MARKETS VERSUS MECHANISMS

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ABSTRACT. We demonstrate inherent limits to usage of direct revelation mechanisms (DRM) by corporations inhabiting economies with securities markets. For such firms, the set of feasible DRM may be empty. Even when this set is non-empty, it can be optimal to refrain from posting DRM, instead relying on markets for information. Finally, even if non-randomized DRM posting dominates relying on markets, superior outcomes are achived by randomly reducing reliance on the DRM. These results arise because posting a DRM serves to reduce price impacts of trading, resulting in high endogenous reservation values for would-be informed inside advisers.

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1. Introduction

The provision of decision-relevant information to agents is critical for economic efficiency. Hayek (1945) extolled the virtues of markets in this regard, writing, "We must look at the price system as such a mechanism for communicating information..." More specifically, securities markets are commonly viewed as a vital source of information for firms making operating and real investment decisions. For example, Fama and Miller (1972) write, "(an efficient market) has a very desirable feature. In particular, at any point in time market prices of securities provide accurate signals for resource allocation..." Similarly, Fama (1976) writes, "An efficient capital market is an important component of a capitalist system... if the capital market is to function smoothly in allocating resources, prices of securities must be good indicators of value."

Notwithstanding the ability of securities markets to convey information, economic theory would seem to suggest that firms have access to a superior source of information: direct revelation mechanisms (DRM). After all, the revelation principle informs us that any equilibrium outcome of some indirect revelation mechanism (IRM), can also be achieved by a DRM in which truth-telling is incentive compatible. Thus, one may view a market-reliant firm as using securities markets as an IRM for eliciting information from some privately informed trader. But the revelation principle would seem to suggest that the firm can do at least as well by "hiring" said trader as part of a DRM. That is, rather than leaving the informed trader outside its boundaries, the firm can bring her inside and provide incentives through a DRM. In fact, economic theory points to another benefit to bringing an informed agent inside firm boundaries: insulation of uninformed shareholders from adverse selection. After all, under exclusivity (contractual or legal prohibitions on securities trading by insiders), an informed agent brought in-house cannot trade at the expense of uninformed shareholders forced to sell due to liquidity shocks.

In this paper, we point to an inherent limitation to the use of DRM by public corporations ("firms") inhabiting real-world economies with competitive securities markets. In particular, we show that for firms in such economies, the set of feasible incentive compatible DRM may actually be empty. Moreover, even when this feasible set is non-empty, the firm may nevertheless find it optimal to refrain from posting a DRM, instead relying exclusively on the securities market for information. Finally, even in those instances where the non-randomized scheme of posting a DRM with probability one dominates relying on the market with probability one, the firm can always achieve superior outcomes by reducing reliance on the DRM at the margin by randomly limiting the ability of an informed agent to sign on.

In order to understand these results, it is important to first highlight one of the key benefits associated with market-reliance, that is, refraining from posting any DRM and instead relying exclusively on the securities market for information. As we show, when the firm fails to post a mechanism, all agents in the economy are aware that, if an informed agent actually exists (an event with probability $a \in (0,1)$ in our model), that agent will then actively trade on their private information in the securities market. In light of this, a competitive market maker will set securities prices in a way that is sensitive to order flow. In other words, when the market knows that an informed agent, should they exist, has been left outside the firm and free to trade, then trading will have adverse price impact. But note, such price impact serves as a natural device for curtailing the informational rent captured by an informed agent. That is, the price formation mechanism in a competitive securities market, when left to its own devices, serves as a natural mitigator of informational rents.

With the preceding discussion in mind, consider instead a firm that posts a DRM (offers a job), one designed to satisfy the participation constraint (PC) of the informed outsider (should she exist), while screening out incompetents (who are infinite in number). In order to satisfy the PC, the firm must pay the informed outsider an expected wage equal to her outside option, with her outside option being equal to the expected trading gains she will capture if she deviates by leaving the DRM sitting on the table. But note, the very act of posting such a DRM fundamentally alters the nature of beliefs regarding the probability of informed trading in the securities market. In particular, since the DRM satisfies the PC, all agents, including the market maker, believe that the informed agent will take it up if she exists. Conversely, if the informed agent deviates and leaves the mechanism sitting, the market maker will come to believe that she does not exist. And holding such a belief, the market maker will set the secondary market stock price in a way that is invariant to order flow. Anticipating the ability to trade with zero price impact off-equilibrium dramatically increases the expert's reservation value.

As we show, in some instances, the reservation value effect just described is sufficiently powerful to cause the feasible set in the mechanism design problem to become empty, implying that the only feasible strategy for the corporation is to abandon all attempts to bring expertise inside the firm, instead relying exclusively on the stock market for its information. And even in those instances in which the DRM feasible set is non-empty, it may be optimal to refrain from posting a mechanism. The benefit of posting a mechanism is that first-best project selection is implemented and shareholders are insulated from adverse selection in the secondary stock market. However, these benefits must be sufficient to offset the high endogenous wage bill, a wage bill reflective of the high endogenous reservation value of an informed expert who anticipates being able to trade with zero price impact should she reject the DRM.

We extend this benchmark setting by considering a corporation that also enjoys access to a randomized marketing technology with the feature that an expert may or may not see the posted mechanism, with the firm being able to fix this observation probability at a level of its own choosing. Here we derive our complementary result, showing that even when parameters are such that the corporation attains a higher value under the DRM than under exclusive reliance on the market, firm value is nevertheless decreasing in the job posting observation probability as this probability approaches one. That is, the corporation necessarily increases its value by ensuring that the posted mechanism will not be accepted with certainty. Intuitively, deliberately releasing the expert back into the securities market with positive probability increases the sensitivity of stock price to order flow, which serves to reduce the expert's gain to deviating from insider to outside trader.

In light of these results, our paper contributes to the literature on the boundaries of the firm.[1] Williamson (1985) emphasizes the firm as a device for avoiding transactions costs. Grossman and Hart (1986) and Hart and Moore (1990) argue that firm boundaries allocate residual control rights optimally given the need for relationship specific investments. Other ideas include resolving incentive problems (e.g. Holmstrom 1999) and minimizing rent seeking (e.g. Klein 2000).

In contrast, we analyze a corporation's decision regarding whether to bring informed expertise inside the firm, via the DRM, which can be interpreted as an employment contract offer, or to refrain from using a mechanism and instead rely on market provision of information. Our model reveals the following central tradeoff: bringing the expert inside the firm increases production efficiency but is more costly than relying on the market for information. Indeed, we show that the wage cost of posting an employment contract is greater than the adverse selection costs of relying on the market for information provision. After all, when the DRM is not posted, the market is aware that an expert may be trading in the market. The expert must then trade less aggressively, which results in lower adverse selection costs. However, because the expert is trading less aggressively, beliefs do not always change enough to convince the firm to alter production decisions. Thus, firms which rely on the market for information sometimes have less information than firms which bring expertise inside the firm. We fully characterize the regions of the parameter space for which the expert should be inside the firm. For example, if an expert exists with high probability, it is optimal to be market-reliant in the sense of failing to post a mechanism. After all, in this case, the stock price will be especially sensitive to

[1]See Williamson (2002) and Gibbons (2005) for review articles.

order flow, making it more informative. This improves production efficiency, as well as reducing adverse selection (trading loss) costs borne by the uninformed shareholders of the market-reliant firm.

A growing literature analyzes feedback between the information contained in securities prices and economic decisions (Bond, Goldstein, and Prescott 2009; Boleslavsky, Kelly, and Taylor 2013; and Bond and Goldstein 2015). This literature establishes limitations on the information that may be gleaned from securities prices, an effect operative in our model as well. For example, a short seller with private information that the state is bad knows that if short selling is too aggressive, the firm will infer the private information and take corrective action, eliminating the information advantage. Therefore, the short seller trades less aggressively, limiting the information contained in securities prices. However, in contrast to our model, this literature assumes (with few exceptions, discussed below) that expertise resides outside the boundaries of the firm. We depart from this literature by treating as endogenous the choice between outside (market-based) information production versus inside (managerial) information production.

The first exception is Dow and Gorton (1997) who conduct a side-by-side comparison of a decentralized securities market economy with a direct communication economy (sans securities market). Their analysis in the spirit of the comparative economic systems literature in which alternative information schemes are, essentially, put on different planets. In such a side-by-side comparison, the revelation principle informs us that the direct communication economy must yield weakly better outcomes. However, Dow and Gorton hamstring the direct communication economy with tighter limited liability constraints, rendering the outcome of their information system comparison parameter-dependent. Our analysis differs fundamentally in that we take as given the existence of a competitive securities market, and then consider whether a corporation should post a DRM given the market's existence. This explains why our findings should not be interpreted as any kind of refutation of the revelation principle, which is certainly correct. After all, the full de novo mechanism design problem would bring under its umbrella the arrangements under which investors trade securities, e.g. particular pricing schedules would be specified as a function of declarations of liquidity shocks. In contrast, we place the DRM inside an economy with a standard competitive market microstructure.

The second exception is Kahn and Winton (1998), who allow large investors to obtain ownership of the firm prior to obtaining prior information, shifting part of the cost of information to the uninformed shareholders. We depart from this paper in that we assume a widely held firm which accounts for the welfare of the individual shareholders when selling the firm.

