positive impact on their future performance. The opposite is predicted for those with good past performance. Ge and Zhang (2004) examine this asymmetry in a panel of mutual funds whose disclosure policies differ in terms of the frequency with which they disclose. Controlling for other determinants of fund performance, they find that performance is indeed positively related to disclosure frequency when past performance has been poor, and negatively related when past performance has been good.

The attributes that describe investment companies in our model are the same as those featured in prominent models of mutual funds. The liquidity provided by mutual funds to their investors through redemption privileges is emphasized in Chordia (1996) and Nanda, Narayanan and Warther (2000). Their work, and that of Berk and Green (2004), also assume that investment companies possess the consistent ability to discover profitable investment ideas. The primary difference between our model and theirs is that their focus is on the relationship between the mutual fund and its investors. In those models, the costs associated with liquidity provision and the rents to the manager's ability are exogenous, and the mutual fund's fee structure and fund size are endogenous. Since our focus is on disclosure of operating decisions, we analyze the relationship between the investment company and the security market in which it operates. The costs associated with liquidity provision and the rents to ability are endogenous in our model, and we take the fee structure and fund size as having been determined prior to the operating decisions whose disclosure we analyze. These approaches are mutually consistent. To the extent that the optimal fee structure and resulting fund size in the earlier models depend on liquidity provision costs and rents to ability, our model describes how these costs and rents arise.

Endogenizing these costs and rents yields predictions that are not available in existing models. For example, a common presumption in the literature on funds flows is that if an investment company faces likely future redemptions, it should invest less in risky assets and hold a greater cash reserve in order to fund those redemptions. This can be correct if the main cost of redemption is an exogenous friction (e.g., commissions on trading out of an investment position). However, if the investment company has ability, the primary cost of redemption is the lost opportunity to capitalize on its ability over time for the benefit of investors. In this case, the investment company should trade more aggressively in anticipation of the redemption to exploit its ability to the fullest while it has the resources to do so.

Our results on voluntary and involuntary disclosure suggest that current disclosure rules, which distinguish between mutual funds and hedge funds, are consistent with the private incentives these companies have to disclose their holdings. This suggests that the current regulations are not a burden to the industry. However, we show that homogenizing these rules by mandating disclosure of operating decisions for hedge funds will eliminate information acquisition that would be profitable in the absence of a disclosure mandate. This, in turn, reduces industry profit and could result in less information being available to the market as a whole through the system of prices and disclosures. The tension facing regulators in this case is similar to that of insider trading—the public good of investor protection achieved through greater transparency must be weighed against the costs associated with a less informative price system. The difference, of course, is that profits to insiders are regarded as ill-gotten gains at the expense of investors because insiders have a priveledged position in the firm with respect to information acquisition. This is not the case for investment companies that would lose profitable opportunities as a result of a uniform disclosure mandate. Those profits are a result of a comparative advantage at "arm's length" information acquisition whose benefit accrues to investors.

In our model, the ability of the IC is common knowledge and there is no incentive conflict between its managers and shareholders. Even in this pristine setting, we show that disclosure policy is an important element of an investment company's strategy. This does not mean we believe agency conflicts are unimportant. On the contrary, reports by agents play key roles in screening and contracting problems. However, there are good reasons for analyzing disclosure policies in the absence of these complications. First, it enables us to identify the components of the IC's disclosure policy that flow simply from the desire to maximize expected profit. This is important when interpreting empirical evidence. For example, our model predicts that if redemptions follow poor performance, investment managers should increase their exposure to risk when recent performance has been poor. This behavior has been documented empirically, and attributed to the nature of the compensation contract that managers typically face in the mutual fund industry. Our model explains this simply as a consequence of profit maximization. The second reason for abstracting from these complications is that the screening of managers, incentive provision and monitoring in the investment management setting can be accomplished through non-public reports to an oversight board, an intermediary or a rating agency.[2] Despite this, much of the disclosure that occurs in this

[2] Gervais, Lynch and Musto (2005) is an excellent illustration of this idea. In their model, a family of fund managers

industry, particularly the disclosure that is mandated, is made publicly. Disclosures in our model are made to the market as a whole. Therefore, the forces that drive disclosure in our model relate to those we believe are important for understanding public disclosure.

The paper is organized as follows. The next section provides some background on the regulatory framework. Section 2 presents the model, a discussion of our results, and empirical implications. Section 3 concludes.

1. Regulatory Framework

The mutual fund literature highlights redemption privileges of investors as a key feature of these organizations. Since this is an important aspect of our model also, we briefly review how current regulations constrain redemption privileges and mandate disclosure depending on how the organization is structured.

The Investment Company Act defines which investment management businesses are investment companies and therefore subject to its provisions. An investment company so defined that has $25 million or more under management can conduct business only if it registers with the SEC and complies with a number of periodic filing (i.e., public disclosure) mandates. The particular disclosure we focus on in this paper regards disclosure of portfolio holdings. Prior to July 2004, semi-annual filings were required in conjunction with financial statements and other supporting information. As noted earlier, a recent rule change now requires detailed holdings to be reported quarterly.[3,4]

The definition of an investment company is sufficiently broad that any firm engaged in in-

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is able to screen its members by ability because it can use information that managers cannot credibly communicate to investors.

[3]These rules are based on the premise that disclosure is more valuable in real time than after-the-fact. For example, in real time, investors can use information in the disclosure to manage better their individual portfolios of securities and mutual funds. If disclosures were simply used to check a fund's compliance with its stated investment objectives, annual reporting of quarterly holdings would be sufficient. Our model's predictions conform to the premise underlying existing rules. When the investment company wishes to disclose voluntarily, the type of disclosure it will seek is disclosure in real time.

[4]Whether quarterly and semi-annual disclosure frequencies are meaningfully different in terms of the constraints or opportunities they present to firms is an empirical question. One well-known dispute over just this difference has existed for years between the auto company Porche and the Frankfurt stock exchange. The exchange requires quarterly disclosure of financial results for stocks included in the DAX indexes. In 2001, Porche became eligible for inclusion in the midcap index, but was denied because it discloses financial information only semi-annually, and has refused to disclose at a quarterly frequency over concern for inducing a short-term focus in management decisions. Since 2001, Porche has pursued litigation against the Frankfurt exchange to force the exchange to include Porche in the index despite its unwillingness to disclose quarterly. (See *The Economist*, Nov. 13, 2004.) Inclusion in the index is not a matter of indifference to Porche, and therefore neither must be its reluctance to disclose on a quarterly frequency. Ge and Zheng (2004) document differences in the performance of mutual funds that disclose with quarterly and semi-annual frequencies. Their results are discussed in detail in subsection 2.5 below.

vestment management is considered to be an investment company unless it is structured to satisfy specific exclusions spelled out in the Act. Hedge funds, private equity funds, and venture capital funds typically qualify for one of two exclusions. Both exclusions require that the firm neither makes nor proposes to make a public offering of its securities. One of the exclusions requires that the fund has 100 or less "accredited" investors. The other does not limit the number of investors, but instead requires that investors are "qualified" at the time they purchase their shares.[5] The SEC has developed safe-harbor rules to guide firms in how to avoid running afoul of the public offering provision, and in how investors are to be counted in determining whether they number 100 or less. Companies that qualify for either of these exclusions are exempt from registration, and therefore, the disclosure requirements of the Act. They need not disclose publicly their portfolio holdings at any time. In fact, they are not required to disclose their holdings even to their own investors, though many precommit to doing so.

Companies that are required to register under the Act can issue redeemable securities (open-end funds), non-redeemable securities (closed-end funds), or securities that are redeemed at infrequent intervals (interval funds). Since the firm, rather than a market, specifies the terms on which investors redeem, several provisions of the Act and related rules focus on how open-end investment companies must handle redemptions. In particular, open-end companies are required to compute share value and accept tenders for redemption daily and settle any tendered shares within seven business days. Therefore, a registered company that organizes itself as an open-end fund *must* have a very liberal redemption policy (i.e., offer redemptions at a daily frequency). Companies that are exempt from registration can issue securities with whatever redemption privileges they want. Hedge funds typically restrict redemptions to specific dates each quarter or annually and require prior notification of the desire to redeem, despite having the freedom to choose less restrictive redemption policies.

To summarize, firms in the investment management business differ in whether they are compelled to disclose their holdings by whether they must register under the Investment Company Act or not. They also differ in their openness to redemption, and these are independent dimensions along which firms differ. The state of the industry is that among those that register and are subject to mandatory disclosure of holdings, a vast majority select an open-end structure, which imposes a very liberal redemption policy.[6] By contrast, firms that are exempt from registration issue securities

[5] "Accredited" means persons having $200,000 in annual income or net worth of $1 million or more. "Qualified" means owning $5 million or more in investments. The latter exemption is relatively recent, enacted in 1997.

[6] The Investment Company Institute reports that at the end of 2003 there was a total of 8124 open-end funds (of

with restrictive redemption policies, and are typically secretive about their holdings. Our model examines the forces that determine these choices.[7]

2. Model

Two elements of investment company (IC) structure are key to our analysis. First, ICs are in the business of managing the money of others, so they issue claims against the assets they manage. The claims issued may allow redemptions to force liquidation of investment positions before the profit to those positions is fully realized. Edelen (1999) reports that 70% of flows in and out of mutual funds in his sample are traded into the fund's portfolio, and that about half of the trading activity of the median mutual fund is attributable to funds flows. Alternatively, the contractual agreement between the IC and investors may preclude redemption except at infrequent pre-specified intervals as is common for hedge funds. The second important element of IC structure is that ICs are continuing enterprises and they must generate sequences of investment ideas in order to continue in existence.

In analyzing insider trading, it is common to assume the insider knows the security's liquidation value $\tilde{v}$ before trading begins. This makes sense if the time span is short between when the insider receives his information and when $\tilde{v}$ is realized. Time spans are longer in analyzing disclosure for ICs. It would be extreme to assume that, before trading begins, the IC knows what the value of the security will be several months or quarters ahead. Consequently, we write the eventual payoff to the security as the sum of independent innovations $\tilde{v} = \tilde{v}_1 + \tilde{v}_2$ that the IC learns as time passes—v_t is observed by the IC prior to trading at time t.[8] We refer to $\{v_1, v_2\}$ as the IC's stream of investment ideas. The variance ratio $\phi = \frac{\sigma^2_{v2}}{\sigma^2_{v1}}$ reflects how the quality of the IC's investment ideas is distributed across time. If $\phi \geq 1$, ($\phi < 1$) the information the IC learns in the future is at

which 4598 were equity funds) whose average NAV was $910 million ($800 million). There were only 586 (130 equity) closed-end funds whose average NAV was $402 million ($355 million). Current statistics for the hedge fund industry are difficult to come by (for free). However, the article cited in footnote 1 reports some statistics obtained from Hedge Fund Research, Inc. At the end of Q3 of 2004 there were approximately 7,165 hedge funds worldwide, with a total of $890 billion under management (p. 33). These are managed by 2,750 hedge fund firms, only 160 of which have $1 billion or more under management (p. 39). Thus, for every eight open-end mutual funds there are seven hedge funds; but only 160 hedge fund *companies* (which may advise multiple hedge funds) have assets under management that approximates the NAV of the *average* open-end mutual fund.

[7] Another important distinction is that firms defined as investment companies must hold diversified positions and cannot use leverage, short positions or derivatives as meaningful components of their investment strategies. These limitations are not placed on exempt companies. We do not address this difference in our model. However, Ko (2003) examines the tradeoff associated with a non-public disclosure by a borrower to a lender with whom the borrower competes in asset markets. His model identifies conditions under which disclosure to a lender can be voluntary for, say, a hedge fund as a consequence of holding a levered position.

[8] We model trading as though it occurs in one discrete event, but this is not essential. Positions could be acquired over time within periods and disclosed at period ends.

least as (less) important in determining the security's payoff as the information known at the time of the IC's first investment in the security. If $\phi = 0$, the IC is *fully* informed before it trades into its first position in the security, and future information plays no role. We will see later that the temporal distribution of the quality of the IC's information interacts with disclosure in a manner that has a significant impact on the IC's and market maker's strategies.

ICs are different from a company disclosing the quality of its products or financial information about itself because disclosure by the IC generally degrades the quality of its product. Disclosing decreases the profitability of the IC's stream of investment ideas because disclosing reduces the IC's informational advantage.[9] This perspective dominates the IC's decisions if the structure of claims against the IC's assets constrains or discourages redemption. In this case, the IC has flexibility to trade into investment positions over time. The IC therefore prefers to maintain secrecy with respect to its trading strategy so as not to reveal any more private information than necessary to execute the trades. However, if redemptions are likely, the IC knows that it must acquire the investment position without delay and is likely to be forced to liquidate the position at *market prices* that may not fully reflect the true value of the investment the IC has acquired. The possibility of early liquidation makes disclosure desirable because the disclosure communicates some of the IC's information to the market. Acquiring the position quickly and disclosing it enables the IC to liquidate at a price closer to the security's true value than would have been possible had the position been kept secret. These conflicting incentives drive the intuition behind the model. We analyze how they affect the IC's trading decisions, the IC's desire to acquire information and disclose its holdings, and the impact of regulations that require disclosure on the IC's behavior and profit.

Figure 1 summarizes the sequence of events. Before trading begins, the IC chooses a disclosure policy regarding its holdings, or learns that a mandate to disclose exists. The IC observes component v_1 of the true value $v = v_1 + v_2$ of the security. At time 1, the IC takes an investment position in the security. If the disclosure policy the IC chose (or a mandate) requires it, the IC then discloses its holdings between times 1 and 2. The IC then observes v_2. If redemptions do not occur, the IC can trade again at time 2 and payoffs occur at time 3 when the security's true value is publicly revealed. If redemptions do occur, then the IC must liquidate its position at time 2 and the IC's payoff per share is the time-2 *market price* rather than the security's true value v. We assume that the value of the informational advantage associated with having observed v_2 is lost; i.e., the investment manager cannot credibly sell this signal. This assumption makes the expected profit

[9] See Wermers (2001) for a nice discussion of the many ways frequent disclosure reduces the value of the IC's informational advantage.

function simpler by omitting a term associated with the value of selling v_2. However, it does not affect the results because the omitted term would scale expected profit the same regardless of the disclosure policy chosen by the IC.[10,11]

We use a two-period model because it is the simplest setting that captures the tradeoffs we analyze. The essential element is that disclosure conveys information for a future liquidation—whenever that might happen, and regardless of whether prior liquidations occurred. By ordering disclosure prior to redemption in the second period, we can capture this in just a single period in the model.

We use Kyle's (1985) model as the structure for determining equilibrium security prices and trades by the IC. The differences are the choice the IC makes (or the mandate) to disclose its holdings, the possibility that redemptions force early liquidation, and the assumption that the IC has a stream of investment ideas.[12] Using Kyle's model clarifies the role played by just these effects in determining disclosure policies because it abstracts from risk aversion, non-competitive market making and incentive conflicts between the IC's managers and its investors.