A critical feature of our model is the endogeneity of the reservation value created by the market. Other literature focuses on type-dependent outside options (e.g. Jullien 2000) or outside options created endogenously from relationship specific investments (Rasula and Sonderegger 2010). This literature shows that efficiency increases if the principal randomizes whether or not the contract is implemented, by more efficiently screening out low types. In our framework, the outside option is not type specific, but is specific to the design of the mechanism. Interestingly, we also show that randomization improves efficiency. If the firm randomizes whether or not the contract is implemented (say by controlling how widely the contract is advertised), efficiency improves because the market is aware that the expert is trading in the market with positive probability, which reduces adverse selection costs.

Our results are related to the welfare analysis of insider trading regulations. Previous literature establishes conditions under which prohibiting an insider from trading in a securities market enhances welfare (Leland 1992, Fishman and Hagerty 1992). This literature takes the existence of an insider as exogenous. In our model, the firm endogenously decides whether private information is inside or outside the firm.

Our results have important implications for the comparative economic systems literature. This literature attempts side-by-side comparisons of parable economies using alternative allocative schemes, as exemplified in the debates regarding the relative allocative efficiency of market economies versus centrally planned economies. Here Green and Laffont (1976) show that any mechanism that is efficient and incentive compatible must be in the Vickrey-Clarke-Groves (VCG) family. Moreover, Makowski and Ostroy (1987) show that the perfectly competitive mechanism is the only VCG mechanism that is budget balancing and individually rational. Our results suggest that while a side-by-side comparison provides an important first step, mechanisms can interact with markets in the same economy.

The literature on mechanism design has its origins with Hurwicz (1972) who introduced the notion of incentive compatibility. Variations on the revelation principle were discovered independently by Gibbard (1973), Holmstrom (1977), Maskin (1979), and Myerson (1979).

2. Production Technology

Consider a canonical firm-level decision problem with an information asymmetry. Since we are particularly interested in the informational role of securities markets, we consider a widely-held firm with tradeable shares. In particular, a set of atomistic shareholders own all outstanding shares. Both the number of outstanding shares and the total measure of shareholders are normalized to one. The firm is unlevered, ruling out distortions in real decisions arising from conflicts of interest between debt and equity. Outstanding equity is normalized to one share, and is held by a continuum of atomistic shareholders.

The firm must choose between a risky business strategy (R) and a safe business strategy (S). The terminal cash flow of the firm under strategy R is a binary random variable ω drawn from $\{0, 1\}$. Below, we shall speak of ω as the economic *state*. All agents have common prior $\Pr(\omega = 0) = q$, where $q \in (0, 1)$. If the firm instead adopts business strategy S, it is insulated from risk, receiving a sure terminal cash flow equal to $1 - c$, where $c \in (0, 1)$. To fix ideas, one can think of the safe strategy as paying a cost c to insulate the firm from the negative consequences of the bad economic state $\omega = 0$. Throughout the analysis, we assume $c > q$. Notice, under this assumption, the risky strategy is optimal if the decision is based upon prior beliefs. Assumption A1 summarizes the assumptions on the prior beliefs and cost:

Assumption A1. $0 < q < c < 1$.

A large investor exists with privately known type $T \in \{E, N\}$. If $T = E$, the investor is an "expert" endowed with the ability to observe ω at the time it is determined by Nature. A type-i expert knows the state is $\omega = i$. The economic state ω is unobserved by all other agents, until the game ends. If $T = N$, the investor is a "non-expert" who has no private information. The probability that an expert exists, $\Pr(T = E) = a$, is common knowledge.

We assume the large investor has wealth $b \geq 0$ to cover short positions in the market. In addition, the large investor is capable of posting a "bond" worth $B \geq 0$ if hired as an adviser to the firm. The bond represents the maximum amount the legal system can credibly seize from a firm's adviser inclusive of reputational costs. In practice, B is a function of an adviser's wealth, financial structure, the legal system, and the value advisers attach to their reputation. In general, one would expect that $B \geq b$. However, if the courts are incapable of capturing much of a (bad) adviser's wealth, then $B \leq b$ is possible. We are agnostic on this question.

In addition, we assume there are an infinite number of other large uninformed agents with the same bonding capability (B) and the same ability (b) to cover short sales.

3. The Case for Mechanisms

This section presents the traditional case for the direct revelation mechanism (DRM) as an optimal means for eliciting private information from an informed agent. In particular, it will be shown that, given sufficient bonding capability, the firm can devise a DRM which achieves the joint objectives of truthful revelation by an expert and the screening out of incompetents, while pinning the expert to their reservation value. Importantly, the present section treats the privately informed agent's reservation value as an exogenous parameter, a standard assumption in the mechanism design literature. Section 6 analyzes the DRM when the reservation value is an endogenous feature of a market economy.

3.1. **Mechanism Design.** The firm seeks to design an optimal DRM in light of the following sequence of events. First, the large investor's type T is drawn from $\{E, N\}$. Next the firm offers all agents in the economy the opportunity to participate in the mechanism. To fix ideas, one can think of the mechanism as being a consulting contract or an employment contract to supervise the strategic choice of the firm. The firm offers the mechanism/contract on a first-come, first-serve basis, and only one agent may take up the contract. We assume *exclusivity:* the contract includes a provision which prohibits the expert from trading in the secondary market.[2]

An expert (type E) opting to leave the mechanism on the table can attain reservation value $\underline{u} \geq 0$. Non-experts have reservation value normalized at 0. After agents make their decision whether to take up the contract, Nature determines the state ω. At this time, the expert privately observes the state, if said expert exists. Next, the agent reports the state if hired by the firm. For simplicity we assume the agent's report is public, but this is not important since the report could be inferred based on the firm's subsequent choice of business strategy. The firm then chooses a business strategy in an optimal way given the agent's report or the prior information, if no agent was hired, as we demand renegotiation proofness of the business strategy choice. Finally, the courts verify the firm cash flow and the firm pays a wage to the agent.

3.2. **Optimal Mechanism.** The firm posts a contract where the wage w paid to the consultant depends only upon the realized cash flow $\varphi \in \{0, 1, 1-c\}$, not the reported state:

$$w \in \{w_0, w_1, w_{1-c}\}.$$

To see that this is without loss of generality, suppose instead a wage $w = w_{r\varphi}$ which depends on the report r and the realized cash flow:

$$w \in \{w_{10}, w_{11-c}, w_{11}, w_{00}, w_{01-c}, w_{01}\}.$$

Under the optimal contract derived below, it is sequentially rational to follow the advice of the agent and we assume the firm cannot commit to a strategy which sometimes ignores the advice of the agent. Therefore the wages w_{11-c}, w_{01}, and w_{00} are irrelevant. Thus, we need only specify wages which are contingent upon terminal cash flow:

$$w \in \{w_{10}, w_{11}, w_{01-c}\} \equiv \{w_0, w_1, w_{1-c}\}. \tag{1}$$

[2]One can view an expert who signs the contract to be an employee of the firm, who is then barred from trading by insider trading laws. We relax the exclusivity assumption in Section 8.

The objective of the firm is to minimize the expected wage bill subject to the relevant incentive constraints.

$$\min_{w_0, w_1, w_{1-c}} \quad (1-q)w_1 + qw_{1-c}, \tag{2}$$

subject to constraints ensuring non-experts will not take up the contract (SC); a bona fide expert voluntarily takes up the posted contract (PC); truthful report of the state by an expert (TR); and the bonding limit (BOND).

$$w_{1-c} \leq 0 \tag{SC1}$$

$$qw_0 + (1-q)w_1 \leq 0 \tag{SC2}$$

$$(1-q)w_1 + qw_{1-c} \geq \underline{u} \tag{PC}$$

$$w_1 \geq w_{1-c} \tag{TR1}$$

$$w_{1-c} \geq w_0 \tag{TR0}$$

$$w_i \geq -B \quad \forall\, i \in \{0, 1, 1-c\}. \tag{BOND}$$

It is readily verified that satisfaction of the PC and SC1 constraints guarantees satisfaction of the TR1 constraint, while satisfaction of the PC and SC2 constraints guarantees satisfaction of the TR0 constraint. We then have the following lemma.

Lemma 1. *Suppose the feasible set for the mechanism design program is non-empty. Then the expected wage of the expert under the optimal mechanism is the expert's reservation value,* $\underline{u}$.

Proof. Suppose to the contrary the feasible set is non-empty, and that there is a candidate optimal contract at which the PC constraint is slack. It follows that $w_1 > 0$ under this contract and so one may decrease w_1 infinitesimally, satisfy all constraints, and reduce the expected wage bill. This contradicts optimality of the initially posited contract. □

Based on the preceding lemma, we next solve the following dual problem determining the maximum reservation value, denoted $\underline{u}^{\max}$, at which it is feasible to satisfy all stipulated constraints of the mechanism design program:

$$\underline{u}^{\max} \equiv \max_{w_0, w_1, w_{1-c}} \quad (1-q)w_1 + qw_{1-c}, \tag{3}$$

subject to SC1, SC2, and BOND.

The wage w_0 only enters the program through constraints SC2 and BOND. From these two constraints, it is apparently optimal to relax SC2 as much as possible while still satisfying BOND. Therefore, the solution to the dual problem features $w_0 = -B$. Next, the maximum wage resulting from the safe outcome (increasing the dual program maximand), which satisfies all constraints is $w_{1-c} = 0$. Thus, the remaining screening constraint SC1 is also binding in this dual program. Finally, the dual program solution sets the wage w_1 equal to the maximum value that satisfies SC2. In summary, the solution to this program is:

$$(w_0^*, w_{1-c}^*, w_1^*) = \left(-B, 0, \frac{qB}{1-q}\right) \Rightarrow \underline{u}^{\max} = qB. \tag{4}$$

We thus have proved the following proposition.

Proposition 1. *A feasible mechanism exists if and only if the expert has reservation value* $\underline{u} \leq qB$*. An optimal mechanism pinning the expert to the reservation value* $\underline{u}$ *features the wage vector:*

$$(w_0, w_{1-c}, w_1) = \left(-B, 0, \frac{\underline{u}}{1-q}\right).$$

The optimal mechanism is intuitive. First, since an incompetent agent can hide ignorance by always reporting $\omega = 0$, so that the firm implements the safe strategy, the optimal mechanism offers a wage payment of zero if the firm's adviser recommends the safe strategy.

Next, the contract features maximum punishment $w_0 = -B$ when the realized cash flow is zero, since this case implies the firm implemented the risky project following an incorrect report that $\omega = 1$. Finally, the wage w_1 is set so that the expert's participation constraint is just binding.

The preceding proposition illustrates a central tension in the market for expert advice. If the expert's reservation value exceeds qB, the feasible set is empty and the market for expert advice breaks down. Intuitively, under the optimal mechanism an increase in $\underline{u}$ is accommodated through an increase in w_1. However, this makes reporting $\omega = 1$ and gambling on receiving w_1 increasingly attractive for an incompetent. When the reservation value exceeds $\underline{u}^{\max} = qB$, constraint SC2 is violated, the firm can no longer screen out incompetents, and the mechanism breaks down.

In the event that the screening constraint cannot be satisfied, the firm knows that the posting of some alternative mechanism that failed to screen out incompetents would be taken up, first-come first-serve, by an uninformed large agent, since such agents are infinite in number. But this leaves the firm no better off than if it fails to post any mechanism.

Next, consider firm value in the event that the feasible set for the DRM is non-empty. If the large investor is informed, the firm implements the optimal strategy for each state and the expected wage bill is $\underline{u}$. If the large investor is not informed, the mechanism is not taken up, there are no wages paid, and the firm implements the risky strategy. Thus, the implied ex ante firm value attained under the optimal DRM is:

$$\begin{aligned} V_{DRM} &= a\left[q(1-c) + (1-q) - \underline{u}\right] + (1-a)(1-q) \\ &= (1-q) + aq(1-c) - a\underline{u}. \end{aligned} \tag{5}$$

4. The Market

This section considers a firm that refrains from posting a mechanism, instead relying on the market for the provision of information. In particular, if an expert with knowledge of the state exists and trades in the market, the trades reveal information about the state to the firm. Below, we call such a firm *market-reliant*.

The firm anticipates the expert trader behaves so that the state is not necessarily revealed with probability one. Thus, the market may provide only a noisy signal of the information held by an expert trader. Consequently, the firm may not implement the correct state-contingent business strategy even if an informed agent exists in the economy ($T = E$). Further, if the expert trader's information is not fully revealed by order flow, the firm's shareholders are exposed to adverse selection. That is, shareholders forced to sell due to liquidity shocks are exposed to mispricing in the secondary market. Such underpricing will be capitalized into the stock price ex ante.

4.1. **Market Microstructure.** The timing of events in the securities market is as follows. The large investor's type $T \in \{E, N\}$ is drawn by nature. The large investor then submits an order to sell $t \in [-1, 1]$ shares. Because most of the activity in the model will be on the sell side of the market, positive $t > 0$ represents a sell order and negative t represents a buy order. At the same point in time, with probability $l \in (0, 1)$ the firm's atomistic shareholders receive a liquidity shock. If a liquidity shock arrives, then a random measure of the atomistic shareholders sell their shares. The sell order of such shocked shareholders is distributed $U[0, 1]$. Below z denotes the sell order size of the atomistic shareholders, which is 0 if there is no liquidity shock.

A market maker exists who clears the trades. We assume no barriers to entry, so the market maker earns zero profits. The market maker observes the order pair (z, t), either or both of which may be zero. The market maker cannot observe the source of each order and is thus unsure whether z or t is the order submitted by the large investor. The market maker and the firm have identical prior information, and so the firm is also unsure as to which order was submitted by the large investor.

Based on the observed orders, the market maker updates beliefs about the state. To ensure zero profits, the market maker executes the orders at a price equal to the expected terminal cash flow of the firm, anticipating the firm will choose an optimal business strategy in light of the updated beliefs. The firm then chooses a business strategy. Finally, all players receive payoffs and the game ends.

4.2. **Price and Payoffs.** Throughout the paper we consider Perfect Bayesian Equilibrium (PBE). To this end, let $\chi(z, t)$ denote market maker and firm beliefs regarding the probability of $\omega = 0$ based upon observing the order pair (z, t). Let $\alpha(z, t)$ denote the probability the firm switches to the safe strategy after observing the order pair (z, t). Sequential rationality on the part of the firm implies:

$$\alpha(z,t) = \begin{cases} 0 & \text{if} \quad \chi(z,t) < c \\ [0,1] & \text{if} \quad \chi(z,t) = c \\ 1 & \text{if} \quad \chi(z,t) > c \end{cases} . \tag{6}$$

The sequential rationality condition (6) implies that the market maker will set the stock price $p(z,t) \geq 1 - c$. It follows that the maximum loss the large investor can incur on any short sale is c per unit shorted. The next assumption ensures the large investor has sufficient outside wealth to cover losses on the largest possible short sale of one unit:

Assumption A2. *$b \geq c$.*

In order to make zero profit, the market maker must set the stock price equal to the expected cash flow of the firm. The secondary market stock price is then:

$$p(z,t) = [1 - \alpha(z,t)][1 - \chi(z,t)] + \alpha(z,t)(1-c). \tag{7}$$

Both the anticipated business strategy and beliefs about the state influence the secondary market stock price.

Consider now the optimal trading strategy of an expert $(T = E)$. The type 1 expert knows that, under the risky strategy, a share will be worth 1, and that under the safe strategy a share will be worth $1 - c$. Thus, the random (due to random z) payoff to a type 1 investor from *selling* t shares will be:

$$\begin{aligned} u_1(z,t) &= t[p(z,t) - (1 - \alpha(z,t)) - \alpha(z,t)(1-c)] \\ &= -t\chi(z,t)[1 - \alpha(z,t)]. \end{aligned} \tag{8}$$

Here the second equality follows from (7). From equation (8), a type 1 expert obtains a weakly positive payoff from buying shares and a weakly negative payoff from selling shares.

The type 0 expert knows that under the risky strategy a share will be worth 0, and that under the safe strategy a share will be worth $1 - c$. Thus, the payoff to a type 0 investor from *selling* t shares is:

$$\begin{aligned} u_0(z,t) &= t[p(z,t) - \alpha(z,t)(1-c)] \\ &= t[1 - \chi(z,t)][1 - \alpha(z,t)]. \end{aligned} \tag{9}$$

From equation (9), a type 0 expert obtains a weakly positive payoff from selling shares and a weakly negative payoff from buying shares.

Consider finally the trading incentives of the uninformed ($T = N$) large investor. The non-expert believes that under the risky strategy a share will be worth 1 with probability

$1-q$, and worth $1-c$ under the safe strategy. Thus, the non-expert's payoff from *selling* t shares is:

$$u_N(z,t) = t[p(z,t) - (1-\alpha(z,t))(1-q) - \alpha(z,t)(1-c)] \\ = t[q - \chi(z,t)][1-\alpha(z,t)]. \tag{10}$$

From equation (10), a non-expert obtains a weakly positive payoff from selling (buying) shares if selling (buying) shares results in $\chi(z,t) \leq (\geq) q$.

We have the following lemma.

Lemma 2. *Given any belief function $\chi(.,.) \in [0,1]$ for the market maker and the firm, and any firm business strategy $\alpha(\cdot,\cdot) \in [0,1]$, for all possible realizations of liquidity trades z:*

- *The type 1 expert's payoff from submitting a buy order is weakly greater than from not trading, which is weakly greater than the payoff from submitting a sell order.*
- *The type 0 expert's payoff from submitting a sell order is weakly greater than from not trading, which is weakly greater than the payoff from submitting a buy order.*

In light of the preceding lemma, we shall characterize equilibria in which the type 0 expert places a sell order ($t > 0$) with probability 1, and the type 1 expert places a buy ($t < 0$) order with probability 1.[3] That is, each expert type is always active in equilibrium and confines trades to the side of the market consistent with their information. We refer to this as *natural trading*.

4.3. **Strategies and Beliefs.** We next evaluate belief formation when the expert investor engages in natural trading. To this end, consider first a pair of orders in which one of the orders is a buy. The buy order cannot originate in response to a liquidity shock, but must instead come from either the type 1 expert or the non-expert investor $(T = N)$. In either case, observing a buy order cannot reveal bad news about the state. Consider next the arrival of two sell orders. Two sell orders can only arrive if a liquidity shock occurred. Hence, the other sell order must either originate with the type 0 expert or the non-expert investor. In either case, this combination of orders cannot reveal good news about the state. Finally, consider the arrival of one sell order paired with one zero order. The zero order cannot originate with the expert investor $(T = E)$. Therefore three possibilities exist: (1) no liquidity shock occurred and the sell order was placed by the type 0 expert; (2) no liquidity shock occurred and the sell order was placed by the non-expert investor; or (3) or the liquidity shock occurred and the non-expert placed an order of 0. In all three cases, this combination of trades cannot reveal good news about the state. We thus have the following lemma.