Risk-neutrality in Kyle's model implies that disclosure policies will not be based on differences across ICs in the risk preferences of investors, and possibly, differences in their preference for resolving uncertainty. Second, competitive market making implies that our conclusions will not be driven by the types of securities ICs trade. It would be easy, for example, to draw the conclusion that disclosure is undesirable for hedge funds vis-a-vis mutual funds because the former trade assets in non-competitive markets and fear that other traders will back away from their liquidations to extract rents—predatory trading as described in Brunnermeier and Pedersen (2005). Finally, incentive conflicts between the IC's managers and investors would lead to trading strategies designed to maximize the size of the fund or the manager's fees rather than the expected profit to the fund's shareholders. The objective of the informed trader in Kyle's model is one of maximizing expected profit. Assigning this objective to the IC in our model ensures that the IC's managers make the same decision that investors would if they had the same information as the IC.[13]

[10] It will always be in the IC's interest to disclose *conditional* upon learning that redemptions will force liquidation if doing so will affect the price in a beneficial manner, and not to disclose otherwise. However, our focus is on whether the IC will commit ex-ante to follow a *policy* of disclosing in order to compare what the IC will do voluntarily to what it would be required to do under a regulatory mandate to disclose. In practice, ICs that are not required to disclose (exempt organizations) state their disclosure commitment in the offering documents—they actually do precommit.

[11] See Admati and Pfleiderer (1990) and Fishman and Hagerty (1995b) for analyses of information sales.

[12] Back and Pedersen (1998) and Boulatov and Livdan (2005) are other dynamic models in the spirit of Kyle (1985) in which informed traders observe a sequence of signals. Neither examines disclosure, however.

[13] Our results do not depend on how the investment manager and investors split the surplus to the manager's ability.

Whether the IC faces redemptions that require liquidation at time 2 is known to the market maker. We model redemptions by assuming that with probability q, redemptions cause the IC's entire time-1 position in the security to be liquidated at time 2. The assumption that the occurrence of liquidation is known to the market maker ensures that the market maker's interpretation of time-2 order flow is well-defined. We could assume instead that the market maker is unaware of redemptions and therefore (counter factually) ignores the possibility that time-2 order flow contains any information about v_1. The results would be qualitatively the same, but the IC would favor disclosure over a slightly larger parameter space.

Our analysis views q as a predetermined parameter in the IC's disclosure and trading decisions. Though we do not specify the determinants of q, the existing literature suggests two obvious candidates—the IC's fee structure and past performance. High redemption fees attract a clientele for which q is lower than if redemption fees were low or nonexistent [see Nanda, et.al. (2000)], and resources flow out of ICs with poor performance [see Sirri and Tufano (1998)]. The empirical implications of this association are discussed later.

Our model analyzes a single investment position. In reality, ICs trade multiple positions simultaneously. When they liquidate to fund redemptions, they can choose positions whose liquidation has the smallest impact on expected profit (a delivery option). Since our model ignores the delivery option, it may overstate the quantitative importance of liquidation vis-a-vis its importance in real markets. However, the qualitative aspects of our results will still be relevant provided that early liquidation causes ICs to forego using a dynamic strategy to exploit some profitable investment ideas.[14]

In a standard Kyle (1985) model, unlimited borrowing at a zero interest rate is the justification for why the insider is unconstrained in the size of the position he may take. In the mutual fund literature, unlimited borrowing would enable the fund to finance redemptions entirely with borrowing. The fund could therefore provide liquidity to investors costlessly. In order not to lose the tractability of the Kyle model, we therefore must assume that the IC starts with sufficient funds to finance its initial investment and that if liquidation does not occur, it either has a cash reserve from its initial funding or raises new funds to finance its incremental investment at time

The empirical evidence for both mutual funds and hedge funds is that managers capture the entire surplus on average [Edelen (1999), Ackerman et.al. (1999) and Johnson (2004)].

[14] Short positions require resources in the form of collateral—either cash or long positions in assets. If redemptions draw down cash or long positions pledged as collateral, then the short must be closed also. This mitigates the value of delivery options for ICs that hold short positions. In fact, it implies that the size of the positions liquidated could be greater than the dollar value of the redemption.

2. If redemptions do force liquidation, we assume that the IC must return to investors the entire value of securities held and whatever cash reserve it has. This is for simplicity. What is essential is that the IC must liquidate a significant portion of a profitable investment opportunity in order to satisfy a constraint such as redemption (or to fund an even better investment opportunity). This makes our model unrealistic for ICs that never face resource constraints—i.e., always having more cash than redemptions and good investment ideas. However, as long as resource constraints are time-varying our analysis can be viewed as an examination of how anticipated future resource constraints affect decisions at times when resources are relatively plentiful. This preserves the crucial element of our story—that the IC's disclosure and trading decisions are made with an awareness that positions may have to be liquidated prior to the full resolution of the uncertainty upon which the initial investment was based.

Conditional on its precommitment to disclose or not, the IC's objective is to maximize expected profit through time by choosing holdings x_t at each trading date. In each trading round the IC's order is batched for execution with the net orders of liquidity traders u_t. All orders are then executed by a risk-neutral market maker at a price P_t equal to the expected value of the security conditional on current and past net order flow and any disclosures that have been made. In accordance with Kyle (1985), we assume that $\tilde{v}_1 \sim N(0, \sigma_{v1}^2)$, $\tilde{v}_2 \sim N(0, \sigma_{v2}^2)$, and $\tilde{u}_1, \tilde{u}_2 \sim iidN(0, \sigma_u^2)$ are mutually independent and independent of whether redemptions force liquidation. We also assume that σ_u does not depend on the disclosure decision of the IC. This means, for example, that the uninformed do not condition their participation on the precommitment of the IC to disclose or whether there is a mandate to disclose.[15] The vector of exogenous parameters $(\sigma_{v1}, \sigma_{v2}, \sigma_u, q)$ summarizes the IC's stream of investment ideas, the liquidity of the security market in which it trades, and the nature of the claims against its assets. Also, as in Kyle, we focus on the existence and characterization of pure-strategy equilibria in which prices are linear.

In order to analyze whether a precommitment to disclosure will be made, we have to work out the equilibria in models with and without disclosure, and compare the expected profit to the IC across equilibria. Both of these models are new to the literature. Even if $\sigma_{v2}^2 = 0$, the model without disclosure is different from a two-period Kyle (1985) model because the IC faces the possibility of early liquidation and Kyle's insider does not. The characterization of the strategies of

[15] This assumption would have to be weakened if liquidity traders have discretion in how they trade. For example, if liquidity traders are modeled as risk-averse exponential-utility maximizers as in Mendelson and Tunca (2004), then the variance of liquidity trading would likely be greater if the IC discloses than if it does not. The impact on our results would be that the *voluntary* disclosure region in Figure 2 below would be larger because disclosing has an added benefit of attracting greater participation by the uninformed.

both the informed trader and the market maker are different from those in Kyle's model, and how they respond to the possibility of early liquidation is interesting in its own right. The model with disclosure is different from existing models also. The closest existing model is that of Huddart, et.al. (2001), which analyzes a standard Kyle model (i.e., $\sigma_{v2}^2 = q = 0$). They show that equilibrium does not exist in pure strategies with disclosure. They then construct an equilibrium in which the insider follows a randomized trading strategy.

2.1 No Disclosure

In this section, we assume that the IC does not disclose its trades, nor does it face a mandate to disclose. Since we are interested in disclosure *policies*, we assume that the IC discloses credibly only if it precommits. For example, unless the IC has in place a compliance system and reporting mechanism to regulatory authorities, disclosures it makes are not considered credible.[16]

The IC's initial endowment of the security is zero. Before trading commences, the IC observes v_1 and trades the quantity Δx_1 at a price of P_1 per unit. Order flow is $\omega_1 = \Delta x_1 + u_1$. Between times 1 and 2 the IC and the market learn whether redemptions will force the IC to liquidate its position or not. The IC also learns v_2. If liquidation is not forced, the IC trades Δx_2 at price P_2, and order flow is $\omega_2 = \Delta x_2 + u_2$. However, if liquidation is forced, the IC reverses its time-1 position at price $\hat{P}_2$, and order flow is $\hat{\omega}_2 = -\Delta x_1 + u_2$. Note that if liquidation is forced, then the market maker observes two conditionally independent signals of Δx_1, which depend on v_1 alone. If liquidation is not forced, the sequence of equilibrium order flow contains information about $\tilde{v}_1$ and $\tilde{v}_2$.

Equilibrium prices are the market maker's expected value of $\tilde{v}$ conditional on his information. In setting P_1, the market maker conditions on ω_1. In setting the time-2 price, he conditions on ω_1 and either $\hat{\omega}_2$ or ω_2 depending on whether redemptions force liquidation or not. Since the market maker knows whether liquidation is forced, he knows whether the functional form of the random order flow he observes at time 2 is $\hat{\omega}_2$ or ω_2. We restrict attention to equilibria in which prices are affine functions of variables the market maker observes:

$$
\begin{aligned}
P_1 &= \psi_1 + \lambda_1 \omega_1 \\
P_2 &= P_1 + \psi_2 + \lambda_2 \omega_2 \\
\hat{P}_2 &= P_1 + \hat{\psi}_2 + \hat{\lambda}_2 (\hat{\omega}_2 + \hat{\theta}_2 \omega_1).
\end{aligned}
\tag{1}
$$

[16] This assumption seems to have practical merit. In pointing out the incentives hedge funds have for selective disclosure, a recent article by the editor of Fortune cautions investors to "Count only the performance numbers that the [hedge fund], in advance, promised to reveal publicly. Disregard anything else." (*Fortune,* January 21, 2005, p. 22)

The IC's (random) profit is given by

$$\tilde{\pi} = \begin{cases} (\hat{P}_2 - P_1)\Delta x_1 + 0 & \text{with probability } q \\ (\tilde{v} - P_1)\Delta x_1 + (\tilde{v} - P_2)\Delta x_2 & \text{with probability } 1-q \end{cases}$$

where, despite the absence of tildes, the prices are random variables as well. The first line indicates that, with probability q, the IC will be forced to liquidate its time-1 position at time 2 and carry a zero position thereafter. The IC maximizes expected profit by choosing Δx_1 and Δx_2 conditional on the information it has at the time. We solve this by backward induction.

If liquidation is not forced at time 2, the IC chooses its time-2 trade according to

$$\max_{\Delta x_2} E\left[(\tilde{v} - P_2)\Delta x_2 | v_1, v_2, P_1\right].$$

Substituting for P_2 from equation (1), taking expectations, and rearranging the first-order condition yields

$$\Delta x_2^* = \delta_2 + \beta_2(\tilde{v} - P_1) \tag{2}$$

where expressions for δ_2 and β_2 are given in equations labeled (A.1) in the Appendix. The second-order condition is satisfied if $\lambda_2 > 0$.

The IC's problem at time 1 is to maximize the expected value of

$$\tilde{\pi}(\Delta x_1) = \begin{cases} (\hat{P}_2 - P_1)\Delta x_1 + 0 & \text{with probability } q \\ (\tilde{v} - P_1)\Delta x_1 + (\tilde{v} - P_2)\Delta x_2^* & \text{with probability } 1-q \end{cases} \tag{3}$$

conditional only on v_1. After substituting for the Ps from (1), Δx_2^* from (2), and taking expectations conditional on v_1, the equation is quadratic in the choice variable Δx_1. The first-order condition implies

$$\Delta x_1^* = \beta_0 + \beta_1 v_1,$$

where β_0 and β_1 are given in equations (A.5) and (A.6) in the Appendix.

This illustrates that even after adding the possibility of early liquidation and a stream of investment ideas to the standard Kyle (1985) model, affine prices still imply that the IC's strategies are linear. Linearity of the IC's strategies in v_1 and v_2 implies that order flow is linear in these variables, and in u_1 and u_2, and hence is normally distributed. Since the market maker's inference problem involves only normal variates, conditional expectations are linear. Provided that second-order conditions are satisfied, this gets us most of the way to establishing the existence of an equilibrium with linear prices and pure strategies.

The price parameters are computed using the Kalman filter, and the results appear as equations (A.8) - (A.14) in the Appendix. These, along with the equations describing the parameters in the

IC's strategy are eleven equations in eleven unknowns. It is clear from inspection that the unique solution to five of these equations is $\delta_2 = \psi_2 = \hat{\psi}_2 = \beta_0 = \psi_1 = 0$. The remaining equations can be solved for unique values of $\lambda_1, \lambda_2, \hat{\lambda}_2, \hat{\theta}_2$, and β_2 in terms of exogenous parameters and β_1. Finally, $\beta_1 = h_*^{\frac{1}{2}} \frac{\sigma_{v1}}{\sigma_u}$, where h_* is defined implicitly as the solution to $G(h_*; \phi, q) = 0$, where

$$G(h; \phi, q) = \frac{1}{h+1} \left\{ 1 - \frac{1}{2} \left(\frac{h}{(h+1)^2 \phi + (h+1)} \right)^{\frac{1}{2}} + \frac{q}{1-q} \left(\frac{h}{2h+1} \right) \right\} - \frac{1}{2}$$

and $\phi \equiv \frac{\sigma_{v2}^2}{\sigma_{v1}^2}$.

In a *single*-period Kyle (1985) model, the insider's strategy coefficient is simply $\frac{\sigma_{v1}}{\sigma_u}$. Therefore, the leading $h_*^{\frac{1}{2}}$ that appears in the solution for β_1 in this model is a scale factor that incorporates the effects of (i) multiple rounds of trading, (ii) multiple investment ideas, and (iii) the possibility of forced liquidation. Despite these additional complications, it is possible to characterize the equilibrium in detail analytically as summarized in the propositions below (proofs appear in the Appendix).

<u>Proposition 1</u>. *For any σ_{v1}, σ_{v2}, σ_u and $q < 1$, there exists a unique linear equilibrium when the IC does not disclose its time-1 trade. Equilibrium parameter values are given by equations (A.1), (A.5)-(A.6), (A.8)-(A.14) in the Appendix.*

As part of the proof of Proposition 1, we show that h_* is positive and unique, and that the second-order condition for the IC's time-1 problem is satisfied if and only if the positive root of $h_*^{\frac{1}{2}}$ is selected in defining β_1.

Numerical solutions to this model are easy to obtain for any set of exogenous parameters. Given values for q and ϕ, the (unique positive) value of h_* that satisfies $G(h_*; \phi, q) = 0$ can be found via a simple search (e.g., the solver tool in Excel). This, combined with exogenous values for σ_{v1} and σ_u determine β_1, which in turn determines the values of the other endogenous variables.