[3]The buy orders can be arbitarily small implying the type 1 investor's wealth constraint is satisfied.

Lemma 3. *In any equilibrium in which the large informed investor engages in natural trading,*

- *beliefs have the following properties:*
  1. *If a buy order exists, then beliefs about the state must become weakly more favorable,* $\chi(z,t) \leq q$.
  2. *If two sell orders exist, then beliefs must become weakly less favorable,* $\chi(z,t) \geq q$.
  3. *If a sell order and a zero order exist, then beliefs must become weakly less favorable, with* $\chi(z,t) \geq q$.
- *a non-expert's payoff from a zero order* ($t = 0$) *is weakly larger than her payoff from submitting either a buy or sell order* ($t \neq 0$).

In light of Lemmas (2) and (3), we focus on equilibria in which the type 0 and 1 experts engage in natural trading and the non-expert investor does not trade. Intuitively, the potential existence of an informed investor causes trades to have adverse price impact. The non-expert $(T = N)$ faces the adverse price impact without the benefit of knowledge of the state, and thus prefers not to trade. Notice, it is in this way, through the price impact of trading, that the market screens out incompetent investors.

And what of the other non-informed investors, assumed to be infinite in number? They too have no incentive to trade. After all, a large investor who submits a buy (sell) order can only expect prices to move against him, with $\chi \leq q$ ($\chi \geq q$), but does not have the benefit of any knowledge about the state. From equation (10) it follows that any uninformed investor obtains a weakly negative payoff from trading. Again, price impact screens out incompetents.

Equilibrium beliefs hinge upon the strategy of the expert investor. A mixed strategy for the expert, $\phi_i(\cdot)$, specifies a density over orders for each of the expert's two possible types, $i \in \{0,1\}$. We allow the expert's strategy to have mass points or be degenerate. We use the Dirac $\delta(\cdot)$ function at mass points. With this in mind, consider market maker and firm beliefs given all possible configurations of orders (z,t).

Two zero orders. Two zero orders implies no liquidity shock occurred and the large investor is a non-expert. Thus, beliefs revert to priors, with $\chi(0,0) = q$. In this case, the sequentially rational firm stays with the risky strategy and $\alpha(0,0) = 0$.

One order is a buy order. Since liquidity shocks result in sell orders, the buy order came from the type 1 expert. Thus, the arrival of a buy order reveals $\omega = 1$, and $\chi(z,t) = 0$. In this case, the sequentially rational firm stays with the risky strategy.

Since only the type 1 expert always places a buy order, if a type 1 expert exists then the firm will correctly implement the risky strategy. That is, the only possibility for errors in the firm's choice of strategy occurs when either the state is $\omega = 0$ or when the large investor is uninformed.

Two sell orders. If two sell orders arrive, one of the sell orders must come from the type 0 expert. That is, two sell orders reveal $\omega = 0$, and so beliefs are $\chi(z, t) = 1$. In this case, the sequentially rational firm switches to the safe strategy. Since the informed investor always places a sell order in the bad state, if a type 0 expert exists and a liquidity shock occurs, then the firm correctly switches to the safe strategy.

A sell order and a zero order. One sell order and a zero order can arise in two ways: (1) sell order submitted by the type 0 expert and no liquidity shock, (2) if a liquidity shock occurs and the large investor is a non-expert (and thus inactive). For a sell order of size t, Bayes' rule implies beliefs are:

$$\chi(0, t) = \frac{aq(1-l)\phi_0(t) + (1-a)ql}{aq(1-l)\phi_0(t) + (1-a)l}. \tag{11}$$

Let:

$$K(a, l, q) \equiv q\left(\frac{a}{1-a}\right)\left(\frac{1-l}{l}\right). \tag{12}$$

Here K measures market informativeness (specifically the informativeness of a sell order cum zero order): the numerator $aq(1-l)$ is the probability that the expert made the sell order, whereas the denominator $(1-a)l$ is the probability that the liquidity traders made the sell order. Beliefs in the case of one sell order plus one zero order, equation (11), can be expressed compactly as:

$$\chi(0, t) = \frac{K\phi_0(t) + q}{K\phi_0(t) + 1}. \tag{13}$$

In the present case, the sequentially rational strategy of the firm is ambiguous. In particular, since $c > q$, in order to induce the firm to switch to the safe strategy it must be that the observation of a single sell order (cum zero order) causes the firm to revise its beliefs sufficiently in the negative direction, with t being such that $\chi(0, t) \geq c$. Whether this is the case depends upon the size of the sell order and the equilibrium strategy of the type 0 investor.

Table 1 summarizes the analysis thus far.

5. Equilibrium

As just described in the previous subsection, and as indicated in Table 1, beliefs and firm strategy are unambiguous for all order flow configurations except for a sell order combined with a zero order. The objective of this subsection is to identify equilibria of the full trading game by focusing on this particular order flow configuration.

State	Liquidity Shock?	Expert?	Trades	Beliefs	Strategy	Probability
0	N	N	0, 0	q	R	$q(1-l)(1-a)$
0	N	Y	0, Sell	$\chi(0,t)$	TBD	$q(1-l)a$
0	Y	N	Sell, 0	$\chi(t,0)$	TBD	$ql(1-a)$
0	Y	Y	Sell, Sell	1	S	qla
1	N	N	0, 0	q	R	$(1-q)(1-l)(1-a)$
1	N	Y	0, Buy	0	R	$(1-q)(1-l)a$
1	Y	N	Sell, 0	$\chi(t,0)$	TBD	$(1-q)l(1-a)$
1	Y	Y	Sell, Buy	0	R	$(1-q)la$

TABLE 1. Trading, Beliefs and Strategy.

5.1. **Always Switch Equilibrium.** Intuition suggests that if the cost of switching to the safe strategy is sufficiently low, say c very close to q, then a sell order of *any size* (combined with a zero order) conveys sufficient negative information to convince the firm to switch to the safe strategy. We label this possibility as an Always Switch Equilibrium.

To derive the range of c for which an Always Switch Equilibrium occurs, suppose the market maker (and firm) observe a sell order and a zero order, but receive no information on the sell order size. Using Bayes' rule, the updated belief is:

$$\hat{\chi} \equiv \frac{aq(1-l)+(1-a)ql}{aq(1-l)+(1-a)l} = \frac{K+q}{K+1} > q. \tag{14}$$

For brevity, let

$$J \equiv \frac{1-q}{1-c}. \tag{15}$$

Then from equation (6) we have:

$$\hat{\chi} \geq c \Longleftrightarrow K \geq J-1. \tag{16}$$

In this case, the observation of a sell order of any size, paired with a zero order, is sufficient to induce the firm to switch to the safe strategy. We have the following proposition.

Proposition 2. *Always Switch Equilibrium: If the cost c of switching to the safe strategy is less than $\hat{\chi}$, a multiplicity of equilibria exist. In all equilibria, Table 1 characterizes equilibrium beliefs and strategies, and:*

- *The type 0 expert uses any trading strategy such that for all $t \in (0,1]$, the mixing density satisfies*

$$\phi_0(t) > \frac{J-1}{K},$$

and makes zero profits.

- *Firm beliefs satisfy:*
$$\chi(0,t) = \chi(t,0) > c,$$
- *Firm strategy: The firm switches to the safe strategy following any sell order paired with a zero order.*
- *Equilibrium price:* $p(0,t) = p(t,0) = 1 - c$.

Equation (14) implies comparative statics:

$$\frac{\partial \hat{\chi}}{\partial q} > 0; \quad \frac{\partial \hat{\chi}}{\partial a} > 0; \quad \frac{\partial \hat{\chi}}{\partial l} < 0. \tag{17}$$

The comparative statics imply the Always Switch Equilibrium obtains when: c is sufficiently low; q is sufficiently high; a is sufficiently high; or l is sufficiently low. Intuitively, if $c - q$ is sufficiently small, then a small negative revision in beliefs is sufficient to bring about a positive expected gain $(\chi - c)$ to switching to the safe strategy. Further, if a is high and l is low, a sell order is more likely to derive from a type 0 seller than the uninformed liquidity traders.

Consider finally the ex ante value of a share when the parameters are such that an Always Switch Equilibrium results. In general, the ex ante share price is equal to expected terminal cash flow less the expectation of the atomistic shareholders' trading losses. Since the market maker makes zero in expectation, the expected loss of atomistic shareholders is equal to the expected trading gain of the informed investor. Here, in the Always Switch Equilibrium, the informed investor makes zero expected trading gain (see Proposition 2).

Consider next the expected cash flow in the Always Switch Equilibrium. Here the firm only deviates from the full information optimal strategy in two cases. First, if no liquidity shock occurs and the large investor is a non-expert, then the firm executes the risky strategy which is not optimal if $\omega = 0$. Relative to full information, a loss of $1 - c$ results in this scenario, which occurs with probability $q(1 - l)(1 - a)$. Second, if $\omega = 1$, the firm should implement the risky strategy, but instead switches to the safe strategy if a liquidity shock occurs and the large investor is a non-expert. Relative to full information, a loss of c results in this scenario which occurs with probability $(1 - q)l(1 - a)$.

From the preceding arguments the ex ante share price in the event of the Always Switch Equilibrium is:

$$V_{AS} = \underbrace{q(1-c) + (1-q)}_{Full\ information} - (1-a)[q(1-l)(1-c) + (1-q)lc]. \tag{18}$$

5.2. **Non-Switch Equilibrium.** The previous subsection showed that if c is sufficiently small, an Always Switch Equilibrium obtains. Conversely, intuition suggests that if c is sufficiently high, the gain to switching to the safe strategy is sufficiently small such that the observation of a single sell order combined with zero order never moves beliefs sufficiently to induce the firm to switch to the safe strategy. We denote such an equilibrium a Non-Switch Equilibrium, with the understanding that this label only describes the firm's behavior in response to a sell order cum zero order. As shown in Table 1, the firm still switches to the safe strategy in response to two sell orders, since such an order flow configuration fully reveals $\omega = 0$.

In order for a Non-Switch Equilibrium to exist, the type 0 expert cannot reveal too much information through trade. Keeping this in mind, we now conjecture (and verify) a Non-Switch Equilibrium in which the type 0 plays a proper mixed strategy with minimum sell order size m, and featuring an atomless mixing density ϕ_0 that vanishes as the sell order size approaches m.

Notice, if the density ϕ_0 does indeed vanish as the sell order approaches m, equation (13) implies that the market maker forms belief $\chi(0, m) = q$, and sets the stock price $p(0, m)$ equal to $1 - q$. Since the type 0 expert sells, a liquidity shock reveals $\omega = 0$, resulting in zero profits for the expert. Thus, the expected profit to the type 0 investor from a short sale of size m given the conjecture that the firm does not switch is $(1 - l)m(1 - q)$. Equation (13) implies that for all $t > m$ the type 0 mixing condition is:

$$(1 - l)m(1 - q) = E_Z[u_0(z, t)] = (1 - l)t \left[1 - \frac{K\phi_0(t) + q}{K\phi_0(t) + 1}\right]. \tag{19}$$

Equation (19) implies the type 0 mixing density is the following linear increasing function, which indeed vanishes as t approaches m, as conjectured:

$$\phi_0(t) = \frac{t - m}{mK}. \tag{20}$$

Since the mixing density must integrate to one, we have:

$$\int_m^1 \phi_0(t)dt = 1 \Rightarrow m = F(K) \equiv 1 + K - \sqrt{(1 + K)^2 - 1} \in (0, 1). \tag{21}$$

Equation (21) implies F is decreasing, while equation (12) implies K is increasing in a and decreasing in l. Therefore, the type 0 expert's minimum short sale size has the following properties:

$$\frac{\partial m}{\partial a} < 0;\ \frac{\partial m}{\partial l} > 0. \tag{22}$$

Intuitively, the type 0 investor must trade less aggressively the higher the market maker's prior regarding the existence of an informed investor. Conversely, the type 0 investor can trade more aggressively the higher the probability of a camouflaging liquidity shock.

Equation (13) implies the belief function is strictly increasing in ϕ_0, while the mixing density just derived increases linearly in t. Thus, the maximum value of $\chi(0, t)$ in the conjectured Non-Switch Equilibrium is:

$$\overline{\chi} \equiv \frac{K\phi_0(1)+q}{K\phi_0(1)+1} = 1 - m(1-q). \tag{23}$$

Equations (22) and (23) imply comparative statics:

$$\frac{\partial \overline{\chi}}{\partial a} > 0; \frac{\partial \overline{\chi}}{\partial l} < 0. \tag{24}$$

From the sequential rationality condition (6), the firm never switches to the safe strategy if $\overline{\chi} \leq c$. Thus, a Non-Switch Equilibrium occurs if c is sufficiently high; a is sufficiently low; or l is sufficiently high. Intuitively, if c is very high relative to q, substantially more pessimistic beliefs are required to induce a switch to the safe strategy. Conversely, if a is low or l is high, the arrival of a single sell order cum zero order is more likely to have come from the uninformed liquidity traders than from a type 0 expert, so the belief revision is small.

To summarize, we have the following proposition.

Proposition 3. *Non-Switch Equilibrium: If $\overline{\chi} < c$, Table 1 characterizes all equilibrium beliefs and strategies, with:*

- *For all t exceeding the minimum sell order size $m = 1 + K - \sqrt{(1+K)^2 - 1}$, the type 0 expert sells shares according to the trading density $\phi_0(t) = (t-m)/mK$.*
- *Firm beliefs: $\chi(0,t) = \chi(t,0) = 1 - (1-q)m/t$.*
- *Firm strategy: The firm plays the risky strategy following any sell order paired with a zero order.*
- *Equilibrium price: $p(0,t) = p(t,0) = (1-q)m/t$.*

Consider finally ex ante share value in the Non-Switch Equilibrium. As a benchmark, a strictly hypothetical firm implementing the risky strategy with probability 1 has expected cash flow $1-q$. In contrast, in the equilibrium characterized in Proposition 3, the firm switches to the safe strategy given two sell orders, which reveal the true state $\omega = 0$. This outcome occurs with probability qla and generates an increase in cash flow of $1-c$ relative to the firm that always implements the risky strategy.

Consider next the expected trading losses of the atomistic shareholders. These losses equal the expected trading gain of the large investor. Only a large investor who is a type 0 expert makes a positive trading gain and then only if no liquidity shock occurs. The expected trading gain for all sell orders implemented in equilibrium equals the expected trading gain for the smallest equilibrium sell order, m, which yields an expected gain equal to $(1-l)m(1-q)$.

From the preceding analysis, we obtain the following expression for the ex ante share price in the event of the Non-Switch Equilibrium:

$$V_{NS} = 1 - q + qla(1-c) - aq(1-l)m(1-q). \tag{25}$$

5.3. **Mixed Switching Equilibrium.** Subsections 5.1 and 5.2 analyzed equilibria for low and high values of the switching cost parameter c. We conjecture and verify that for intermediate values of the switching cost, $c \in (\hat{\chi}, \overline{\chi})$, a range of low sell order sizes exists such that (when paired with a zero order) the firm adheres to the risky strategy, and a region of high sell order sizes for which the firm switches to the safe strategy with positive probability $\alpha \in (0,1)$. Further, we conjecture (and verify) the type 0 expert plays a proper mixed strategy featuring an atomless density $\phi_0^{\dagger}$ that vanishes as the sell order size approaches a minimum size, denoted $m^{\dagger}$.

Intuitively, the expert trades more shares with lower probability so that all equilibrium sell orders generate equal expected gain as required by the mixing condition. Further, the expert generates positive expected trading profits by making sure that no order induces the firm to switch to the safe strategy with probability 1, which would eliminate the information advantage.

Notice, if the density $\phi_0^{\dagger}$ does indeed vanish as the sell order size approaches $m^{\dagger}$, then equation (13) implies that, if no liquidity shock occurs, the market maker forms belief $\chi(0, m^{\dagger}) = q$, since the market maker knows such a trade originated with the expert with probability zero. The stock price is then $p(0, m^{\dagger}) = 1 - q$. Given such beliefs the firm then executes the risky strategy, so the expected profit to the type 0 expert from a short sale of size $m^{\dagger}$ is $(1-l)m^{\dagger}(1-q)$. Consider then sell orders by the type 0 investor of size $t \geq m$ sufficiently small so that the firm continues to use the risky strategy with probability one. We have the following mixing condition, with corresponding beliefs for the market maker and firm:

$$\begin{aligned}(1-l)m^{\dagger}(1-q) &= (1-l)t[1-\chi(0,t)] \\ &\Rightarrow \chi(0,t) = 1 - \frac{m^{\dagger}(1-q)}{t}.\end{aligned} \tag{26}$$

From equation (13) the order flow density on the region where $\alpha(0,t) = 0$ is:

$$\Rightarrow \phi_0^{\dagger}(t) = \frac{t - m^{\dagger}}{Km^{\dagger}}. \tag{27}$$

Notice, on the posited non-switching region, the function $\chi(0,t)$ is strictly increasing in t. That is, the market maker becomes more pessimistic the larger the sell order, with the fall in the stock price discouraging the type 0 investor from placing larger sell orders. It remains to compute the region where adherence to the risky strategy is sequentially rational for the firm ($\chi(0,t) \leq c$). We thus posit the existence of a critical sell order size,

θ, at which the optimal firm policy changes from non-switching to switching to the safe strategy with some positive probability $\alpha \in (0,1)$. From the sequential rationality of the firm's strategy decision, the critical sell order size satisfies:

$$\chi(0,\theta) = 1 - \frac{m_0^\dagger(1-q)}{\theta} = c \Rightarrow \theta = Jm^\dagger. \tag{28}$$

Consider next a region for which we conjecture the firm has an interior probability of switching. On such an interval the firm must be indifferent between strategies. From equation (13) the firm's mixing condition is:

$$\chi(0,t) = \frac{K\phi_0(t)+q}{K\phi_0(t)+1} = c \Rightarrow \phi_0^\dagger(t) = \frac{c-q}{K(1-c)} = \frac{J-1}{K}. \tag{29}$$

Thus, the type 0 expert's order flow density is flat over the conjectured region where the firm mixes.