Since this model differs from a dynamic Kyle (1985) model in the assumptions that $q \neq 0$ and $\sigma_{v2} \neq 0$, the next set of results summarizes how these differences affect the equilibrium behavior of the IC and market prices. To ensure existence, these results assume that $q < 1$.

<u>Proposition 2</u>. *The greater is the probability of liquidation, q, the more aggressively the IC trades at time 1.*

It is tempting to think of q approaching one as a single-period Kyle model because the IC approaches having only one opportunity to trade on its information. However, this description is incomplete because early liquidation in our model occurs at the time-2 *market price* whereas liquidation occurs at the security's true value in a single-period Kyle model. If collapsing to a single trading round were the dominant effect of early liquidation, the IC's trade would converge, as $q \to 1$, to that of a single-period Kyle insider. This does not happen in our model.

When q is small, the IC trades less aggressively than in a single-period Kyle model because there is a high probability that it will be able to trade again at time 2. This is similar to why the insider in a multi-period Kyle model trades less aggressively than in a single-period Kyle model. As q increases, the IC increases the aggressiveness of its time-1 trade for two reasons. First, the IC is increasingly likely to have only one opportunity to trade, so restraining itself at time 1 in anticipation of another opportunity to trade at time 2 is less valuable. Second, making its time-1 trade more aggressive increases the information content of the sequence of order flow. This, in turn, increases the precision of the time-2 market price as a forecast of the security's true value, and raises (lowers) the expected price at which the IC will liquidate a long (short) position if liquidation is forced. This effect is strong enough that, as q increases, the IC trades even more aggressively than if it were the insider in a single-period Kyle model.[17] In fact, as $q \to 1$, the size of the IC's trade gets arbitrarily large.

Proposition 2 summarizes the impact of q on the IC's strategy at time 1. The next result shows that q has an impact on the IC's trading strategy and prices at time 2, even after the uncertainty about liquidation is resolved.

<u>Proposition 3</u>. *The greater is q, the more aggressively the IC trades at time 2 and the less sensitive is the time-2 price to order flow (in the event that the IC does not liquidate at time 2).*

If redemptions do not force liquidation at time 2, q has no direct effect on the IC's time-2 trade; so Proposition 3 must be understood through the impact of q on behavior at time 1. Since greater q leads to more aggressive trading at time 1, less uncertainty about $\tilde{v}$ exists after time-1 trading, which induces the IC to trade more aggressively at time 2. This is because, at time 2, the IC faces a single-period Kyle model. Its strategy coefficient is the ratio of the variance of liquidity trade to the variance of uncertainty about $\tilde{v}$ faced by the market maker. Less uncertainty implies more aggressive trading. Less uncertainty and more aggressive trading also lead the market maker to set prices that are less sensitive to each unit of order flow.

Propositions 2 and 3 taken together imply that the possibility of early liquidation does not merely shift trading by the IC from time 1 to time 2 or vice-versa, but rather that it increases

[17] Since $h_*=1$ corresponds to a trading strategy that is identical to that of a single-period Kyle insider, values of q for which the IC trades more aggressively are q for which $h_*>1$. This boundary is defined precisely in Proposition 4 below.

trading overall by the IC. An implication of these results is that ICs with high probabilities of redemption will not invest less in securities in order to hold excess cash to fund redemptions. Instead, the IC will invest *more* in securities to capitalize on its investment ideas while it has the resources to do so.

The increase in overall trading by the IC decreases the sensitivity of prices to order flow at time 2. However, the impact on the sensitivity of the time-1 price depends on how aggressively the IC trades at time 1, which in turn depends on q and ϕ.

Proposition 4. *The sensitivity of the time-1 price to order flow is larger for larger q if and only if* $\frac{q}{1-q} < \frac{3}{2\sqrt{2}}\left(\frac{1}{1+2\phi}\right)^{\frac{1}{2}}$.

This result says that unless ϕ is large, equilibrium λ_1 is an inverted-U-shaped function of q. To interpret this result, it helps to note that the condition on q and ϕ in the statement of the proposition is equivalent to $h_* < 1$. Recall that when $h_* = 1$, the IC trades as aggressively as if it were a single-period Kyle (1985) insider. One of the properties of a single-period Kyle model is that the optimal strategy of the insider maximizes the price sensitivity to order flow, where price sensitivity is viewed as a function of the insider's strategy coefficient. This is not true in dynamic models, and our model in particular. In a standard dynamic Kyle model ($q = \phi = 0$), the insider's strategy will always be less aggressive than in a single-period model. In our model, the IC's time-1 strategy ranges from being less to more aggressive than in a single-period Kyle model, depending on the values of q and ϕ.

The condition in the statement of the proposition reflects the fact that the IC trades less aggressively when q is small than when q is large. If $\phi = 1$, for example, the point at which price sensitivity at time 1 is maximized in our model is when $q \approx 0.38$, so λ_1 is increasing (decreasing) in q if q is below (above) 0.38. When q is small, liquidation is unlikely and the IC faces an environment that is very similar to a standard dynamic Kyle (1985) model. It therefore does not trade aggressively enough to maximize λ_1 because it wants to preserve a portion of its informational advantage for the second period. However, as q increases, the IC's investment horizon shortens to a single period *and* it will be forced to liquidate at a market price. Both of these facts make the IC willing to trade more aggressively, which will increase λ_1 to the point where the IC trades as aggressively as a single-period Kyle insider. Beyond that point further increases in q continue to lead to more aggressive trading by the IC, but the information content of those incremental trades is less per unit traded. In this region λ_1 decreases as q increases further.

The next result summarizes how the second investment idea affects equilibrium behavior.

Proposition 5. *The more important is the IC's time-2 investment idea (the larger is σ_{v2}), the more aggressively the IC trades at both time 1 and time 2, and the less sensitive is the time-2 price to order flow. The sensitivity of the time-1 price to order flow is larger for larger σ_{v2} if and only if $\frac{q}{1-q} < \frac{3}{2\sqrt{2}}\left(\frac{1}{1+2\phi}\right)^{\frac{1}{2}}$.*

The greater is the informational advantage the IC expects to have in the future, the more aggressively it trades on whatever advantage it has at time 1. When the IC anticipates having a large future informational advantage, it "saves" less of its current information for a later trading date.

If the IC is not required to liquidate at time 2, the greater informational advantage induces it to trade more aggressively than if it did not enjoy such an advantage. The time-2 price is less sensitive for two reasons. First, the more aggressive time-2 trading by the IC means prices are less sensitive to each unit of order flow. Second, the market maker learned more at time 1 because the IC traded more aggressively then as well. Consequently, the market maker's beliefs have been updated more regarding the v_1 component prior to time-2 than would have been true had σ_{v2} been smaller. The logic for the sensitivity of the time-1 price is similar to that given following Proposition 4. The value of σ_{v2} affects the condition determining whether the IC trades less or more aggressively than a single-period Kyle insider through $\phi \equiv \frac{\sigma_{v2}^2}{\sigma_{v1}^2}$.

We address later whether the IC voluntarily precommits to disclosing its time 1 trade. This will depend on whether such a commitment enhances or detracts from the IC's equilibrium expected profit without disclosure. As with the equilibrium value of β_1, equilibrium expected profit without disclosure is defined in terms of h_*.

Proposition 6. *If the IC does not disclose its time-1 trade, equilibrium expected profit is given by*

$$\bar{\pi}_N^* = \frac{\sigma_u \sigma_{v1}}{2}(1-q)(h_*+1)^{\frac{1}{2}} \left\{ \left(\frac{h_*}{h_*+1}\right)^{\frac{1}{2}} + \left(\frac{1}{1+\phi(h_*+1)}\right)^{\frac{1}{2}} \left[\frac{1}{h_*+1} + \frac{h_*}{(h_*+1)^2} + \phi\right] \right\}.$$

This profit function has a separability property that we will later see is useful for characterizing the IC's disclosure behavior. The leading term $\frac{\sigma_u \sigma_{v1}}{2}$ is the value that equilibrium expected profit takes in a standard single-period Kyle (1985) model. Thus, expected profit in our model is expected profit in a single-period Kyle model scaled by the remainder of the expression. Since h_* depends only on q and ϕ, this scale factor depends only on q and ϕ also—and not on σ_u, or on σ_{v1} except through the ratio $\phi \equiv \frac{\sigma_{v2}^2}{\sigma_{v1}^2}$. We will refer to this scale factor as $N(q, \phi)$ below; i.e., $\bar{\pi}_N^* = \frac{\sigma_u \sigma_{v1}}{2} N(q, \phi)$.

Besides early liquidation (q), the scale factor captures two things. First, it captures the value of the opportunity to trade twice on v_1 rather than once as in a static model. This aspect can be isolated by evaluating the scale factor at $q = 0$ and $\phi = 0$. Second, it captures the value of the second signal. This can be isolated by evaluating the scale factor as $\sigma_{v1} \to 0$. Since h_* is chosen to maximize expected profit, the envelope theorem implies that the direct effects of varying q and ϕ on $\bar{\pi}_N^*$ prevail in equilibrium. Therefore, $\bar{\pi}_N^*$ is decreasing in q and increasing in σ_{v1} and σ_{v2} (i.e., ϕ holding σ_{v1} fixed).

2.2 Precommitment to Disclose

The model without disclosure was complicated by the dynamic nature of the IC's problem. The model in which the IC precommits to disclose also has to be solved as a dynamic problem. However, when an equilibrium exists, the periods decouple because the disclosure eliminates the IC's advantage with respect to the information, $\tilde{v}_1$, that motivates the time-1 trade. This enables us to solve for all endogenous variables explicitly in terms of the exogenous variables. The difficulty is that if both q and ϕ are small, a linear equilibrium in pure strategies will not exist.

To see why not, suppose the market maker believes the IC's time-1 order can be inverted for v_1. Then with ϕ small, the time-2 price will be insensitive to time-2 order flow because the disclosure gives the market maker almost full information about the value of the security. If q is also small, the IC expects to trade at time 2 rather than liquidate. If the time-2 price is insensitive to order flow, the IC should trade contrary to his information at time 1 to mislead the market maker by his disclosure, planning to follow up with a large trade at time 2 in the direction of his information. Knowing this, it would not be rational for the market maker to attempt to infer v_1 from the disclosure of the IC's time-1 trade. Alternatively, suppose the market maker believes the IC's disclosure is uninformative about $\tilde{v}_1$. This means the market maker believes the IC's time-1 trade and hence order flow at time 1 are also uninformative. The time-1 price will be insensitive to time-1 order flow and it would then be in the interest of the IC to place a large order at time 1 in the direction dictated by his information. Consequently, his trade and disclosure would be informative about $\tilde{v}_1$, contradicting the supposition that the market maker believes the IC's disclosure is uninformative.

Huddart et.al. (2004) examines regulations that require insiders to disclose their trades in a standard Kyle (1985) model. They point out that this non-existence problem arises in their setting; i.e., at the "corner" of our model where $\phi = q = 0$. They construct a mixed-strategy equilibrium for the situation in which the insider faces a disclosure mandate. In their equilibrium, the insider follows a linear strategy plus noise by adding a normally-distributed random error to an otherwise pure-strategy trade. Adding the error prevents the disclosure from conveying too much information early, which in turn, prevents future prices from being insensitive to order flow.

Their result is remarkable because *normally*-distributed noise can achieve this, preserving the tractability of Kyle's (1985) model. The conditions that describe agents' understanding of the environment required of mixed strategies in a Kyle model are quite strong, however. The insider must mix in a way that elicits a pricing strategy by the market maker that leaves the insider indifferent across all pure-strategy choices. Since the support of the normal distribution is the entire real line, the insider must mix in a very precise way across an infinite number of possibilities between which he is indifferent. At times, he must take large positions on information of little consequence or small positions when his information is significant. Moreover, the market maker is learning through time, so the insider must recalibrate the variance of the distribution of randomization noise in each trading round to reflect the evolution of the market maker's beliefs; and the market maker must know the variance of the mixing variable at all times.

In our model, the assumption that the IC receives a stream of investment ideas prevents too much information about the terminal payoff from being conveyed by the disclosure. We show below that a pure strategy equilibrium exists with disclosure provided that $\phi > (1-q)/(1+q)$. This is not an especially stringent condition. The right-hand side attains its maximum of one at $q = 0$. As long as q is positive, it suffices that $\phi \geq 1$—the investment idea the IC receives in the second period is at least as important as the one received in the first period.[18]

We now turn to analyzing the model with disclosure. The modification we make to the structure described in subsection 2.1 is that the IC discloses its time-1 trade Δx_1 prior to trading at time 2. This means the information set upon which the market maker sets the time-2 price includes Δx_1 and time-2 order flow.[19] Since we focus on equilibria in which prices are affine functions of the information the market maker observes, the functional forms are

$$\begin{aligned} P_1 &= \psi_1 + \lambda_1 \omega_1 \\ P_2 &= \alpha_2 \Delta x_1 + \psi_2 + \lambda_2 \omega_2 \\ \hat{P}_2 &= \hat{\alpha}_2 \Delta x_1 + \hat{\psi}_2 + \hat{\lambda}_2(\hat{\omega}_2 + \hat{\theta}_2 \Delta x_1). \end{aligned} \tag{4}$$

The solution procedure is the same as in subsection 2.1 above.

[18] The intuition for this is the reverse of the intuition for why an equilibrium fails to exist when q and ϕ are small. As long as either q or ϕ are not small, the IC will want to avoid the destabilizing impact on the time-2 price created by taking a large position at time 1 in an attempt to mislead the market about v_1. If the IC has to liquidate early, the destabilizing trade will hurt its liquidation proceeds. If $\phi \geq 1$, the second signal is at least as informative as the first, and it will regret having misled the market if the second signal contradicts the first.

[19] Conditioning on time-1 order flow, $\omega_1 = \Delta x_1 + u_1$, is redundant because only Δx_1 is informative for v.