Ensuring the order flow density integrates to one pins down the minimum short sale size. We have:

$$\frac{1}{Km^\dagger}\int_{m^\dagger}^{\theta^\dagger}(t-m^\dagger)dt + (1-\theta^\dagger)\left(\frac{J-1}{K}\right) = 1 \Rightarrow m^\dagger = \frac{2(J-K-1)}{J^2-1}. \tag{30}$$

Finally, the firm must mix in a way such that the type 0 expert is indifferent over trade sizes. On the firm's mixing interval, market maker beliefs are constant at $\chi = c$, and the stock price is $p = 1-c$. The type 0 expert's mixing condition is thus:

$$(1-l)m^\dagger(1-q) = (1-l)t(1-c)[1-\alpha(0,t)] \Rightarrow \alpha(0,t) = 1 - \frac{m^\dagger(1-q)}{t(1-c)} = 1 - \frac{m^\dagger J}{t}. \tag{31}$$

Notice, the implication is that on the firm's strategy mixing interval, the probability of switching to the safe strategy increases in the sell order size, which dampens the type 0 expert's incentive to place larger sell orders.

We have the following proposition:

Proposition 4. *Mixed Switching Equilibrium: if $c \in (\hat{\chi}, \overline{\chi})$, Table 1 characterizes all equilibrium beliefs and strategies, with:*

- *Strategy and beliefs of the firm following any sell order paired with a zero order:*
  - *Risky strategy region: for $t \in \left[m^\dagger, Jm^\dagger\right]$, the firm implements the risky strategy and $\chi(0,t) = \chi(t,0) = 1-(1-q)m^\dagger/t$.*
  - *Mixed switching region: for $t \in (Jm^\dagger, 1$, the firm switches to the safe strategy with probability $\alpha\,(t,0) = \alpha\,(0,t) = 1 - m^\dagger J/t$ and $\chi(0,t) = \chi(t,0) = c$.*

- *The type 0 expert sells shares according to the trading density*

$$\phi_0(t) = \begin{cases} \frac{t-m^\dagger}{m^\dagger K} & t \in [m^\dagger, Jm^\dagger] \\ \frac{J-1}{K} & t \geq Jm^\dagger \end{cases} \tag{32}$$

$$m^\dagger = \frac{2(J-K-1)}{J^2-1}. \tag{33}$$

- *Equilibrium price:* $p(0,t) = p(t,0) = (1-q)m^\dagger/t$ *for* $t \in [m^\dagger, Jm^\dagger]$ *and* $p(t,0) = p(0,t) = 1-c$ *for* $t \in [Jm^\dagger, 1]$.

Consider finally the ex ante share value under the Mixed Switching Equilibrium. A first useful observation is that the expected cash flow of the firm is here identical to that of the firm under the Non-Switch Equilibrium. To see this, note that in the Mixed Switching Equilibrium, in response to a single sell order cum zero order the firm either strictly prefers the risky strategy (for small sell orders) or is indifferent between the risky and safe strategies (for larger sell orders). Thus, one can compute expected cash flow as if the firm always implements the risky strategy in response to a single sell order.

Next, the expected trading losses of the atomistic shareholders are just equal to the expected trading gain of the large investor. The large investor only makes a positive trading gain if she is a type-0 expert and no liquidity shock occurs. The expected trading gain of the type-0 expert for all sell orders implemented in equilibrium equals the expected trading gain of the smallest equilibrium sell order, equal to $(1-l)m^\dagger(1-q)$.

The preceding arguments imply that the ex ante value of the firm in the Mixed Switching Equilibrium is identical in form to the firm value in the Non-Switch Equilibrium, with the sole difference being that the appropriate minimum type zero short sale $m^\dagger$ replaces m. Thus, the ex ante firm value under the Mixed Switching Equilibrium is:

$$V_{MIX} = 1 - q + qla(1-c) - aq(1-l)m^\dagger(1-q). \tag{34}$$

6. Is Posting a Mechanism Optimal?

Having analyzed mechanisms and markets above, the present section determines conditions under which the firm optimally abstains from posting a mechanism.

6.1. **Reservation Values in Market Economies.**

Section 3 presented the standard argument supporting direct revelation mechanisms as devices for eliciting private information from an informed expert. In particular, Proposition 1 showed that if the large investor has sufficient bonding capability $(B \geq \underline{u}/q)$, then a mechanism exists for screening out incompetents, eliciting the informed agent's private information, and pinning her to her reservation value $\underline{u}$. Critically, the informed agent's reservation value was therein treated as an exogenous parameter, as is standard in the mechanism design literature. This subsection determines the equilibrium value of $\underline{u}$ in our securities market economy.

Consider now the parameter $\underline{u}$, the opportunity cost the informed investor sacrifices if she signs on to the mechanism. To evaluate this opportunity cost, suppose the informed investor exists ($T = E$) and that the firm indeed posts the mechanism. Recall, the optimal mechanism satisfies the participation constraint of an informed agent. This assures markets that an informed agent would take up the posted mechanism should she exist. Therefore, if the expert deviates by failing to sign on to the posted mechanism, the market maker and firm will conclude that no informed expert exists $(T = N)$. Critically, price formation by the market maker will no longer be as described in Sections 4 and 5, since those sections considered a firm that did *not* post a mechanism.

We now evaluate the type of price formation that an expert anticipates when deviating by not taking up the posted mechanism. Consider first pricing in the event a single sell order arrives, after the posted mechanism has been left sitting. The mechanism left sitting "reveals" to the market maker (and firm) that no informed investor exists and so the market maker concludes that the single sell order results from atomistic shareholders facing a liquidity shock. The market maker therefore sets the price equal to the expected cash flow under the risky strategy, $p = 1 - q$. Importantly, the market maker sets this price *regardless of the sell order size*. That is, since the market maker believes the large investor is uninformed, the size of the trade has no price impact. The absence of price impact in the stock market here stands in stark contrast to the nature of price formation if the firm does not post a mechanism (Sections 4 and 5).

Consider now what happens when the expert deviates and places a buy order. Since the firm posted the optimal mechanism, a buy order is a zero probability event on the equilibrium path. After all, if an expert exists ($T = E$), she will take up the mechanism and is prohibited from trading. Hence, any beliefs are consistent with equilibrium in response to a buy order. However, to make the best case for mechanisms, we adopt the conservative assumption that in the event of a mechanism being posted and left unaccepted, the arrival of a buy order is attributed to a type 1 expert, so said expert earns zero profits from deviating.

Similarly, if the firm posts the mechanism, then the arrival of two sell orders is a zero probability event on the equilibrium path, so any beliefs are consistent with equilibrium. Here too we make the most favorable assumption possible for the mechanism. If the mechanism is posted and rejected, but then two sell orders arrive, then the market maker correctly believes the type 0 expert placed a sell order, and again the expert earns zero profits.

In light of the preceding discussion consider the optimal strategy of an expert who deviates by rejecting the mechanism. If $\omega = 1$, there is zero profit to be made from any buy order. However, if $\omega = 0$, the expert earns maximal expected profits by shorting 1 unit of stock. After all, she makes zero profit if a liquidity shock arrives. However, if there is no liquidity shock, she enjoys the ability to sell with zero price impact, with the market maker setting $p = 1 - q$. It follows that the reservation value of an informed expert in our market economy is given by:

$$\underline{u} = q(1-q)(1-l). \tag{35}$$

6.2. **Markets versus Mechanisms.** Given the endogenous reservation value of an informed investor (35), we can assess whether posting a mechanism is optimal for the firm. Recall from Proposition 1 that the feasible set for the mechanism design program is non-empty if and only if $qB \geq \underline{u}$. The next proposition is immediate from equations (5) and (35).

Proposition 5. *If the informed agent has sufficient bonding capability,*

$$B \geq (1-q)(1-l), \tag{36}$$

then the ex ante share price attained by a firm opting to post the optimal mechanism is:

$$V_{DRM} = (1-q) + aq\left[1 - c - (1-q)(1-l)\right]. \tag{37}$$

Otherwise, the mechanism is not feasible and no mechanism is posted.

The second part of Proposition 5 is our first important negative result: The existence of stock market trading opportunities, with beliefs and payoffs that are a function of an informed expert's decision to participate in a mechanism, can cause an otherwise optimal mechanism to become infeasible. Intuitively, if a mechanism is posted, an informed investor can capture especially large trading gains by deviating and rejecting the mechanism. In order to counter this strong temptation to deviate, the mechanism-reliant firm must offer ever higher rewards for correct advice (w_1). But in so doing, the firm also increases the temptation of incompetents to take up the mechanism. If the trading gains following a deviation become sufficiently high (equation (35)), accomplishing the dual tasks of eliciting expert participation in the mechanism and the screening out of incompetents becomes impossible.

The remainder of the analysis assumes equation (36) holds and the firm posting a mechanism obtains an ex ante share price given in equation (37). Recall, Section 5 derived the ex ante share price obtained by a firm that refrains from posting a mechanism. Therefore, we turn next to a case-by-case comparison of the ex ante stock prices attained by mechanism-reliant versus market-reliant firms.

The first scenario analyzed in Section 5 was the market-reliant firm facing a sufficiently low switching cost such that the firm would switch to the safe strategy with probability one in response to any sell order paired with zero order (the Always Switch Equilibrium). Equations (18) and (37) imply:

$$l(1-a)(c-q) \leq aq(1-q)(1-l) \Leftrightarrow V_{AS} \geq V_{DRM}. \tag{38}$$

The inequality (38) illustrates the fundamental tradeoff between the market and mechanism in the present scenario. Specifically, the right side captures the expected wage bill for a firm posting a mechanism, which reflects the high reservation value of an informed expert. The left side of the inequality captures the cost of relatively less efficient production of a market-reliant firm. To see this, note that production for the market-reliant firm differs from production for the mechanism-reliant firm only in the event that there is no informed investor and a liquidity shock occurs. Notice, with no informed agent present in the economy, it is optimal to implement the risk strategy, since this is optimal under prior beliefs. However, here the market-reliant firm incorrectly switches to the safe strategy. The difference in expected cash flow due to the difference in production decisions in this scenario is $c-q$, and the probability of this scenario is $l(1-a)$.