PROPOSITION 7. *A sufficient condition for a unique pure strategy linear equilibrium to exist with disclosure is $\phi > (1-q)/(1+q)$ (a necessary condition is $\phi \geq (1-q)/(1+q)$). In that equilibrium,*

$$P_1 = \left[\frac{1}{2}(1-q^2)^{\frac{1}{2}}\frac{\sigma_{v1}}{\sigma_u}\right]\omega_1$$
$$P_2 = \left[\left(\frac{1-q}{1+q}\right)^{\frac{1}{2}}\frac{\sigma_{v1}}{\sigma_u}\right]\Delta x_1 + \left[\frac{\sigma_{v2}}{2\sigma_u}\right]\omega_2$$
$$\hat{P}_2 = \left[\left(\frac{1-q}{1+q}\right)^{\frac{1}{2}}\frac{\sigma_{v1}}{\sigma_u}\right]\Delta x_1$$
$$\Delta x_1^* = \left[\left(\frac{1+q}{1-q}\right)^{\frac{1}{2}}\frac{\sigma_u}{\sigma_{v1}}\right]v_1$$
$$\Delta x_2^* = \frac{\sigma_u}{\sigma_{v2}}v_2,$$

where all square roots are positive. In equilibrium, the IC's expected profit is

$$\bar{\pi}_D^* = \frac{\sigma_u\sigma_{v1}}{2}(1-q)\frac{1}{\phi^{\frac{1}{2}}}\left\{1+\phi+\frac{(1-q)(\phi^{\frac{1}{2}}-\gamma^{\frac{1}{2}})^2}{\left[(1-q)\left(\frac{\phi^{\frac{1}{2}}}{\gamma^{\frac{1}{2}}}-\gamma\right)-2q\gamma^{\frac{1}{2}}\phi^{\frac{1}{2}}\right]}\right\}$$

where $\phi = \frac{\sigma_{v2}^2}{\sigma_{v1}^2}$ and $\gamma = \frac{1-q}{1+q}$.

When an equilibrium exists, the disclosure decouples the periods and closed-form solutions are available for all the endogenous variables. If $q = 0$, the formulas for βs and λs correspond to those of two disjoint single-period Kyle (1985) models where v_1 is revealed between trading rounds.

Larger q leads the IC to trade with more urgency at time 1, which in turn reduces the sensitivity of prices to order flow. In fact, for *all* $q > 0$ the IC trades more aggressively than the insider in even a single-period Kyle model. This is because, when the IC trades, it accounts for the impact of its trading on the disclosure (the same way it accounts for its trading on order flow). The larger is q, the more desirable is communicating via the disclosure, so the IC trades more aggressively. This result is similar to Proposition 2, but the reasoning behind it is different.

Since the periods decouple, if the IC is not forced to liquidate at time 2, its strategy and the pricing strategy of the market maker are unaffected by the fact that the IC *might* have had to liquidate instead. This is very different from the model without disclosure. There, the possibility of liquidation leads the IC to trade more aggressively in *both* periods, which affects pricing strategies in both periods (Propositions 2 and 3).

The profit function here has the same separability property as the profit function in the model without disclosure, $\bar{\pi}_N^*$. Both are composed of profit to a single-period Kyle insider, $\frac{\sigma_u\sigma_{v1}}{2}$, times a scale factor that depends only on q and ϕ. We will refer to this scale factor as $D(q,\phi)$ below; i.e., $\bar{\pi}^*_D = \frac{\sigma_u \sigma_{v1}}{2} D(q,\phi)$. As before, the scale factor captures early liquidation, the value of being able to trade on v_1 twice, and the value of the second investment idea v_2.

2.3 Voluntary and Mandated Disclosure

Whether the IC voluntarily commits to a policy of disclosing its positions depends on whether its ex-ante expected profit is greater with disclosure than without. If the IC chooses to disclose, its ex-ante expected profit is given by $\bar{\pi}^*_D = \frac{\sigma_u \sigma_{v1}}{2} D(q,\phi)$. If the IC chooses not to disclose, profit is given by $\bar{\pi}^*_N = \frac{\sigma_u \sigma_{v1}}{2} N(q,\phi)$. Provided that an equilibrium exists, the IC will precommit to a policy of voluntary disclosure if and only if $D(q,\phi) > N(q,\phi)$. The separable form of the profit functions and the fact that the existence condition involves only q and ϕ imply that whether disclosure is voluntary or even feasible is not affected by σ_u, and depends on σ_{v1} and σ_{v2} only through the ratio $\phi \equiv \frac{\sigma^2_{v2}}{\sigma^2_{v1}}$. Economically, this means that the incentive the IC has to disclose does not depend on characteristics of the security market such as the level of camouflage provided by liquidity traders or the scale of the informational asymmetry about the value of the security. All that matters are attributes unique to the IC—whether redemption is likely to force liquidation (q) and the importance of the future in what the IC learns about its current investment opportunities (ϕ). This is convenient for exposition because only two parameters are responsible for whether equilibrium exists with disclosure, and for describing the IC's preference for disclosure. We can graph, in only two dimensions, parameter regions under which the various possibilities occur.

Figure 2 displays the values of $D(q,\phi) - N(q,\phi)$ by varying q over $(0,1)$ and ϕ over [0.2,2.0] in discrete increments. The unshaded region covering most of the parameter space is where disclosure is voluntary. The medium shaded region is where an equilibrium exists if disclosure is mandated, but where disclosure by the IC is not voluntary. The dark shaded region near the origin is where equilibrium exists without disclosure, but no pure strategy linear equilibrium exists if disclosure is mandated.[20]

The region over which an equilibrium does not exist was explained in the previous subsection; it relates to cases in which liquidation is unlikely and the IC is nearly fully-informed at time 1. The voluntary disclosure region covers a majority of the rest of the parameter space where the probability of forced liquidation is moderate to high. This is because the expected increase in profit

[20] Non-existence is not limited to linear equilibria, but applies generally for any disclosure that *fully* communicates what the IC knows about v. In particular, there cannot exist *any* equilibrium in which the IC's disclosure is invertible for v_1 when $\phi < (1+q)/(1-q)$. The reason is because if the IC's disclosure were invertible and there were an equilibrium, prices would have to be linear because conditional expectations are linear in v_1. This is not contrary to the Huddart et.al. (2004) result because in their mixed-strategy equilibrium, disclosure is not invertible.

from liquidating at a time-2 price that has adjusted more fully to v_1 outweighs the expected benefit to trading on v_1 again at time 2 if liquidation does not occur. Alternatively, if the probability of forced liquidation is low, voluntary disclosure will not occur. The expected benefit to trading on v_1 over two periods outweighs the benefit to having a more informative price in the (low probability) event of liquidation. The range of q for which disclosure occurs expands as ϕ increases because as the relative importance of v_1 decreases, so does the value of trading on it dynamically.

One way to understand these results in light of the institutions we observe is that an IC that issues securities with lock up provisions that constrain investor redemptions will not voluntarily precommit to disclose. For these ICs, the likelihood that redemptions will cause the IC to liquidate positions early is small. This suggests that hedge funds will resist disclosure even without malevolent intent or a desire to perpetrate fraud. Such resistance is simply a consequence of wanting to protect the value of exploiting a dynamic strategy. By contrast, open-end mutual funds that have moderate q will commit voluntarily to a policy of disclosing because disclosure improves the terms on which early liquidation occurs. Disclosure is, in fact, mandated for mutual funds but not hedge funds, suggesting that current regulations are actually designed to serve the divergent private incentives of these types of funds. It is also consistent with the hypothesis that ICs have been successful in guiding the evolution of regulation in a manner that is optimal from their distinct perspectives.[21] The way the SEC implemented the new quarterly disclosure rule suggests this also. The rule requires quarterly disclosure of quarterly holdings. An alternative would have been annual disclosure of quarterly holdings. This would have allowed investors the information needed to verify whether the IC's investments were consistent with the objectives stated in its offering documents, but would not have served the interest of disclosing holdings to improve prices at which liquidation occurs. Something akin to annual disclosure of quarter-end holdings may achieve the SEC's potential future objectives for greater transparency with respect to hedge fund investments without impairing the ability of hedge funds to profit from following dynamic strategies.[22]

[21] Our model does not explain why open-end funds would need regulation in order to enforce disclosure because the single IC in our model internalizes the entire benefit from disclosing. In an extended model with multiple ICs, the ICs could well prefer a mandate as a coordination device to control free-rider problems. Without a mandate, ICs might withhold disclosure in an attempt to free-ride on the disclosure of other ICs who hold the same securities. In this case, an equilibrium with disclosure may not exist even though the ICs would collectively be better off if all were to disclose. Admati and Pfleiderer (2000) examine free-rider problems in disclosure by non-financial companies.

[22] Disclosure is also mandated for *closed-end* registered investment companies. Our model predicts that this is not consistent with the private incentives of those companies, which begs the question of why such funds are organized in that manner. One possibility is that closed-end companies begin as hedge funds that subsequently make a public offering, or as open-end funds that decide to discontinue taking further investment. In these cases, it seems conceivable that the IC would be willing to bear the cost of the disclosure mandate in order to achieve whatever benefits it perceives to broadening its investor base (in the case of a hedge fund) or capping its size (in the case of an

2.4 Costly Information Acquisition

Our results so far assume that the IC is *endowed* with investment ideas v_1 and v_2. A legal mandate to disclose reduces the expected profit of ICs that would otherwise not voluntarily commit to a policy of disclosing. However, expected profit will still be positive when information is free because the informational advantage is valuable even if the number of periods over which the IC can work the information is truncated by the disclosure mandate.

It is more realistic to assume that the IC expends resources to invest in an infrastructure that generates the ideas about the security—e.g., assign an analyst to cover the security, attend conferences, etc.—which we incorporate by assuming that in order to receive the signals, the IC must make an ex-ante investment of c. Under these circumstances, information will be acquired only if expected profit net of the information cost is positive.

If disclosure is mandated, the IC acquires information if $\bar{\pi}_D^* > c$; if disclosure is not mandated, the IC acquires if $\max\{\bar{\pi}_D^*, \bar{\pi}_N^*\} > c$. If c is very small (large), the IC acquires (does not acquire) information regardless of whether disclosure is mandated; so the mandate has no effect on information acquisition. However, for intermediate values of c, the mandate to disclose can crowd out efficient information acquisition by the IC.

A mandate will affect an IC's information acquisition decision if and only if investing in information is profitable without a mandate, but not profitable when a mandate exists:

$$\bar{\pi}_N^* - c > 0 \qquad \text{and} \qquad \bar{\pi}_D^* - c < 0.$$

In view of the separability properties of these profit functions, this discussion can be summarized as follows.

<u>Proposition 8</u>. *Assume an equilibrium with disclosure exists. A mandate to disclose will affect the IC's information acquisition decision, by eliminating information acquisition by the IC, if and only if*

$$D(q,\phi) < \frac{c}{\frac{1}{2}\sigma_u \sigma_{v1}} < N(q,\phi).$$

The proposition says that a disclosure mandate wipes out what would otherwise be profitable IC information acquisition in a region of parameter values where the cost of information is high

open-end fund). Though many closed-end funds began as hedge funds, our understanding is that most closed-end funds were registered investment companies from the start. Our model cannot explain this if organizing as a hedge fund is an option—i.e., if the investment manager can raise sufficient funds while qualifying for an exemption from registration. An explanation that lies outside our model is that the closed-end form is chosen when a broad investor base is required and when the assets the fund plans to hold are sufficiently illiquid that trading to fund redemptions would be very costly for the fund (e.g., real estate, municipal bonds and the like).

enough that pursuing a dynamic strategy is *necessary* in order to profit from the information. Stated another way, the mandate does not affect acquisition of information that could be considered "low-hanging fruit." Instead, it affects the kind of information that only sophisticated acquirers of information are likely to have, as information that is even more expensive would not have been acquired by anyone. ICs whose viability is impaired by a disclosure mandate are those that trade on information that is profitable only in the absence of disclosure. The competitive advantage of these IC's is in their ability to exploit *over time* the information they learn, which is precisely what the disclosure mandate eliminates.

Figure 3 illustrates. The square whose lower-left corner is the origin is the region over which no information is acquired even when a mandate does not exist. Imposing a mandate on an IC in the square has no impact on its information acquisition decision. The area outside the square and above the 45-degree line represents ICs that disclose voluntarily. Here again, a mandate has no impact on information acquisition. The rectangle to the right of the square and below the 45-degree line is where a mandate eliminates information acquisition by the IC. The area above it, but still to the right of the 45-degree line, is where a mandate would not affect the IC's information acquisition decision, but would compel an otherwise unwilling IC to disclose his trade. Such an IC might be the intended target of a regulation that imposes a disclosure mandate with the goal of maximizing the information available publicly in securities markets. However, the elimination of information acquisition by the unintended targets in the area below has the opposite effect. The relative sizes of these areas depend on c. Since $D(\cdot)$ and $N(\cdot)$ are both bounded, Figure 3 is a bounded rectangle. If c is high to start with, the area in which imposing a mandate eliminates information acquisition is much larger than the area of unwilling disclosers who continue to acquire information. In this case, imposing a mandate could reduce publicly available information.

A more specific perspective is provided in Figure 4, which depicts the impact of a disclosure mandate on an IC for which $\phi = 1$, for various levels of $\frac{c}{\frac{1}{2}\sigma_u \sigma_{v1}}$. The union of the shaded regions is the set of parameter values under which information will be acquired in the absence of a disclosure mandate. The medium shaded region is the area where disclosure will be voluntary, and the darkest region is the set of parameters for which a disclosure mandate will crowd out information acquisition. As noted above, the information whose acquisition is crowded out is high-cost information whose acquisition was at the margin of profitability under voluntary disclosure. The IC *must* follow a dynamic strategy in order to profit sufficiently from this information to justify its cost. At the left and beyond where information is inexpensive, a mandate increases publicly available information. At the right and beyond, where information is expensive, imposing a mandate decreases publicly available information.

2.5 Empirical Implications

We consider first how the possibility of liquidation affects investment company trading strategies. Then we explain the implications for information acquisition, performance and the imposition of disclosure mandates.

Sirri and Tufano (1992), Sapp and Tiwari (2004) and others document empirically that fund flows follow performance, which implies that redemptions increase (decrease) when performance has been poor (good). According to Propositions 2 and 7, ICs expecting an increase in redemptions will trade more aggressively on the information they have. It will therefore appear as though they are taking additional risk to boost returns to "make up for" poor past performance, when in fact, they are optimally trading more aggressively to capture profits to information in anticipation of redemptions. This shift in behavior is documented by Brown, Harlow and Starks (1996). They study a sample of growth oriented mutual funds and find that poor performers at mid-year increase risk more than others. They offer an agency explanation as an interpretation of these findings. Specifically, managers increase risk at shareholders' expense to increase the probability of finishing the year with a top ranking among their peers, thus enabling them to attract more funds and earn higher fees the following year. This prediction emerges from our model in the absence of agency considerations, however. If a manager's forecast of the probability of redemptions increases, he increases his risk exposure simply to maximize the expected profit to the fund and its investors.

The redemption experience of an IC will, from time to time, diverge from what was expected when the disclosure policy was chosen. For example, an IC that chooses a liberal disclosure policy may find itself in a situation where the intensity of redemptions is low. Under these circumstances, its disclosure policy choice actually hurts its future performance. Alternatively, if the intensity of redemptions is high (as the IC expected when choosing a liberal policy) its choice enhances its future performance. Thus, a liberal disclosure policy can either detract from or enhance performance depending on whether the intensity of redemptions turns out to be low or high. In addition, the Sirri-Tufano (1992) finding indicates that performance drives redemption intensity. Combining these observations yields a subtle asymmetric prediction. When past performance is poor, a liberal disclosure policy is performance-enhancing because disclosure moves prices in a direction more favorable to redemptions associated with the poor performance. When past performance is good, a liberal redemption policy hurts performance because disclosure truncates the time the IC has to exploit its private information. The opposite is predicted for ICs without liberal disclosure policies.