The inequality (38) is satisfied for: a sufficiently high; l sufficiently low; and c sufficiently low (close to q). Recall, these are precisely the conditions under which the Always Switch Equilibrium obtains for the market-reliant firm. Rearranging equation (38) we find:

$$c \leq q\left[1+(1-q)\left(\frac{a}{1-a}\right)\left(\frac{1-l}{l}\right)\right] \equiv c^* \Leftrightarrow V_{AS} \geq V_{DRM}. \tag{39}$$

Next, the Always Switch Equilibrium obtains if $c \leq \hat{\chi}$. But inspection of equations (14) and (39) reveals that $\hat{\chi} \leq c^*$. That is, whenever the Always Switch Equilibrium obtains, the market dominates the mechanism. And so we have the following proposition.

Proposition 6. *If $c \leq \hat{\chi}$ (or equivalently $K \geq J-1$), the market-reliant firm implements the Always Switch Equilibrium and attains a higher ex ante share price by refraining from posting a mechanism.*

That the market reliant firm attains a higher firm value is striking given the lack of institutional restrictions placed on the mechanism. Indeed, the revelation principle indicates that any incentive compatible allocation achievable through an institutional arrangement is also achievable via a direct mechanism which satisfies incentive compatibility. Since one can view “the market” as a particular institutional arrangement, it may appear that Proposition 6 violates the revelation principle. However, the apparent contradiction is resolved by noting that the DRM is indeed optimal for a fixed reservation value, but can be sub-optimal with respect to alternative arrangements that lead to variations in the reservation value.

The second scenario, analyzed in Section 5, was the market-reliant firm facing a sufficiently high switching cost ($c \geq \overline{\chi}$) such that the firm never switches to the safe strategy in response to a sell order paired with zero order, the Non-Switch Equilibrium. From equations (25) and (37), we find:

$$aq(1-l)(1-c) \leq aq(1-l)(1-q)(1-m) \Leftrightarrow V_{NS} \geq V_{DRM}. \tag{40}$$

The preceding equation again reveals the fundamental tradeoff between markets and mechanisms, a tradeoff between production efficiency and relative adverse selection costs. The left side of the equation reflects the fact that even if the investor is informed, the market-reliant firm incorrectly fails to switch to the safe strategy in the bad state absent a fully revealing liquidity shock, with the output loss equal to $1-c$. The right side of the equation reflects the difference in relative adverse selection costs. Specifically, the type 0 investor is forced to trade less aggressively if the firm does not post a mechanism, with her minimum sell size equal to m shares. In contrast, if a mechanism is posted, a type 0 investor anticipates the possibility of being able to deviate and trade aggressively, selling one share with zero price impact. As argued above, this deviation gain represents the informed investor's opportunity cost of participating in the mechanism and is reflected in the expected wage bill for the mechanism-reliant firm.

Rearranging equation (40) we find:

$$c \geq c^{**} \equiv q + m(1-q) \Leftrightarrow V_{NS} \geq V_{DRM}. \tag{41}$$

Equation (41) reveals that the market dominates the mechanism if the switching cost is sufficiently high. After all, if the switching cost is indeed sufficiently high, the production inefficiency arising from reliance on the market is small.

The next proposition follows from equations (23) and (41):

Proposition 7. *Suppose $c \geq \overline{\chi}$ (or equivalently, $K \in \left[0, \frac{(J-1)^2}{2J}\right]$). Then:*

- *The market-reliant firm implements the Non-Switch Equilibrium.*
- *If $J \geq 2$ the market reliant firm value exceeds the mechanism reliant firm value for K sufficiently large:*

$$V_{NS} \geq V_{DRM} \Leftrightarrow K \in \left[\frac{1}{2J\,(J-1)}, \frac{(J-1)^2}{2J}\right],$$
$$V_{NS} < V_{DRM} \Leftrightarrow K \in \left[0, \frac{1}{2J\,(J-1)}\right).$$

- *If instead $J < 2$, the mechanism reliant firm value exceeds the market reliant firm value.*

Recall from equation (12), K is the likelihood ratio that a sell order (cum zero order) originates with type 0 expert as opposed to arising from liquidity sales. A larger value of K favors the market because trades by the type 0 expert reveal more information, reducing adverse selection costs to the atomistic traders.[4] Proposition 7 further indicates that as J increases, the region of K for which the market reliant firm value exceeds the mechanism reliant firm value widens. Recall from equation (15) we know J is increasing in c. Larger values of the switching cost c (and therefore J) reduce the production efficiency benefit of the mechanism.

Recall, finally, that intermediate values of the switching cost parameter c resulted in a Mixed Switching Equilibrium. Here the ex ante firm value was identical to the firm value under the Non-Switch Equilibrium, with the sole difference being that the relevant minimum type zero short sale size $m^{\dagger}$ replacing m. Therefore, the economic tradeoffs are identical in form, with conditions (40) and (41) continuing to apply, again with $m^{\dagger}$ replacing m. Thus, we have the following proposition.

Proposition 8. *Suppose $c \in [\hat{\chi}, \overline{\chi}]$, or equivalently $K \in \left[\frac{(J-1)^2}{2J}, J-1\right]$. Then:*

- *The market-reliant firm implements the Mixed Switching Equilibrium.*
- *If $J \geq 2$, the market reliant firm value exceeds the mechanism reliant firm value.*
- *If $J < 2$, the market reliant firm value exceeds the mechanism reliant firm value for K sufficiently large:*

$$V_{MS} \geq V_{DRM} \Leftrightarrow K \in \left[\frac{(J-1)\left(1+2J-J^2\right)}{2J}, J-1\right],$$

$$V_{MS} < V_{DRM} \Leftrightarrow K \in \left[\frac{(J-1)^2}{2J}, \frac{(J-1)\left(1+2J-J^2\right)}{2J}\right).$$

Like Proposition 7, Proposition 8 indicates that the market reliant firm has higher firm value for K sufficiently large (high informativeness of a single sell order) or if c (and therefore J) is sufficiently large (the production efficiency benefit of the mechanism is small).

7. The Case Against Mechanisms: A Limit Result

The preceding section demonstrated that a firm potentially achieves higher value relying on the market than upon a revelation mechanism when the latter is placed within an economy with a securities market. A potential concern with this demonstration is that our analysis of the mechanism-based firm relied upon positing beliefs of the market maker and firm off the equilibrium path, as we considered a potential deviation

[4]Recall also from equation (35) that the wage/outside option under the mechanism is independent of K, as the mechanism prevents deviations with no price impact.

by the expert under which she fails to sign on to the mechanism and instead trades in the securities market. To address this concern, this section analyzes a slightly different technological environment in which expert trading necessarily occurs with positive probability on the equilibrium path. Moreover, this analysis highlights how the standard mechanism can be improved upon through randomization.

To motivate the analysis, recall that the preceding sections revealed the following weakness of a traditional mechanism when it is placed in the context of a securities market economy: a mechanism that induces the expert to participate with probability 1, should she exist, generates a high endogenous reservation value, due to the ability to trade with zero price impact (in the sense described above) should she deviate and leave the contract sitting. This line of reasoning suggests that it might be possible to improve upon the traditional mechanism by endogenously generating some doubt regarding the existence of an expert ($T = E$) even after a contract has been posted and left sitting on the table.

7.1. **Commitment Technology.** In light of the preceding reasoning, suppose now that the firm has access to a marketing technology having the feature that even after the mechanism has been posted, it is not necessarily the case that the expert will see it even if she exists. Rather, the firm can fix, in a way observable to all agents in the economy, a probability $\pi \in [0, 1)$ that the contract will be observed by the expert. For example, by marketing the adviser position more widely, the firm can increase the probability the expert will see it. Notice, this technology subsumes the market-based firm as a special case where $\pi = 0$. And in the limit, as π tends to 1, we approximate the traditional mechanism setting in which a posted offering is observed with probability 1.

To begin, notice that for each possible choice of $\pi \in [0, 1)$, the mechanism design program is identical in form to that considered in the original DRM program. That is, for each given π there is an optimal (wage minimizing) contract that serves to: screen out incompetents; induce voluntary participation by the expert (should she see the job offering); and induce truthful state revelation by the expert. Under the optimal contract, the expert will be pinned to her reservation value if she signs on. However, since variation in π will lead to variation in the pricing rule used by the market maker, in a manner to be described below, the expert's reservation value will now be a function of π. Reflective of this fact, we now write the expert's reservation value as $\underline{u}(\pi)$.

7.2. **Market Beliefs.** We now fix some $\pi \in [0, 1)$ and evaluate the beliefs of the market maker (and firm) on the equilibrium path in the event that the contract is not taken up. This outcome can arise from one of two possibilities. One possibility is that there is no expert, which occurs with probability $1 - a$. Another possibility is that the expert exists, but she did not see the posted advertisement, an event that occurs with probability

$a(1-\pi)$. Notice, even though the mechanism is posted, securities market trading by the expert occurs with positive probability on the equilibrium path.