Even though mutual funds face disclosure mandates, there is cross-sectional variation in disclosure policies because funds are free to choose more liberal policies than those mandated by the SEC. Ge and Zhang (2004) examine these differences empirically by identifying funds that disclose semi-annually according to the federal mandate, and those that voluntarily precommit to disclose quarterly either to shareholders, large institutional clients or fund tracking firms. Ge and Zhang analyze the performance of a panel of funds in a regression framework that includes interaction variables between whether the fund discloses quarterly and whether its recent past performance is in the top or bottom quintile of performance for all funds. They document that quarterly disclosure has a positive impact on performance for funds whose past performance is poor and a negative impact for funds whose past performance is good. This finding matches the prediction of our model. Moreover, Ge and Zhang show that their result is robust to the inclusion of a variety of other possible determinants of fund performance, and to whether the returns examined are raw or risk adjusted.

The idea that the realized redemption intensity may not conform to what was expected at the time the IC chose its policy can also be interpreted as a prediction about how managers migrate across fund types. Successful managers will be those for whom the redemption intensity is lowest. These managers will have better performance in an environment without disclosure. Managers with good track records will therefore be expected to migrate from the mutual fund business to join or start hedge funds where secrecy can be maintained.

To consider the model's predictions for differences in performance between hedge funds and mutual funds, we now suppose that the single IC and investment cycle in the model depicts one of many iid "draws" of the exogenous parameters, the collection of which form a panel (cross-section over time) of ICs. Suppose for the moment that all ICs set management fees at competitive levels—i.e., just sufficient to cover information acquisition costs. The current disclosure rules for investment companies exempt hedge funds from disclosure. By virtue of this exemption, Proposition 8 indicates that some information will be profitable only for hedge funds to acquire. This is because there is a set of draws for which information acquisition is profitable for hedge funds, but not mutual funds. Such information will be relatively expensive among the information that is acquired. This implies that hedge funds will have larger fees *even if fees are set at competitive levels*, and also larger average net-of-fee returns, than ICs that have disclosure mandates such as mutual funds. Moreover, if fees are set at levels that enable managers to capture the surplus to their abilities, as in Berk and Green (2004), then hedge funds will have *much* larger fees and gross-of-fee performance than mutual funds, but zero net-of-fee performance. This characterization is consistent with the empirical evidence on mutual and hedge fund performance [Edelen (1999) and Ackerman et.al.(1999)].

This logic can also be used to predict what will happen if the regulatory regime changes from one in which exempt and non-exempt ICs face different disclosure requirements to a regime where the requirement to disclose is imposed on all ICs. Proposition 8 implies that the change to a uniform mandate will reduce the fees and profitability of hedge funds relative to mutual funds. Note that these fee and performance reductions will not be a consequence of greater competition among ICs brought about by added transparency, as might be the claim of the regulator who proposed the change. Instead, it reflects the fact that the disclosure mandate causes some otherwise profitable information acquisition to be foregone.

Proposition 8 applies to parameter values in which a pure-strategy equilibrium exists with disclosure. In order to predict the impact of a mandate for parameters where a pure strategy equilibrium does not exist with disclosure requires knowledge of the market maker's and IC's off-equilibrium beliefs. One possibility is that the IC resorts to a mixed strategy as in Huddart, et.al. (2004). They show that expected profit is lower with disclosure than without in their equilibrium, so the qualitative message of our result applies in their situation as well. Alternatively, if the non-existence of a pure-strategy linear equilibrium means that no market will be made in the security, the IC expects zero profit and will not acquire information. In this case, a disclosure mandate does more than crowd out information acquisition. It causes a public market for the security to cease to exist.

3. Conclusion

We present a model in which an investment company is characterized as having a stream of investment ideas, and as subject to redemptions that lead to early liquidation of investment positions. In this setting, the cost associated with liquidity provision and the benefit of exploiting investment ideas are endogenous. We analyze the trading strategies, security prices and disclosure policies that arise in equilibrium. We then examine how a disclosure mandate distorts information acquisition, trading and profit.

We show that if the probability of redemption is low, the investment company will not voluntarily disclose its holdings. Doing so eliminates the extra profit associated with pursuing a dynamic versus static trading strategy in exploiting investment ideas. However, if the probability of redemption is moderate to high, the investment company discloses voluntarily. In this case, the disclosure sufficiently improves the price at which early liquidation occurs that the investment company is willing to forego the extra profit to following a dynamic strategy. Knowing this, the investment company trades more aggressively on its investment ideas when the probability of redemption is high. We also show that, when information is costly, a mandate to disclose crowds out what would otherwise be profitable information acquisition by some investment companies that would not voluntarily disclose.

Our results are consistent with the interpretation that existing disclosure rules for mutual and hedge funds match the private incentives of these types of organizations to disclose their holdings. However, our results also sound a cautionary note regarding extending to hedge funds disclosure rules that now apply to mutual funds. The crowding out of information acquisition can, paradoxically, make markets with mandated disclosure less informationally efficient than markets without mandated disclosure.

In our model, redemption is the reason holdings are liquidated. The focus on redemption enables us to avoid modeling changes in the opportunities faced by the investment company. If investment opportunities were to change, sometimes improving faster than cash inflows, then the investment company may wish to liquidate some holdings because new cash inflows do not grow fast enough. In this case, disclosure enables the investment company to maximize the liquidation proceeds to less profitable investments so the funds can be shifted to more profitable ones. What makes disclosure valuable is a *gap* between new funds available and improvements in investment opportunities. In our model, this gap is created by redemptions. However, in a more general setting, the investment company will precommit to a policy of disclosing if it anticipates sufficiently large or frequent gaps, whether the source is actual redemption or just insufficient growth in cash inflows.

Our analysis does not consider the possible role that disclosure plays in deterring style drift, asset substitution, or increasing investor participation in markets either directly or through investment companies. Thus, even in a setting where incentive conflicts are nonexistent, we show that disclosure policy is an important element of an investment company's business strategy, and that regulatory policy concerning disclosure has important and predictable effects on information acquisition, trading strategies and profits in the investment management business.

Figure 1
Timeline of Events

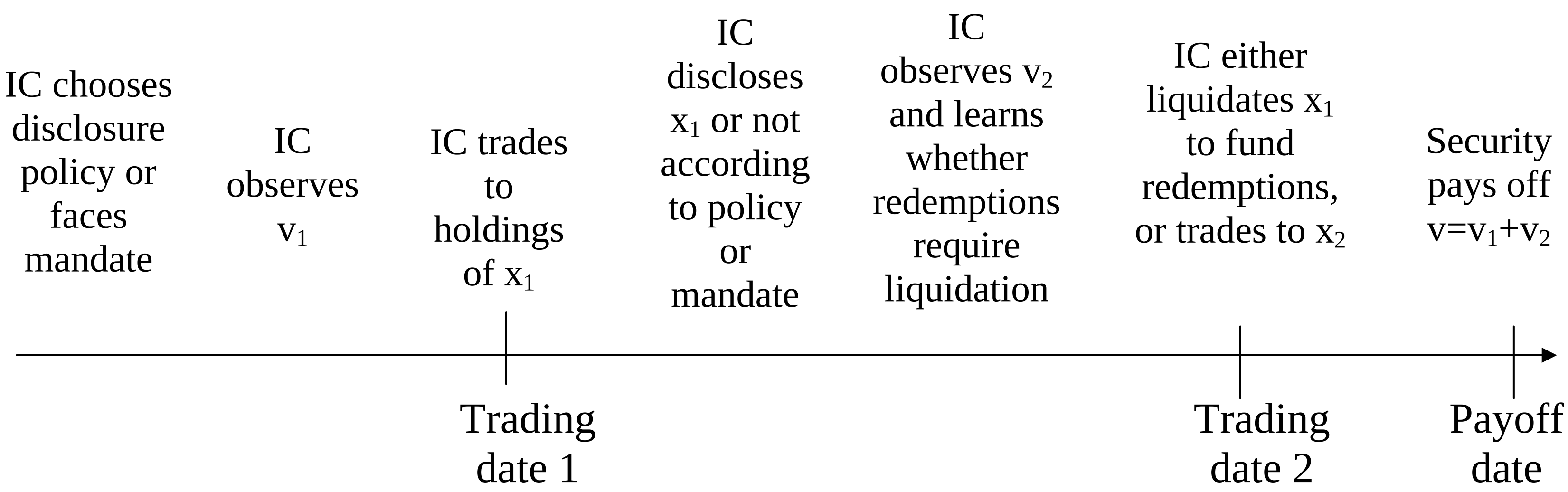

Figure 2
Voluntary Disclosure Region when Information is Costless

D(q,ϕ) - N(q,ϕ)

q \ ϕ	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
0.00	-0.580	-0.451	-0.358	-0.292	-0.244	-0.208	-0.180	-0.159	-0.142	-0.128
0.05	-0.515	-0.393	-0.305	-0.243	-0.197	-0.163	-0.138	-0.117	-0.101	-0.088
0.10	-0.453	-0.338	-0.255	-0.196	-0.153	-0.122	-0.097	-0.079	-0.063	-0.051
0.15	-0.394	-0.285	-0.208	-0.153	-0.112	-0.083	-0.060	-0.042	-0.028	-0.017
0.20	-0.338	-0.236	-0.163	-0.112	-0.074	-0.047	-0.025	-0.009	0.004	0.015
0.25	-0.285	-0.190	-0.122	-0.074	-0.039	-0.013	0.006	0.022	0.034	0.044
0.30	-0.235	-0.146	-0.084	-0.039	-0.007	0.017	0.035	0.049	0.061	0.070
0.35	-0.189	-0.106	-0.048	-0.007	0.023	0.045	0.061	0.074	0.085	0.093
0.40	-0.145	-0.070	-0.016	0.022	0.049	0.069	0.084	0.096	0.105	0.113
0.45	-0.105	-0.036	0.013	0.048	0.072	0.091	0.104	0.115	0.123	0.130
0.50	-0.068	-0.005	0.039	0.070	0.093	0.109	0.121	0.131	0.138	0.144
0.55	-0.035	0.022	0.062	0.090	0.110	0.124	0.135	0.143	0.150	0.155
0.60	-0.004	0.047	0.082	0.107	0.124	0.136	0.146	0.153	0.158	0.163
0.65	0.024	0.068	0.099	0.120	0.134	0.145	0.153	0.159	0.163	0.167
0.70	0.049	0.087	0.113	0.130	0.142	0.150	0.156	0.161	0.165	0.168
0.75	0.071	0.102	0.122	0.135	0.145	0.151	0.156	0.159	0.162	0.164
0.80	0.088	0.111	0.127	0.136	0.143	0.147	0.150	0.153	0.155	0.156
0.85	0.098	0.115	0.125	0.131	0.135	0.137	0.139	0.141	0.142	0.143
0.90	0.099	0.108	0.113	0.117	0.118	0.120	0.121	0.122	0.122	0.123
0.95	0.083	0.086	0.088	0.088	0.089	0.089	0.090	0.090	0.090	0.090
0.999	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013

unshaded is the voluntary disclosure region
no equilibrium exists in pure strategies
grey is the no disclosure region

Figure 3
Impact of Disclosure Mandate on Information Acquisition

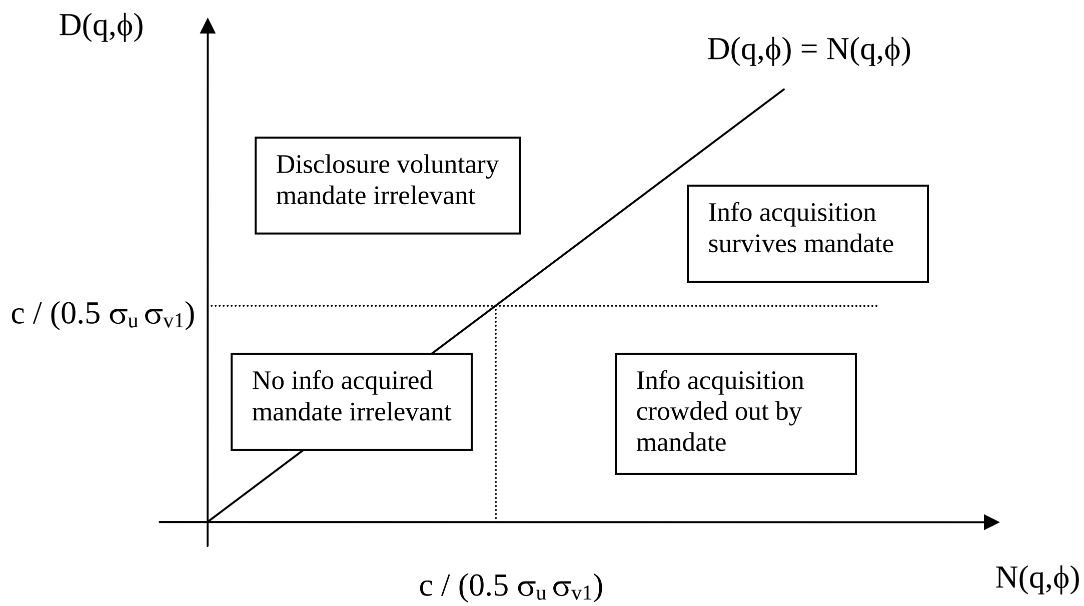

Figure 4
Acquisition of Costly Information when $\phi = 1$

max{ D, N } - c / (0.5 σ_u σ_{v1})

C / (0.5 σ_u σ_{v1})

q	1.50	1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90	1.95
0.05	0.6460	0.5960	0.5460	0.4960	0.4460	0.3960	0.3460	0.2960	0.2460	0.1960
0.10	0.5484	0.4984	0.4484	0.3984	0.3484	0.2984	0.2484	0.1984	0.1484	0.0984
0.15	0.4511	0.4011	0.3511	0.3011	0.2511	0.2011	0.1511	0.1011	0.0511	0.0011
0.20	0.3541	0.3041	0.2541	0.2041	0.1541	0.1041	0.0541	0.0041	-0.0459	-0.0959
0.25	0.2572	0.2072	0.1572	0.1072	0.0572	0.0072	-0.0428	-0.0928	-0.1428	-0.1928
0.30	0.1605	0.1105	0.0605	0.0105	-0.0395	-0.0895	-0.1395	-0.1895	-0.2395	-0.2895
0.35	0.0867	0.0367	-0.0133	-0.0633	-0.1133	-0.1633	-0.2133	-0.2633	-0.3133	-0.3633
0.40	0.0165	-0.0335	-0.0835	-0.1335	-0.1835	-0.2335	-0.2835	-0.3335	-0.3835	-0.4335
0.45	-0.0570	-0.1070	-0.1570	-0.2070	-0.2570	-0.3070	-0.3570	-0.4070	-0.4570	-0.5070
0.50	-0.1340	-0.1840	-0.2340	-0.2840	-0.3340	-0.3840	-0.4340	-0.4840	-0.5340	-0.5840
0.55	-0.2148	-0.2648	-0.3148	-0.3648	-0.4148	-0.4648	-0.5148	-0.5648	-0.6148	-0.6648
0.60	-0.3000	-0.3500	-0.4000	-0.4500	-0.5000	-0.5500	-0.6000	-0.6500	-0.7000	-0.7500
0.65	-0.3901	-0.4401	-0.4901	-0.5401	-0.5901	-0.6401	-0.6901	-0.7401	-0.7901	-0.8401
0.70	-0.4859	-0.5359	-0.5859	-0.6359	-0.6859	-0.7359	-0.7859	-0.8359	-0.8859	-0.9359
0.75	-0.5886	-0.6386	-0.6886	-0.7386	-0.7886	-0.8386	-0.8886	-0.9386	-0.9886	-1.0386
0.80	-0.7000	-0.7500	-0.8000	-0.8500	-0.9000	-0.9500	-1.0000	-1.0500	-1.1000	-1.1500
0.85	-0.8232	-0.8732	-0.9232	-0.9732	-1.0232	-1.0732	-1.1232	-1.1732	-1.2232	-1.2732
0.90	-0.9641	-1.0141	-1.0641	-1.1141	-1.1641	-1.2141	-1.2641	-1.3141	-1.3641	-1.4141
0.95	-1.1378	-1.1878	-1.2378	-1.2878	-1.3378	-1.3878	-1.4378	-1.4878	-1.5378	-1.5878
0.999	-1.4543	-1.5043	-1.5543	-1.6043	-1.6543	-1.7043	-1.7543	-1.8043	-1.8543	-1.9043

costly information is not acquired even without a mandate
costly information is acquired even with a mandate
disclosure is voluntary - mandate irrelevant
mandate crowds out information acquisition

APPENDIX

Proof of Proposition 1: Conditional on not being forced to liquidate at time 2, the IC solves

$$\max_{\Delta x_2} E\left[(\tilde{v} - P_2)\Delta x_2 | v_1, v_2, P_1\right].$$

Recognizing that $v = v_1 + v_2$, substituting for P_2 from equation (1) and taking expectations yields the equivalent problem

$$\max_{\Delta x_2} (v - P_1 - \psi_2)\Delta x_2 - \lambda_2 \Delta x_2^2.$$

Solving the first-order condition for Δx_2 yields:

$$\Delta x_2^* = \delta_2 + \beta_2 (v - P_1)$$

where

$$\delta_2 = -\frac{\psi_2}{2\lambda_2} \qquad \text{and} \qquad \beta_2 = \frac{1}{2\lambda_2}. \tag{A.1}$$

The second-order condition is $\lambda_2 > 0$. If the IC is forced to liquidate at time 2, $\hat{\Delta} x_2 = -\Delta x_1$.

At time 1, the IC solves

$$\max_{\Delta x_1} E\left[\tilde{\pi}(\Delta x_1) | v_1\right]$$

where $\tilde{\pi}(\Delta x_1)$ is given in equation (3). Noting that

$$\begin{aligned} (v - P_2)\Delta x_2^* &= \frac{(v - P_2)(v - P_1 - \psi_2)}{2\lambda_2} \\ &= \frac{1}{4\lambda_2}(v - P_1 - \psi_2)^2 - \frac{1}{2}(v - P_1 - \psi_2)u_2 \end{aligned}$$

substituting for the Ps from equation (1), and taking expectations, we have

$$\begin{aligned} E\left[\tilde{\pi}(\Delta x_1)|v_1\right] = (1-q)&\left\{(v_1 - \psi_1 - \lambda_1 \Delta x_1)\Delta x_1 + \frac{1}{4\lambda_2} E\left[(\tilde{v} - P_1 - \psi_2)^2 | v_1\right]\right\} \\ &+ q\left\{(\hat{\psi}_2 + \hat{\lambda}_2(-\Delta x_1 + \hat{\theta}_2 \Delta x_1))\Delta x_1\right\}. \end{aligned} \tag{A.2}$$

Furthermore,

$$\begin{aligned} E\left[(\tilde{v} - P_1 - \psi_2)^2 | v_1\right] = v_1^2 + \sigma_{v2}^2 - 2v_1(\psi_1 + \psi_2) + \lambda_1^2 \sigma_u^2 + (\psi_1 + \psi_2)^2 \\ - 2(v_1 - \psi_1 - \psi_2)\lambda_1 \Delta x_1 + \lambda_1^2 \Delta x_1^2. \end{aligned} \tag{A.3}$$

Combining (A.2) and (A.3), and ignoring terms that do not depend on Δx_1 yields the profit function

$$\begin{aligned} E\left[\tilde{\pi}(\Delta x_1)|v_1\right] = (1-q)&\left\{(v_1 - \theta_1)\Delta x_1 - \lambda_1 \Delta x_1^2 \right. \\ &\left. + \frac{1}{4\lambda_2}\left[\lambda_1^2 \Delta x_1^2 - 2(v_1 - \theta_1 - \psi_2)\lambda_1 \Delta x_1\right]\right\} \\ &+ q\left\{\hat{\psi}_2 \Delta x_1 + \hat{\lambda}_2(\hat{\theta}_2 - 1)\Delta x_1^2\right\}. \end{aligned} \tag{A.4}$$

Note that expected profit depends directly on v_1 only through the event that the IC is not forced to liquidate. If the IC is forced to liquidate, the liquidation proceeds depend only on what the market maker infers about the security's value through order flow. Solving the first order condition from (A.4) for Δx_1 yields

$$\Delta x_1^* = \beta_0 + \beta_1 v_1$$

where

$$\beta_0 = \frac{q\hat{\psi}_2 + (1-q)\left\{\frac{\lambda_1}{2\lambda_2}(\psi_1 + \psi_2) - \theta_1\right\}}{2\left\{(1-q)\lambda_1\left(1 - \frac{\lambda_1}{4\lambda_2}\right) + q\hat{\lambda}_2(1-\hat{\lambda}_2)\right\}} \tag{A.5}$$

$$\beta_1 = \frac{(1-q)\left\{1 - \frac{\lambda_1}{2\lambda_2}\right\}}{2\left\{(1-q)\lambda_1\left(1 - \frac{\lambda_1}{4\lambda_2}\right) + q\hat{\lambda}_2(1-\hat{\lambda}_2)\right\}}. \tag{A.6}$$

The second-order condition is

$$(1-q)\lambda_1\left(1 - \frac{\lambda_1}{4\lambda_2}\right) + q\hat{\lambda}_2(1-\hat{\theta}_2) > 0. \tag{A.7}$$

Equilibrium prices are the market maker's conditional expectations of $\tilde{v}$ given the information he has at the time. At time 1,

$$P_1 = E\left[\tilde{v}|\omega_1\right].$$

Since $\omega_1 = \Delta x_1^* + u_1 = \beta_0 + \beta_1 v_1 + u_1$, $\tilde{v}$ and $\tilde{\omega}_1$ are jointly normal random variables. Therefore,

$$E\left[\tilde{v}|\omega_1\right] = E\left[\tilde{v}\right] + \frac{\text{Cov}\left[\tilde{v}\,,\tilde{\omega}_1\right]}{\text{Var}\left[\tilde{\omega}_1\right]}(\omega_1 - E\left[\tilde{\omega}_1\right]).$$

Computing moments and simplifying yields

$$P_1 = \psi_1 + \lambda_1 \omega_1,$$

where

$$\psi_1 = -\frac{\beta_0 \beta_1 \sigma_{v1}^2}{\beta_1^2 \sigma_{v1}^2 + \sigma_u^2} \tag{A.8}$$

$$\lambda_1 = \frac{\beta_1 \sigma_{v1}^2}{\beta_1^2 \sigma_{v1}^2 + \sigma_u^2}. \tag{A.9}$$

If liquidation is not forced at time 2, $P_2 = E\left[\tilde{v}|\omega_2, \omega_1\right]$, or equivalently,

$$P_2 - P_1 = E\left[\tilde{v} - P_1|\omega_2, \omega_1\right].$$

Since $\omega_2 = \Delta x_2^* + u_2 = \delta_2 + \beta_2(v - P_1) + u_2$, the random variables $(\tilde{v} - P_1)$, ω_2 and ω_1 are jointly normally distributed. Therefore,

$$E\left[\tilde{v} - P_1 | \omega_2, \omega_1\right] = E\left[\tilde{v} - P_1 | \omega_1\right] + \frac{\text{Cov}\left[\tilde{v} - P_1\,, \tilde{\omega}_2 | \omega_1\right]}{\text{Var}\left[\tilde{\omega}_2 | \omega_1\right]}\left(\omega_2 - E\left[\tilde{\omega}_2 | \omega_1\right]\right).$$

The conditional moments are

$$\begin{aligned}
\text{Cov}\left[\tilde{v} - P_1\,, \tilde{\omega}_2 | \omega_1\right] &= \beta_2 \text{Var}\left[\tilde{v} - P_1 | \omega_1\right] \\
\text{Var}\left[\tilde{\omega}_2 | \omega_1\right] &= \beta_2^2 \text{Var}\left[\tilde{v} - P_1 | \omega_1\right] + \sigma_u^2 \\
E\left[\tilde{\omega}_2 | \omega_1\right] &= \delta_2 + \beta_2 E\left[\tilde{v} - P_1 | \omega_1\right] = \delta_2 \\
\text{Var}\left[\tilde{v} - P_1 | \omega_1\right] &= \text{Var}\left[\tilde{v} | \omega_1\right] = \text{Var}\left[\tilde{v}\right] - \frac{\text{Cov}\left[\tilde{v}\,, \tilde{\omega}_1\right]^2}{\text{Var}\left[\tilde{\omega}_1\right]} \\
&= \sigma_{v2}^2 + \frac{\sigma_{v1}^2}{\beta_1^2 \frac{\sigma_{v1}^2}{\sigma_{v2}^2} + 1}.
\end{aligned}$$

Substituting and simplifying yields

$$P_2 = P_1 + \psi_2 + \lambda_2 \omega_2,$$

where

$$\psi_2 = -\delta_2 \lambda_2 \tag{A.10}$$

$$\lambda_2 = \frac{\beta_2 \text{Var}\left[\tilde{v} - P_1 | \omega_1\right]}{\beta_2^2 \text{Var}\left[\tilde{v} - P_1 | \omega_1\right] + \sigma_u^2}. \tag{A.11}$$

If liquidation is forced at time 2, $\hat{P}_2 = E\left[\tilde{v} | \hat{\omega}_2, \omega_1\right]$, or equivalently,

$$\hat{P}_2 - P_1 = E\left[\tilde{v} - P_1 | \hat{\omega}_2, \omega_1\right].$$

Since $\hat{\omega}_2 = -\Delta x_1^* + u_2 = -\beta_0 - \beta_1 v_1 + u_2$, the random variables $(\tilde{v} - P_1)$, $\hat{\omega}_2$ and $\hat{\omega}_1$ are jointly normally distributed. Therefore,

$$E\left[\tilde{v} - P_1 | \hat{\omega}_2, \omega_1\right] = E\left[\tilde{v} - P_1 | \omega_1\right] + \frac{\text{Cov}\left[\tilde{v} - P_1\,, \hat{\omega}_2 | \omega_1\right]}{\text{Var}\left[\hat{\omega}_2 | \omega_1\right]}\left(\hat{\omega}_2 - E\left[\hat{\omega}_2 | \omega_1\right]\right).$$

The conditional moments are

$$\begin{aligned}
\text{Cov}\left[\tilde{v} - P_1\,, \hat{\omega}_2 | \omega_1\right] &= -\beta_1 \text{Var}\left[\tilde{v}_1 | \omega_1\right] \\
\text{Var}\left[\hat{\omega}_2 | \omega_1\right] &= \beta_1^2 \text{Var}\left[\tilde{v}_1 | \omega_1\right] + \sigma_u^2 \\
E\left[\hat{\omega}_2 | \omega_1\right] &= -\beta_0 - \beta_1 E\left[\tilde{v}_1 | \omega_1\right] = -\beta_0 - \beta_1 P_1 \\
&= -\beta_0 - \beta_1 \psi_1 - \beta_1 \lambda_1 \omega_1 \\
\text{Var}\left[\tilde{v}_1 | \omega_1\right] &= \text{Var}\left[\tilde{v}_1\right] - \frac{\text{Cov}\left[\tilde{v}_1\,, \tilde{\omega}_1\right]^2}{\text{Var}\left[\tilde{\omega}_1\right]} \\
&= \frac{\sigma_{v1}^2}{\beta_1^2 \frac{\sigma_{v1}^2}{\sigma_{v2}^2} + 1}.
\end{aligned}$$

Substituting and simplifying yields

$$\hat{P}_2 = P_1 + \hat{\psi}_2 + \hat{\lambda}_2(\hat{\omega}_2 + \hat{\theta}_2\omega_1),$$

where

$$\hat{\psi}_2 = (\beta_0 + \beta_1\psi_1)\hat{\lambda}_2 \tag{A.12}$$

$$\hat{\lambda}_2 = \frac{-\beta_1 \text{Var}\left[\tilde{v}_1|\omega_1\right]}{\beta_2^2 \text{Var}\left[\tilde{v}_1|\omega_1\right] + \sigma_u^2} \tag{A.13}$$

$$\hat{\theta}_2 = \beta_1\lambda_1. \tag{A.14}$$

The equations involving $\psi_1, \psi_2, \beta_0, \delta_2$ and $\hat{\psi}_2$ are five independent linear equations to which the unique solution is $\psi_1 = \psi_2 = \beta_0 = \delta_2 = \hat{\psi}_2 = 0$. To solve the remaining equations, begin by rearranging (A.6) as follows

$$\beta_1\lambda_1\left(1 - \frac{\lambda_1}{4\lambda_2}\right) + \frac{q}{1-q}\beta_1\hat{\lambda}_2(1 - \hat{\theta}_2) = \frac{1}{2} - \frac{\lambda_1}{4\lambda_2}$$

then substitute for $\hat{\theta}_2$ from (A.14) and collect like terms

$$(1 - \beta_1\lambda_1)\left\{1 - \frac{\lambda_1}{4\lambda_2} - \frac{q}{1-q}\beta_1\hat{\lambda}_2\right\} = \frac{1}{2}. \tag{A.15}$$