Following the same line of argumentation as above, beliefs will have the following properties. Two zero orders reveal no expert exists and beliefs revert to priors, with $\chi = q$. A buy order reveals trading by a type 1 investor and the state as being $\omega = 1$, so $\chi = 0$. Two sell orders reveal the presence of a type 0 investor and the state as being $\omega = 0$, so $\chi = 1$. Consider finally beliefs in the event of a single sell order combined with a zero order. This possibility can arise in two ways. First, it is possible that: the expert exists, she did not see the advertisement, $\omega = 0$, and liquidity shock occurred. Alternatively, it is possible that the large investor is a non-expert (and thus, passive) and there has been a liquidity shock. For a sell order of size t, beliefs derived from Bayes' rule now take a slightly different form than in the baseline model (with stars used to distinguish this case):

$$\chi_*(0,t) = \frac{a(1-\pi)q(1-l)\phi_0(t) + (1-a)ql}{a(1-\pi)q(1-l)\phi_0(t) + (1-a)l}. \tag{42}$$

Recalling the definition of the variable K (equation (12), let:

$$K_* \equiv K(1-\pi). \tag{43}$$

Beliefs are then identical in form to that in the original model of the market-based firm. In particular:

$$\chi(0,t) = \frac{K_*\phi_0(t) + q}{K_*\phi_0(t) + 1}. \tag{44}$$

7.3. **Equilibrium.** As in the baseline model (Subsection 5.2), intuition suggests that if c is sufficiently high, the gain to switching to the safe strategy is sufficiently small such that the observation of a single sell order combined with zero order can never move beliefs sufficiently to induce the firm to switch to the safe strategy (the Non-Switch Equilibrium). Intuition suggest that a Non-Switch Equilibrium obtains for π sufficiently high, since in such cases an expert trades in the securities market with low probability, attenuating the informativeness of order flow.

Based on the preceding intuition, we conjecture (and verify) a Non-Switch Equilibrium in which the type 0 plays a proper mixed strategy with minimum sell order size m_*, and featuring an atomless mixing density ϕ_0^* that vanishes as the sell order size approaches m_*.

Notice, if the density ϕ_0^* does indeed vanish as the sell order approaches m_*, then equation (44) implies that the market maker forms the belief $\chi(0, m_*) = q$, and sets the stock price $p(0, m_*) = 1 - q$. Accounting for the fact that a liquidity shock in conjunction with a short sale by the investor induces a switch to the safe strategy, and zero informed trading gain, the expected profit to the type 0 investor from a short sale of size m_* is $(1-l)(1-q)m_*$. The implied type 0 mixing condition is that for all $t > m_*$:

$$(1-l)(1-q)m_* = (1-l)t\left[1 - \frac{K_*\phi_0^*(t)+q}{K_*\phi_0^*(t)+1}\right]. \tag{45}$$

From the preceding equation, the type 0 mixing density is a linear increasing function, which indeed vanishes as t approaches m_*, as conjectured:

$$\phi_0^*(t) = \frac{t-m_*}{m_*K_*}. \tag{46}$$

Since the mixing density must integrate to 1, we have:

$$\int_{m_*}^{1} \phi_0^*(t)dt = 1 \Rightarrow m_* = F(K_*). \tag{47}$$

Since the function F is decreasing and K_* is decreasing in π:

$$\frac{\partial m_*}{\partial \pi} = -KF'(K_*) = \frac{m_*K}{[(1+K_*)^2-1]^{1/2}} > 0. \tag{48}$$

The preceding comparative static shows that the type 0 investor trades more aggressively if the firm adopts a higher value of π, since the market maker assesses a lower probability of the presence of an informed trader in the market. This is the key cost associated with adopting a high value of π (both by increasing the wage in the mechanism and the adverse selection costs in the market).

It is readily verified that the posterior beliefs (equation (44)) are strictly increasing in ϕ_0^*, while the mixing density increases linearly in t. Thus, the maximum value of $\chi_*(0,t)$ in the conjectured Non-Switch Equilibrium is:

$$\overline{\chi}_* \equiv \frac{K_*\phi_0^*(1)+q}{K_*\phi_0^*(1)+1} = 1 - m_*(1-q). \tag{49}$$

From the the comparative static properties of m_* we know:

$$\frac{\partial \overline{\chi}_*}{\partial \pi} = -(1-q)\frac{\partial m_*}{\partial \pi} < 0. \tag{50}$$

Thus, the region of the parameter space for which the Non-Switch Equilibrium obtains, $c \geq \overline{\chi}_*$, enlarges for higher values of π. In fact, as π approaches 1, the probability of informed trading tends to zero, and the firm will surely not switch to the safe strategy in response to a sell order cum zero order. Formally, equations (47) and (49) imply:

$$\lim_{\pi \uparrow 1} \overline{\chi}_* = q < c.$$

We thus have the following lemma.

Lemma 4. *If the cost c of switching to the safe strategy is greater than $\overline{\chi}$, then for any $\pi \in [0,1)$, then a Non-Switch Equilibrium obtains. Otherwise, there exists $\pi_{NS} \in (0,1)$ such that a Non-Switch Equilibrium obtains if and only if $\pi \geq \pi_{NS}$.*

The preceding lemma establishes the existence of a π-left neighborhood of the pure mechanism ($\pi = 1$) on which the Non-Switch Equilibrium obtains.

7.4. **The Limit Result.** With the preceding lemma in mind, consider now the components of firm value on the π-left neighborhood of the pure mechanism ($\pi = 1$) on which the Non-Switch Equilibrium obtains. Consider first with the sum of expected shareholder trading losses and the expected wage bill. If the expert exists, but does not see the advertisement, she captures an expected trading gain equal to $q(1-l)(1-q)m_*$. And if the expert exists, and does see the advertisement, the posted mechanism is designed to leave her just indifferent between trading and not. Therefore, if she sees the advertisement, she must capture this same value in expectation through her wages. Therefore, the ex ante discount from cash flow, capturing expected trading losses and wage payments, is just equal to $aq(1-l)(1-q)m_*$.

Consider next expected cash flow, recalling that implementing the risky strategy with probability 1 generates $1-q$ in expectation. In the present context, the firm deviates from the risky strategy in two instances. First, if the expert exists and sees the posted job advertisement, then she accepts the job offer, so that the firm switches to the safe strategy if $\omega = 0$. Second, if the expert exists but does not see the posted job advertisement, then the firm only switches to the safe strategy in the event that $\omega = 0$ and a liquidity shock hits, so that the observation of two sell orders reveals the trading of the type 0 investor. In both the first and second cases, the firm captures a cash flow increase of $1-c$ relative to a firm that implements the risky strategy with probability one. We thus have the following expression for firm value:

$$V(\pi) = 1 - q + qa[\pi + (1-\pi)l](1-c) - aq(1-l)(1-q)m_*. \tag{51}$$

From equation (48):

$$\begin{aligned} V'(\pi) &= qa(1-c)(1-l) - aq(1-l)(1-q)\frac{\partial m_*}{\partial \pi} \\ &= aq(1-l)(1-c)\left[1 - \left(\frac{(1-q)m_*}{1-c}\right)\left(\frac{K}{[(1+K_*)^2-1]^{1/2}}\right)\right]. \end{aligned} \tag{52}$$

Equation (49) and $c \geq \overline{\chi}_*$ imply the first term in large round brackets in the preceding equation is greater than 1. Further, it is readily verified that the second term in large round brackets exceeds 1 provided that $K > 2(1-\pi)/\pi(2-\pi)$, a condition that necessarily holds as π tends to 1. We thus have the following limit result.

Proposition 9. *There exists an open left-neighborhood of the posted mechanism being observed with certainty ($\pi = 1$) such that firm value is strictly decreasing in the mechanism observation probability.*

The significance of Proposition 9 is as follows. Even in those instances in which the firm attains higher value under the non-randomized mechanism with no information gathered from the market ($\pi = 1$ and $K < 1/(2J(J-1))$) than under exclusive reliance on the market ($\pi = 0$), firm value nevertheless increases if the firm marginally increases reliance on the market.

8. Discussion/Alternative Assumptions

We have shown that the existence of a securities market affects mechanism design in two ways. First, the market provides an endogenous outside option in the mechanism design. The particulars of the mechanism affect the value of information to an informed trader in the securities market, and therefore the outside option. Second, the securities market provides an alternative source of information for the firm. For example, Section 7 showed that designing a mechanism so that an informed expert sometimes failed to take up the contract resulted in a lower outside option for the informed trader, thus reducing the cost of the mechanism.

Our assumption that an informed investor who agrees to the contract cannot trade in the market (exclusivity), is also a feature of the mechanism that affects the probability than an informed trader is present in the market. Yet, relaxing exclusivity does not affect the results. To see this, suppose the firm had the power to allow an informed investor who takes up the contract (e.g. an employee) to trade in the market. To reduce adverse selection costs, the firm has an incentive to reveal to the market whether or not an investor is hired and if hired, the expert's report. Thus, hiring the expert with a non-exclusive contract eliminates the informational advantage of the informed investor. To prevent the informed investor from deviating and not signing the contract, the firm must pay the informed investor a wage identical to that in Section 6, because if the informed investor deviates and does not sign the contract, the firm will report this information to the market, and trades take place at price $1 - q$ with no price impact.

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