Note that (A.9) implies

$$1 - \beta_1\lambda_1 = \frac{\sigma_u^2}{\beta_1^2\sigma_{v1}^2 + \sigma_u^2}, \tag{A.16}$$

(A.13) implies

$$\beta_1\hat{\lambda}_2 = \frac{-\beta_1^2\sigma_{v1}^2}{2\beta_1^2\sigma_{v1}^2 + \sigma_u^2}, \tag{A.17}$$

and (A.11) and (A.1) imply

$$\begin{aligned}
\lambda_2\left\{\beta_2^2 \text{Var}\left[\tilde{v}|\omega_1\right] + \sigma_u^2\right\} &= \beta_2 \text{Var}\left[\tilde{v}|\omega_1\right] \\
\lambda_2\left\{\frac{1}{4\lambda_2^2}\text{Var}\left[\tilde{v}|\omega_1\right] + \sigma_u^2\right\} &= \frac{1}{2\lambda_2}\text{Var}\left[\tilde{v}|\omega_1\right] \\
\lambda_2^2 &= \frac{1}{4\sigma_u^2}\text{Var}\left[\tilde{v}|\omega_1\right] \\
&= \frac{1}{4\sigma_u^2}\left\{\frac{(\beta_1^2\sigma_{v1}^2 + \sigma_u^2)\sigma_{v2}^2 + \sigma_{v1}^2\sigma_u^2}{(\beta_1^2\sigma_{v1}^2 + \sigma_u^2)}\right\}.
\end{aligned}$$

The second-order condition for the IC's time-2 choice is $\lambda_2 > 0$, so we select the positive root yielding

$$\frac{1}{\lambda_2} = 2\sigma_u^2\left\{\frac{(\beta_1^2\sigma_{v1}^2 + \sigma_u^2)}{(\beta_1^2\sigma_{v1}^2 + \sigma_u^2)\sigma_{v2}^2 + \sigma_{v1}^2\sigma_u^2}\right\}^{\frac{1}{2}}. \tag{A.18}$$

Multiplying by $\frac{1}{4}\lambda_1$ using the expression in (A.9) yields

$$\frac{\lambda_1}{4\lambda_2} = \frac{1}{2}\left\{\frac{\beta_1^2\frac{\sigma_{v1}^2}{\sigma_u^2}}{\left(\beta_1^2\frac{\sigma_{v1}^2}{\sigma_u^2}+1\right)\left[\left(\beta_1^2\frac{\sigma_{v1}^2}{\sigma_u^2}+1\right)\frac{\sigma_{v2}^2}{\sigma_{v1}^2}+1\right]}\right\}^{\frac{1}{2}}. \tag{A.19}$$

Define $h = \beta_1^2\frac{\sigma_{v1}^2}{\sigma_u^2}$ and $\phi = \frac{\sigma_{v2}^2}{\sigma_{v1}^2}$. Substitute these into (A.16), (A.17) and (A.19), to get

$$\begin{aligned} 1-\beta_1\lambda_1 &= \frac{1}{h+1} \\ \beta_1\hat{\lambda}_2 &= \frac{-h}{2h+1} \\ \frac{\lambda_1}{4\lambda_2} &= \frac{1}{2}\left\{\frac{h}{(h+1)^2\phi+(h+1)]}\right\}^{\frac{1}{2}}. \end{aligned}$$

Substituting these into (A.15) produces

$$\frac{1}{h+1}\left\{1-\frac{1}{2}\left[\frac{h}{(h+1)^2\phi+(h+1)}\right]^{\frac{1}{2}}+\frac{q}{1-q}\left(\frac{h}{2h+1}\right)\right\}-\frac{1}{2}=0. \tag{A.20}$$

Define the left-hand side of the equality to be $G(h;\phi,q)$. This is a necessary condition. If a linear equilibrium exists, then β_1 is given by $h_*^{\frac{1}{2}}\frac{\sigma_u}{\sigma_{v1}}$, where $h_*>0$ solves $G(h_*;\phi,q)=0$; and values for the remaining endogenous variables are (uniquely) determined by their respective equations above. If the second-order condition for the IC's time-1 choice is satisfied at the values so determined, then those values are an equilibrium.

For any $\phi \geq 0$ and $q \in [0,1)$, at least one solution to $G=0$ exists because G is continuous, $G(0;\cdot)=\frac{1}{2}$ and $\lim_{h\to\infty} G(h;\cdot) = -\frac{1}{2}$. Let $h_*>0$ be such a solution and write (A.6) as

$$\beta_1 = \frac{(1-q)\left(1-\frac{\lambda_1}{2\lambda_2}\right)}{\mathcal{S}}.$$

The second-order condition for the IC's time-1 choice is that $\mathcal{S}>0$. By (A.19),

$$\frac{\lambda_1}{2\lambda_2} = \frac{h_*}{(h_*+1)^2\phi+(h_*+1)} < 1$$

where the inequality is clear by inspection. Thus, $1-\frac{\lambda_1}{2\lambda_2}>0$ and hence, the sign of $\mathcal{S}$ is the same as the sign of β_1 in equilibrium. This means that satisfying the second-order condition for the IC's time-1 choice is equivalent to selecting the positive root of h_* in determining β_1 according to $\beta_1 = h_*^{\frac{1}{2}}\frac{\sigma_u}{\sigma_{v1}}$. Taking these facts together implies that (i) any solution to $G=0$ is an equilibrium provided that its positive root is used in determining β_1, and (ii) at least one equilibrium exists for any $\phi \geq 0$ and $q \in [0,1)$.

It turns out that for any $\phi \geq 0$ and $q \in [0,1)$, equilibrium is unique. This is shown by demonstrating that $\frac{\partial G(h_*;\phi,q)}{\partial h} < 0$ when evaluated at a solution h_*. Since G is continuous, this condition is the same as saying that G crosses the h-axis only once.

To verify, differentiate G

$$\frac{\partial G}{\partial h} = \frac{-1}{(h+1)^2}\{\cdot\} + \frac{1}{h+1}\{\cdot\}' = \frac{1}{h+1}\left[\{\cdot\}' - \frac{1}{h+1}\{\cdot\}\right]$$

where the notation is in obvious analogy to (A.20). At a solution h_*, $\frac{1}{h+1}\{\cdot\} = \frac{1}{2}$, so

$$\frac{\partial G}{\partial h} = \frac{1}{h+1}\left[\{\cdot\}' - \frac{1}{2}\right]. \tag{A.21}$$

Define $f(h) = \frac{h}{(h+1)^2\phi + (h+1)}$, and note that

$$\{\cdot\}' = -\frac{1}{4}f^{-\frac{1}{2}}\frac{\partial f}{\partial h} + \left(\frac{q}{1-q}\right)\frac{1}{(2h+1)^2}.$$

At a solution h_*,

$$\frac{q}{1-q} = \frac{2h_*+1}{2h_*}\left[h_* + f(h_*)^{\frac{1}{2}} - 1\right]$$

so,

$$\{\cdot\}' = -\frac{1}{4}f^{-\frac{1}{2}}\frac{\partial f}{\partial h} + \frac{1}{2h_*(2h_*+1)}\left(h_* - 1 + f^{\frac{1}{2}}\right).$$

Substituting this and

$$\frac{\partial f}{\partial h} = \frac{(1-h_*^2)\phi + 1}{[(h_*+1)^2\phi + (h_*+1)]^2}$$

into (A.21) and rearranging yields

$$\begin{aligned} 2(h_*+1)\frac{\partial G}{\partial h} &= \frac{h_*^{\frac{1}{2}} - (1-h_*)[(h_*+1)^2\phi + (h_*+1)]^{\frac{1}{2}}}{h_*(2h_*+1)[(h_*+1)^2\phi + (h_*+1)]^{\frac{1}{2}}} \\ &\quad - \frac{(1-h_*^2)\phi + 1}{2h_*^{\frac{1}{2}}[(h_*+1)^2\phi + (h_*+1)]^{\frac{3}{2}}} - 1 \end{aligned} \tag{A.22}$$

The sign of $\frac{\partial G}{\partial h}$ is the same as the sign of the right-hand side of (A.22). Upon graphing the right-hand side of (A.22) it is evident that the surface lies below zero for all $h_* > 0$ and $\phi > 0$. Conclude, therefore, that $\frac{\partial G}{\partial h}$ is negative in equilibrium, which implies that equilibrium is unique.

Proof of Proposition 2: In equilibrium,

$$G(h_*(q,\phi); q, \phi) = 0$$

for all $q \in [0,1)$ and $\phi > 0$. Totally differentiating with respect to q and rearranging yields

$$\frac{\partial h_*}{\partial q} = -\frac{\frac{\partial G}{\partial q}}{\frac{\partial G}{\partial h}}.$$

It is easy to see that $\frac{\partial G}{\partial q} > 0$, and $\frac{\partial G}{\partial h} < 0$ from the uniqueness section of the proof of Proposition 1. Therefore, $\frac{\partial h_*}{\partial q}$ and hence $\frac{\partial \beta_1}{\partial q}$ are positive.

Proof of Proposition 3: Let $\beta_t(q)$ denote the equilibrium value of β_t as a function of q holding ϕ fixed; and similarly for $\lambda_t(q)$. By equation (A.18),

$$\lambda_2(q) = \frac{1}{2\sigma_u}\left\{\sigma_{v2}^2 + \frac{\sigma_{v1}^2\sigma_u^2}{\beta_1(q)\,\sigma_{v1}^2 + \sigma_u^2}\right\}^{\frac{1}{2}}.$$

By Proposition 2, $\beta_1'(q) > 0$, so $\lambda_2'(q) < 0$. By equation (A.1),

$$\beta_2(q) = \frac{1}{2\lambda_2(q)}$$

and since $\lambda_2'(q) < 0$, $\beta_2'(q) > 0$.

Proof of Proposition 4: By equation (A.9),

$$\lambda_1(q) = \frac{\beta_1(q)\sigma_{v1}^2}{\beta_1^2(q)\sigma_{v1}^2 + \sigma_u^2}.$$

Differentiating

$$\lambda_1'(q) = \frac{\partial \lambda_1}{\partial \beta_1}\beta_1'(q).$$

Since $\beta_1'(q) > 0$, the sign of $\lambda_1'(q)$ is the same as that of $\frac{\partial \lambda_1}{\partial \beta_1}$. Now,

$$\frac{\partial \lambda_1}{\partial \beta_1} = \frac{\sigma_u^2\sigma_{v1}^2 - \beta_1^2\sigma_{v1}^4}{(\beta_1^2\sigma_{v1}^2 + \sigma_u^2)^2}$$

so

$$\text{Sign}\left\{\frac{\partial \lambda_1}{\partial \beta_1}\right\} = \text{Sign}\left\{\sigma_u^2 - \beta_1^2\sigma_{v1}^2\right\} = \text{Sign}\left\{1 - h_*\right\}.$$

From Proposition 2, we know that h_* is unique and G is decreasing in h at h_*. Therefore, $h_* < 1$ if and only if $G(1,\cdot) < 0$, which is equivalent to

$$\frac{1}{2}\left\{1 - \frac{1}{2}\left(\frac{1}{4\phi + 2}\right)^{\frac{1}{2}} + \frac{q}{1-q}\left(\frac{1}{3}\right)\right\} - \frac{1}{2} < 0$$

which simplifies to

$$\frac{q}{1-q} < \frac{3}{2\sqrt{2}}\left(\frac{1}{2\phi + 1}\right)^{\frac{1}{2}}.$$

Proof of Proposition 5: The proof mirrors the proofs of Propositions 2 - 4, except that ϕ is varied with q and σ_{v1} held fixed. The results rest on the fact that $\frac{\partial G}{\partial \phi} > 0$ in equilibrium, just as Propositions 2 - 4 rested on the fact that $\frac{\partial G}{\partial q} > 0$.

Proof of Proposition 6: From (A.4), setting $\theta_1 = \psi_2 = \hat{\psi}_2$ and collecting like terms yields

$$\begin{aligned} E\left[\pi(\Delta x_1)|v_1\right] = (1-q)&\left\{\frac{1}{4\lambda_2}(v_1^2+\sigma_{v2}^2+\lambda_1^2\sigma_u^2)\right\} \\ &+(1-q)\left(1-\frac{\lambda_1}{2\lambda_2}\right)v_1\Delta x_1 \\ &-\left[(1-q)\lambda_1\left(1-\frac{\lambda_1}{4\lambda_2}\right)+q\hat{\lambda}_2(1-\hat{\theta}_2)\right]\Delta x_1^2. \end{aligned}$$

Substituting

$$\Delta x_1^* = \frac{(1-q)\left(1-\frac{\lambda_1}{2\lambda_2}\right)v_1}{2\left[(1-q)\lambda_1\left(1-\frac{\lambda_1}{4\lambda_2}\right)+q\hat{\lambda}_2(1-\hat{\theta}_2)\right]}$$

for Δx_1 and simplifying yields

$$\begin{aligned} E\left[\pi(\Delta x_1^*)|v_1\right] = (1-q)&\left\{\frac{1}{4\lambda_2}(v_1^2+\sigma_{v2}^2+\lambda_1^2\sigma_u^2)\right\} \\ &+\frac{(1-q)^2\left(1-\frac{\lambda_1}{2\lambda_2}\right)^2 v_1^2}{4\left[(1-q)\lambda_1\left(1-\frac{\lambda_1}{4\lambda_2}\right)+q\hat{\lambda}_2(1-\hat{\theta}_2)\right]}. \end{aligned}$$

Substituting into the second term using

$$\beta_1 = \frac{(1-q)\left(1-\frac{\lambda_1}{2\lambda_2}\right)}{2\left[(1-q)\lambda_1\left(1-\frac{\lambda_1}{4\lambda_2}\right)+q\hat{\lambda}_2(1-\hat{\theta}_2)\right]}$$

yields

$$\begin{aligned} E\left[\pi(\Delta x_1^*)|v_1\right] &= (1-q)\left\{\frac{1}{4\lambda_2}(v_1^2+\sigma_{v2}^2+\lambda_1^2\sigma_u^2)+\frac{1}{2}\left(1-\frac{\lambda_1}{2\lambda_2}\right)\beta_1 v_1^2\right\} \\ &= \frac{(1-q)}{4}\left\{\left[\frac{1}{\lambda_2}+2\left(1-\frac{\lambda_1}{2\lambda_2}\right)\beta_1\right]v_1^2+\frac{\sigma_{v2}^2+\lambda_1^2\sigma_u^2}{\lambda_2}\right\}. \end{aligned} \tag{A.23}$$

Using the definitions of h and ϕ, (i.e., $h = \beta_1^2\frac{\sigma_{v1}^2}{\sigma_u^2}$ and $\phi = \frac{\sigma_{v2}^2}{\sigma_{v1}^2}$), equations (A.l8), (A.19) and (A.9) are equivalent to:

$$\begin{aligned} \frac{1}{\lambda_2} &= \frac{2\sigma_u}{\sigma_{v1}}\left\{\frac{h+1}{(h+1)\phi+1}\right\}^{\frac{1}{2}} \\ \frac{\lambda_1}{2\lambda_2} &= \left\{\frac{h}{(h+1)[(h+1)\phi+1]}\right\} \\ \lambda_1^2\sigma_u^2 &= \sigma_{v1}^2\frac{h}{(h+1)^2}, \end{aligned}$$

respectively. Substituting these back into (A.23) and simplifying yields

$$E\left[\pi(\Delta x_1)|v_1\right] = (1-q)\frac{\sigma_u\sigma_{v1}}{2}(h+1)^{\frac{1}{2}}\left\{\left[\left(\frac{h}{h+1}\right)^{\frac{1}{2}} + \left(\frac{1}{1+\phi(h+1)}\right)^{\frac{1}{2}}\left(\frac{1}{h+1}\right)\right]\frac{v_1^2}{\sigma_{v1}^2} + \frac{\phi + \frac{h}{(h+1)^2}}{(1+\phi(h+1))^{\frac{1}{2}}}\right\}.$$

From this equation, and the fact that $h = h_*$ in equilibrium, it is easy to compute the unconditional expectation given in the statement of the proposition.

Proof of Proposition 7: Conditional on not being forced to liquidate at time 2, the IC solves

$$\max_{\Delta x_2} E\left[(\tilde{v} - P_2)\Delta x_2 | v_1, v_2\right].$$

Recognizing that $v = v_1 + v_2$, substituting for P_2 from equation (4) in the text and taking expectations yields the equivalent problem

$$\max_{\Delta x_2}(v - \alpha_2\Delta x_1 - \psi_2)\Delta x_2 - \lambda_2\Delta x_2^2.$$

Solving the first-order condition for Δx_2 yields:

$$\Delta x_2^* = \delta_2 + \beta_2(v - \alpha_2\Delta x_1)$$

where

$$\delta_2 = -\frac{\psi_2}{2\lambda_2} \qquad \text{and} \qquad \beta_2 = \frac{1}{2\lambda_2}. \tag{A.24}$$

The second-order condition is $\lambda_2 > 0$. If the IC is forced to liquidate at time 2, $\widehat{\Delta x_2} = -\Delta x_1$.

At time 1, the IC maximizes the expected value of

$$\tilde{\pi}(\Delta x_1) = \begin{cases} (\tilde{v} - P_1)\Delta x_1 + (v - P_2)\Delta x_2^* & \text{with probability } (1-q) \\ (\tilde{v} - P_1)\Delta x_1 + 0 & \text{with probability } q \end{cases}$$

conditional on v_1. After substituting for Δx_2^* and the functional forms of the prices from equation (4) in the text, completing squares, and taking the conditional expectation yields:

$$\begin{aligned} E\left[\tilde{\pi}(\Delta x_1)|v_1\right] = (1-q)\Big\{&(v_1 - \psi_1)\Delta x_1 - \lambda_1\Delta x_1^2 \\ &+ \frac{1}{4\lambda_2}\left[v_1^2 + \sigma_{v2}^2 - 2v_1\alpha_2\Delta x_1 - 2v_1\psi_2 + (\alpha_2\Delta x_1 + \psi_2)^2\right]\Big\} \\ &+ q\left\{\left(\hat{\alpha}_2 - \hat{\lambda}_2(1-\hat{\theta}_2) - \lambda_1\right)\Delta x_2 + \left(\hat{\psi}_2 - \psi_1\right)\Delta x_1\right\}. \end{aligned} \tag{A.25}$$

Solving the first-order condition for Δx_1 yields:

$$\Delta x_1^* = \beta_0 + \beta_1 v_1$$

where

$$\beta_0 = \frac{(1-q)\left(\frac{\psi_2}{2\lambda_2}\alpha_2 - \psi_1\right) + q\left(\hat{\psi}_2 - \psi_1\right)}{(1-q)\left(2\lambda_1 - \frac{\alpha_2^2}{2\lambda_2}\right) - 2q\left[\hat{\alpha}_2 - \hat{\lambda}_2(1-\hat{\theta}_2) - \lambda_1\right]}$$
$$\beta_1 = \frac{(1-q)\left(1 - \frac{\alpha_2}{2\lambda_2}\right)}{(1-q)\left(2\lambda_1 - \frac{\alpha_2^2}{2\lambda_2}\right) - 2q\left[\hat{\alpha}_2 - \hat{\lambda}_2(1-\hat{\theta}_2) - \lambda_1\right]}. \tag{A.26}$$

The second-order condition simplifies to

$$\left[\lambda_1 + q\hat{\lambda}_2\left(1-\hat{\theta}_2\right)\right] - \left[(1-q)\frac{\alpha_2^2}{4\lambda_2} + q\hat{\alpha}_2\right] > 0. \tag{A.27}$$

Since the λ (α) parameters measure the sensitivity of prices to order flow (the disclosure of Δx_1), this condition means that the market maker's reliance on order flow in drawing an inference about $\tilde{v}$ cannot be small relative to his reliance on the disclosure.

Reasoning exactly as in Proposition 1,

$$P_1 = \psi_1 + \lambda_1\omega_1$$

where

$$\psi_1 = -\frac{\beta_0\beta_1\sigma_{v1}^2}{\beta_1^2\sigma_{v1}^2 + \sigma_u^2} \tag{A.28}$$
$$\lambda_1 = \frac{\beta_1\sigma_{v1}^2}{\beta_1^2\sigma_{v1}^2 + \sigma_u^2}. \tag{A.29}$$

Though the parametric form of P_1 looks the same as in Proposition 1, the values of the endogenous variables will generally not be the same in this model as in the model without disclosure even if the values of the exogenous variables are the same.

If liquidation is not forced at time 2, $P_2 = E\left[\tilde{v}|\omega_2, \omega_1, \Delta x_1^*\right]$. The conditioning variable Δx_1^* is included because we are now working under the assumption that the IC has either precommitted or is under a mandate to disclose. Since $\omega_2 = \Delta x_2^* + u_2 = \delta_2 + \beta_2(v - \alpha_2\Delta x_1^*) + u_2$ and $\Delta x_1^* = \beta_0 + \beta_1 v_1$, all four random variables are jointly normally distributed. Therefore,

$$E\left[\tilde{v}|\omega_2, \omega_1, \Delta x_1^*\right] = E\left[\tilde{v}|\omega_1, \Delta x_1^*\right] + \frac{\text{Cov}\left[\tilde{v}\,, \tilde{\omega}_2|\omega_1, \Delta x_1^*\right]}{\text{Var}\left[\tilde{\omega}_2|\omega_1, \Delta x_1^*\right]}\left(\omega_2 - E\left[\tilde{\omega}_2|\omega_1, \Delta x_1^*\right]\right).$$

If the IC's second-order condition at time 1 is satisfied, then his optimal strategy is an affine function of v_1 and the market maker can invert the disclosure of Δx_1^* for $v_1 = \frac{1}{\beta_1}(\Delta x_1^* - \beta_0)$. Therefore, the conditional moments are

$$
\begin{aligned}
E\left[\tilde{v}|\omega_1, \Delta x_1^*\right] &= \frac{1}{\beta_1}(\Delta x_1^* - \beta_0) \\
\text{Cov}\left[\tilde{v}\,, \tilde{\omega}_2|\omega_1, \Delta x_1^*\right] &= \beta_2 \sigma_{v1}^2 \\
\text{Var}\left[\tilde{\omega}_2|\omega_1, \Delta x_1^*\right] &= \beta_2 \sigma_{v2}^2 + \sigma_u^2 \\
E\left[\tilde{\omega}_2|\omega_1, \Delta x_1^*\right] &= \delta_2 + \beta_2 \left[\frac{1}{\beta_1}(\Delta x_1^* - \beta_0) - \alpha_2 \Delta x_1^*\right].
\end{aligned}
$$

Substituting and collecting like terms yields

$$
P_2 = \alpha_2 \Delta x_1 + \psi_2 + \lambda_2(\omega_2 - \theta_2 \Delta x_1)
$$

where

$$
\alpha_2 = \frac{1}{\beta_1} \tag{A.30}
$$

$$
\psi_2 = -\frac{\beta_0}{\beta_1}\left\{1 - \frac{\beta_2^2 \sigma_{v2}^2}{\beta_2^2 \sigma_{v2}^2 + \sigma_u^2}\right\} - \frac{\beta_2^2 \sigma_{v2}^2}{\beta_2^2 \sigma_{v2}^2 + \sigma_u^2}\delta_2 \tag{A.31}
$$

$$
\lambda_2 = \frac{\beta_2 \sigma_{v2}^2}{\beta_2^2 \sigma_{v2}^2 + \sigma_u^2} \qquad \text{and} \qquad \theta_2 = 0. \tag{A.32}
$$

If liquidation is forced at time 2, $\hat{P}_2 = E\left[\tilde{v}|\hat{\omega}_2, \omega_1, \Delta x_1^*\right]$, where $\hat{\omega}_2 = -\Delta x_1^* + u_2$. Since all the variates are jointly normal,

$$
E\left[\tilde{v}|\hat{\omega}_2, \omega_1, \Delta x_1^*\right] = E\left[\tilde{v}|\omega_1, \Delta x_1^*\right] + \frac{\text{Cov}\left[\tilde{v}\,, \hat{\omega}_2|\omega_1, \Delta x_1^*\right]}{\text{Var}\left[\hat{\omega}_2|\omega_1, \Delta x_1^*\right]}\left(\hat{\omega}_2 - E\left[\hat{\omega}_2|\omega_1, \Delta x_1^*\right]\right).
$$

Assuming the IC's second-order condition is satisfied, Δx_1^* can be inverted for v_1 and the conditional moments are

$$
\begin{aligned}
E\left[\tilde{v}|\omega_1, \Delta x_1^*\right] &= \frac{1}{\beta_1}(\Delta x_1^* - \beta_0) \\
\text{Cov}\left[\tilde{v}\,, \tilde{\omega}_2|\omega_1, \Delta x_1^*\right] &= \text{Cov}\left[v_1 + \tilde{v}_2\,, -\beta_0 + \beta_1 v_1 + \tilde{u}_2|\omega_1, \Delta x_1^*\right] = 0.
\end{aligned}
$$

Therefore,

$$
\hat{P}_2 = \hat{\alpha}_2 \Delta x_1 + \hat{\psi}_2 + \hat{\lambda}_2(\omega_2 - \hat{\theta}_2 \Delta x_1)
$$

where

$$
\hat{\alpha}_2 = \frac{1}{\beta_1} \tag{A.33}
$$

$$
\hat{\psi}_2 = -\beta_0 \tag{A.34}
$$

$$
\hat{\lambda}_2 = \hat{\theta}_2 = 0. \tag{A.35}
$$

The equations involving $\delta_2, \beta_0, \psi_1, \psi_2$ and $\hat{\psi}_2$ are five independent linear equations whose unique solution is zero. Combining equations (A.24) and (A.32) and solving yields

$$\lambda_2 = \frac{\sigma_{v2}}{2\sigma_u} \tag{A.36}$$

$$\beta_2 = \frac{\sigma_u}{\sigma_{v2}}. \tag{A.37}$$

Substituting from (A.29), (A.30), (A.33), (A.35) and (A.36) into equation (A.26) and simplifying yields

$$\beta_1 = \left(\frac{1+q}{1-q}\right)^{\frac{1}{2}} \frac{\sigma_u}{\sigma_{v1}}$$

which implies

$$\hat{\alpha}_2 = \alpha_2 = \left(\frac{1-q}{1+q}\right)^{\frac{1}{2}} \frac{\sigma_{v1}}{\sigma_u}$$

$$\lambda_1 = \frac{1}{2}\frac{\sigma_{v1}}{\sigma_u}(1-q^2)^{\frac{1}{2}}$$

where the signs of $\hat{\alpha}_2, \alpha_2$ and λ_1 are all the same as that of β_1, which depends on whether the positive or negative root of $\left(\frac{1+q}{1-q}\right)$ is selected in computing β_1.

Since $\hat{\lambda}_2 = \hat{\theta}_2 = 0$ in equilibrium, the IC's time-1 second-order condition (A.27) reduces to

$$\lambda_1 - q\hat{\alpha}_2 - (1-q)\frac{\alpha_2^2}{4\lambda_2} > 0. \tag{A.38}$$

If the positive root is selected in computing β_1, then λ_1 and α_2 will also be positive. Substituting those values and α_2 and λ_2 into (A.38) reduces to

$$1 - \left(\frac{1-q}{1+q}\right)^{\frac{1}{2}+} \frac{\sigma_{v1}}{\sigma_{v2}} > 0$$

where $\left(\frac{1-q}{1+q}\right)^{\frac{1}{2}+}$ denotes the positive root. This is equivalent to

$$\phi > \left(\frac{1-q}{1+q}\right).$$

Alternatively, if the negative root is selected in computing β_1, then λ_1 and α_2 will also be negative. Substituting those values and α_2 and λ_2 into (A.38) reduces to

$$-1 - \left(\frac{1-q}{1+q}\right)^{\frac{1}{2}+} \frac{\sigma_{v1}}{\sigma_{v2}} > 0$$

which is false, so the second order condition cannot hold. Therefore, $\beta_1 < 0$ cannot be true in equilibrium.

To compute equilibrium expected profit, collect like terms of Δx_1 in equation (A.25) to get

$$E\left[\tilde{\pi}(\Delta x_1)|v_1\right] = (1-q)\left[1-\frac{\alpha_2}{2\lambda_2}\right]v_1\Delta x_1 - \left[\lambda_1-(1-q)\frac{\alpha_2^2}{4\lambda_2}-q\hat{\alpha}_2\right]\Delta x_1^2 + (1-q)\frac{1}{4\lambda_2}\left(v_1^2+\sigma_{v2}^2\right).$$

Substituting for $\Delta x_1 = \left(\frac{1+q}{1-q}\right)^{\frac{1}{2}}\frac{\sigma_u}{\sigma_{v1}}$ yields

$$E\left[\tilde{\pi}(\Delta x_1)|v_1\right] = \frac{(1-q)}{4\lambda_2}\left(v_1^2+\sigma_{v2}^2\right) + \frac{(1-q)^2\left[\lambda_2-\frac{1}{2}\alpha_2\right]^2 v_1^2}{\{4\lambda_1\lambda_2^2-(1-q)\alpha_2^2\lambda_2-4q\hat{\alpha}_2\lambda_2^2\}}.$$

Substituting for the remaining endogenous variables and taking the expectation over v_1 results in the expression given in the statement of the proposition.

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